



RESEARCH ARTICLE

Anti-Bacterial Efficacy of Aqueous Extract of *Azadirachta indica* A.Juss Flowers

B. Jayanthi^{1*}, T. Ayyappan² and A. Mercy Jenifa³

¹Associate Professor , Department of Pharmacology, Karpaga Vinayaga Institute for Pharmaceutical Sciences, Chengalpattu, (Affiliated to The Tamil Nadu Dr. M.G.R. Medical University, Chennai), Tamil Nadu, India.

²Principal, Department of Pharmaceutics, Karpaga Vinayaga Institute For Pharmaceutical Sciences, Chengalpattu, (Affiliated to The Tamil Nadu Dr. M.G.R. Medical University, Chennai), Tamil Nadu, India.

³Assistant Professor, Department of Pharmacy Practice, Karpaga Vinayaga Institute For Pharmaceutical Sciences, Chengalpattu, (Affiliated to The Tamil Nadu Dr. M.G.R. Medical University, Chennai), Tamil Nadu, India.

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*Address for Correspondence

B. Jayanthi

Associate Professor,

Department of Pharmacology,

Karpaga Vinayaga Institute for Pharmaceutical Sciences, Chengalpattu,

(Affiliated to The Tamil Nadu Dr. M.G.R. Medical University, Chennai),

Tamil Nadu, India.

E.Mail: jayakaran83@gmail.com



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ABSTRACT

People widely use neem (*Azadirachta indica*) to treat various infections, metabolic diseases, and cancerous diseases. The present study was undertaken to prepare aqueous extracts of neem flower by using a decoction method, assessing phytochemical screening and antibacterial activity by the agar disc diffusion method against 4 human bacterial pathogens. The flowers were collected from the surroundings of Chengalpattu, Tamil Nadu. It was used for extraction by a decoction method using distilled water. Phytochemical screening of the aqueous extracts of neem flower revealed positive results for carbohydrates, phenols, glycosides, alkaloids, reducing sugars, saponins, and flavonoids. However, quinone, tannins, amino acids, and terpenoids were not detected in the extracts of neem flowers. The MIC of antibacterial activity against human bacterial pathogens was quantitatively assessed by testing serial concentrations. The human bacterial pathogens *Bacillus subtilis* (gram-positive pathogens) and *Pseudomonas aeruginosa* (gram-negative pathogens) were sensitized up upto 31.25 µg/ml, as recorded by using the Hi-Media Zone Scale.

Keywords: *Azadirachta indica* , Phytochemical screening , Anti bacterial activity of Human pathogens , MIC





INTRODUCTION

Medicinal plants have been used as traditional remedies for a number of human ailments, and several studies detailing the pharmacological characteristics of medicinal plant extracts have been published. Because the plant components increase antibacterial activity, they play a significant role in both preventing and treating disease. Numerous viral, metabolic, or malignant conditions are treated with it [1,]. A member of the Meliaceae family, neem (*Azadirachta indica*) is an evergreen tree that grows all over the world. Neem is a pretty broadleaf that can reach heights of 30 m and widths of 2.5 m. Its typically straight trunk has a diameter of 30 to 80 cm. Its spreading branches grow up to 20 meters broad, forming a circular canopy of deep green foliage and honey-scented flowers. *Azadirachta indica* (Figure: 1).

Local name of Neem: Hindi-neem , Tamil-vembu, vempu , Malayalam-veppu, aryaveppu, aruveppu, kaippan, veppu, vepa , Telugu-vepa. The Indian villager has long considered the neem tree to be a friend and defender. It has been utilized as a natural insecticide and fertilizer for fields, as well as for the preservation of food and grains[2]. Antibacterial, antifungal, and anti-inflammatory properties are among the many biological and pharmacological actions that have been documented. Almost every component of the tree, including the bitter fruits, seeds, oil, leaves, roots, and bark, contains chemicals that have been shown to have antiviral, antifungal, antiplasmodial, antiseptic, antipyretic, and antidiabetic effects[3] [4]. The complex of different components found in *Azadirachta indica*, such as limonoids, nimbin, nimbidin, and nimbolide, contributes to the treatment of sickness. The first polyphenolic flavonoids to be isolated from fresh neem leaves were quercetin and β -sitosterol, which were known to possess antifungal and antibacterial properties[5]. Neem flowers have long been utilized in Ayurveda medicine to treat bile suppression, phlegm, and intestinal worm removal. Higher antioxidant qualities are obtained from neem flower extraction. It was discovered that floral aqueous extracts had stronger antibacterial activity and higher levels of free radical scavenging.

MATERIALS AND METHODS

Collection and Storage condition

Fresh *Azadirachta indica* flowers were gathered from the Chengalpattu, Tamil Nadu, area. verified by Prof. P. Jayaraman, a botanist from the Plant Anatomy Research Center (PARC) in West Tambaram, Chennai. The certificate's registration number was PARC/2020/4332. The fresh *Azadirachta indica* blossoms were properly cleaned two or three times using distilled water before being allowed to dry in the shade. The dried flower was coarsely mashed with a mortar and pestle in a single direction. The resulting powder was then put through mesh (mesh no. 60) and kept in an airtight container.

Aqueous Extract by Decoction Method

Neem flower powder was obtained by boiling it with distilled water (1:3, w/v) for an hour at 40–50°C, followed by filtering. In order to obtain the decoction extract, additional distilled water was added to the marc, and the extraction process was repeated until the final extract was filtered and the filtrate was evaporated on a boiling water bath till weight was reached[6].

Phyto chemical Screening

Test for Carbohydrates: Two milliliters of Molisch's reagent are added to one milliliter of extract. After giving the mixture a good shake, 2 milliliters of sulfuric acid concentrate are gradually added to the test tube's sidewalls. The development of a reddish ring signifies the presence of carbohydrates

Test for Phenols: To 2ml of extract, 3ml of ethanol and a pinch of ferric chloride are added. A greenish yellow color indicates the presence of phenols.



**Jayanthi et al.,****Test for glycosides**

Borntrager's test: To 3 ml of test solution, diluted sulfuric acid was added, boiled for 5 min and filtered. To the cold filtrate, an equal volume of benzene/chloroform was added and shaken well. The organic solvent layer was separated, and ammonia was added. Formation of pink to red color in the ammoniacal layer indicates glycosides.

Test for alkaloids: Mayer's test To a few drops of extract, 2 drops of Mayer's reagent were added by the side of the test tube. A green-colored precipitate confirms the presence of alkaloids.

Test for reducing sugar: To 0.5 ml of extract, 1 ml of water and 5-8 drops of Fehling's solution were added and heated over a water bath. Brick-red precipitate indicates the presence of reducing sugar.

Test for quinone: Add a few drops of extract to 5 ml of HCl. Formation of yellow precipitate indicates the presence of quinone.

Test for tannins: To a portion of extract diluted with water, 3-4 drops of 10% ferric chloride solution were added. Blue color indicates gallic tannins, and green color indicates catecholic tannins.

Test for saponins: Froth test: To a few ml of extract, 20 ml of distilled water was added and shaken for 15 min. Formation of a 1cm layer of foam indicates the presence of saponins.

Test for flavonoids: To a few ml of extract, a few drops of dil. Sulfuric acid was added. Orange color indicates the presence of flavonoids.

Test for amino acids: A few drops of extract and a few drops of ninhydrin solution were added to a test tube. Blue color indicates the presence of amino acids.

Test for terpenoids: To 2 ml of extract, 2 ml of acetic anhydride and conc. sulfuric acid were added. Formation of a green ring indicates the presence of terpenoids[7].

Antibacterial Activity: Bacterial sources were required from Biotechnology Clinix Lab in Chengalpattu.

Preparation of medium: 3.8g of Muller Hinton Agar is added to 100ml of distilled water and autoclaved at 121°C for 15 minutes and poured into sterile petri plates up to a uniform thickness of approximately 4mm, and the agar is allowed to set at ambient temperature, and the plate is used for further steps.

Agar disk diffusion method: The agar plates are inoculated with a standard inoculum of the test microorganism with the sterile cotton swab. Then the filter paper disc (about 6mm in diameter) containing the test compound at the desired concentration was prepared. And the disc was placed on the agar surface by using the sterile forceps. Meanwhile, the petri dishes were incubated at 37°C for 18-24 hours. Further, the antibacterial agents inhibit the germination and growth of the test microorganisms. Then the zone of inhibition was measured by using the Hi-Media Zone Scale[8].

Determination of minimum inhibitory concentration (MIC): The different concentrations (1000, 500, 250, 125, 62.5, and 31.25 µg/ml) of aqueous extract of neem flower were prepared by serial dilution. Then the filter paper discs of 6mm were loaded with the aqueous extract of the desired concentration. And the discs were placed on the agar surface by using the sterile forceps. The petri dish was incubated at room temperature (37°C) and kept aside for 18-24 hours. Then the zone of inhibition (formation of a zone around the disc) was measured by using the Hi-Media Zone Scale. The lowest concentration inhibiting growth was considered to be the Minimum Inhibitory Concentration (MIC)[9].





RESULT AND DISCUSSION

Phyto chemical screening methods

The results of phytochemical screening of *A.I* Flowers in Decoction method (Table.1).

In these results, aqueous extract in the decoction method responses has more phytochemicals, less time consumed, and less expense compared with when other methods of extraction and solvents are used.

MIC of the *A Azadirachta indica A.Juss* flowers in Decoction method (Table 2).

The neem tree has different parts, especially the flower, which contains various phytochemical constituents like alkaloids, glycosides, carbohydrates, phenols, coumarins, terpenoids, amino acids, and flavonoids. Phytochemical analysis of neem flower in the decoction method of extract identified secondary metabolites, which indicates antibacterial activity against gram-positive and gram-negative bacteria. Advantages of this method are that it is less expensive and less time-consuming and gives a high yield of product. The minimum inhibitory concentration was interpreted as the serial dilution concentration of the extract that did not show any visible growth when compared with the negative control. The results of the agar disc diffusion method were found to be Bacteria strains are sensitive to aqueous extract of *Azadirachta indica a.juss* flowers. The antibacterial activity of MIC is shown in Table 2. The *Azadirachta indica a.juss* flower extract exhibited antibacterial activity against the *Bacillus subtilis*, *Staphylococcus aureus* (G+Ve), *Pseudomonas aeruginosa*, and *Klebsiella pneumoniae* (G-Ve) bacteria. *Bacillus subtilis* had 7.96mm at 31.25 µg/ml, *Staphylococcus aureus* had 8.32mm at 123 µg/ml, *Pseudomonas aeruginosa* had 12.38 mm at 31.25 µg/ml, and *Klebsiella pneumoniae* had 8.75mm at 250 µg/ml.

CONCLUSION

In this study, as per the results and discussion, neem flowers were activated against human pathogenic bacterial agents. Further study is needed to describe the potential antibacterial activity of the crude extract in more detail.

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Table.1 The results of phytochemical screening of A.I Flowers in Decoction method

S.NO	Test for Phytochemicals	Decoction method(Aqueous extract)
1.	Test for Carbohydrates	+
2.	Test for Phenol	+
3.	Test for Glycosides (Borntrager's test)	+
4.	Test for Alkaloids (Mater's test)	+
5.	Test for Quinone	-
6.	Test for Tannins	-
7.	Test for Saponins (Froth test)	+
8.	Test for Flavonids	+
9.	Test for Amino acids	+
10.	Test for Terpenoids	+
11.	Test for Coumarine	+

Table 2. MIC of the A AZADIRACHTA INDICA A.JUSS flowers in Decoction method

CONC ↓ Bacteria	1000 µg/ml	500 µg/ml	250 µg/ml	125 µg/ml	62.5 µg/ml	31.25 µg/ml
<i>Bacillus subtilis</i>	16.43mm	15.73mm	11.01mm	10.48mm	8.50mm	7.96mm
<i>Staphylococcus aureus</i>	15.08mm	14.23mm	13.35mm	8.32mm	-	-
<i>Pseudomonas aeruginosa</i>	23.24mm	22.34mm	20.01mm	18.43mm	14.12mm	12.38mm
<i>Klebsiella pneumoniae</i>	15.43mm	13.89mm	8.75mm	-	-	-
Negative control	-	-	-	-	-	-

**Figure 1. Azadirachta indica**



RESEARCH ARTICLE

Applications of Nanotechnology in Veterinary Medicine : A New Frontier in Animal Health

V. Ramakrishnan^{1*}, A. Elamaran² and M.Veeraselvam³

¹Assistant Professor, Department of Veterinary Pharmacology and Toxicology, Veterinary College and Research Institute, Tirunelveli, (Affiliated to Tamil Nadu Veterinary and Animal Sciences University, Chennai), Tamil Nadu, India.

²Assistant Professor, Department of Veterinary Pharmacology and Toxicology, Veterinary College and Research Institute, Orathanadu, Thanjavur, (Affiliated to Tamil Nadu Veterinary and Animal Sciences University, Chennai), Tamil Nadu, India.

³Assistant Professor, Department of Veterinary Medicine, Veterinary College and Research Institute, Orathanadu, Thanjavur, (Affiliated to Tamil Nadu Veterinary and Animal Sciences University, Chennai), Tamil Nadu, India.

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*Address for Correspondence

V. Ramakrishnan

Assistant Professor,

Department of Veterinary Pharmacology and Toxicology,

Veterinary College and Research Institute, Tirunelveli,

(Affiliated to Tamil Nadu Veterinary and Animal Sciences University, Chennai),

Tamil Nadu, India.

E.Mail: ramakrishnanvet@gmail.com



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ABSTRACT

Nanotechnology, defined as the manipulation and application of materials at the nanoscale (1–100 nanometers), has emerged as a revolutionary discipline in veterinary medicine. At this scale, materials exhibit unique physicochemical properties, including increased surface area, enhanced reactivity, and the ability to penetrate biological barriers, which enable novel approaches to diagnostics, therapeutics, and disease prevention. In recent years, the veterinary field has begun to harness these nanoscale properties to enhance animal health, productivity, and welfare through more precise and effective interventions. One of the most promising applications of nanotechnology in veterinary medicine lies in targeted drug delivery. Nanoparticles such as liposomes, dendrimers, and polymeric carriers can encapsulate drugs and deliver them specifically to diseased tissues or organs, thereby increasing therapeutic efficacy while minimizing side effects. This is particularly beneficial in treating chronic infections, parasitic infestations, and cancer in companion animals and livestock. Additionally, nano-formulated drugs can exhibit improved bioavailability, stability, and controlled release profiles, further enhancing treatment outcomes. In the domain of disease diagnostics, nanotechnology offers high sensitivity and specificity through the



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use of nanosensors and quantum dots. These nanoscale devices can detect pathogens, toxins, and biomarkers at very low concentrations, allowing for early diagnosis and timely intervention. Point-of-care nanodiagnostic tools are increasingly being developed for rapid and on-site disease detection in field settings, which is particularly crucial for livestock management and outbreak control in rural and remote areas. Nano-vaccines represent another significant advancement. Engineered nanoparticles can mimic pathogens or deliver antigens in a controlled manner, eliciting robust and long-lasting immune responses. These vaccines often do not require cold-chain storage and can be administered orally or intranasally, making them ideal for mass immunization programs in poultry, ruminants, and swine. Moreover, nanotechnology has shown promise in regenerative medicine, where nanomaterials are used to stimulate tissue repair, enhance wound healing, and support the regeneration of damaged organs. Nano-engineered scaffolds and delivery systems can aid in the controlled release of growth factors, stem cells, or therapeutic agents at injury sites, facilitating faster recovery in injured animals. Despite its immense potential, the application of nanotechnology in veterinary practice faces several challenges. These include the high cost of production, lack of regulatory guidelines, limited understanding of long-term toxicity, and environmental concerns related to nanoparticle accumulation. Addressing these issues through interdisciplinary research, policy development, and risk assessment is essential for the safe and sustainable adoption of nanotechnological innovations in animal health care. In conclusion, nanotechnology presents a new frontier in veterinary medicine, offering innovative solutions for diagnostics, therapeutics, vaccination, and regenerative care. Continued advancements in this field hold the potential to revolutionize animal healthcare systems globally, contributing to improved productivity, disease control, and overall animal well-being.

Keywords: Nanotechnology; Veterinary medicine; Nanoparticles; Targeted drug delivery; Nano-vaccines;

INTRODUCTION

Nanotechnology has emerged as a groundbreaking field in various sectors, including veterinary medicine. By manipulating materials on a nanometer scale, which is one-billionth of a meter, this technology provides unprecedented opportunities for improving diagnostics, treatments, and prevention of diseases in animals. As we continue to understand the full potential of nanotechnology, it promises to revolutionize the way veterinary care is provided, offering solutions that are more precise, effective, and tailored to the needs of individual animals. This comprehensive article explores the diverse applications of nanotechnology in veterinary medicine, its benefits and challenges, and the exciting future directions for this innovative field. The integration of nanotechnology into veterinary medicine marks a paradigm shift from conventional therapeutic and diagnostic methods toward more precise, efficient, and personalized animal health interventions. The ability to manipulate materials at the nanoscale has led to the development of nanocarriers, nanosensors, and nano-adjuvants, which significantly improve the pharmacokinetics, bioavailability, and targeting of veterinary drugs and vaccines ((El-Sayed and Kamel, 2020).

Nanoparticles for Disease Diagnosis and Treatment

Nanoparticles have proven to be a powerful tool for enhancing disease diagnosis and treatment in animals. By targeting specific cells or tissues, nanoparticles can deliver treatments more accurately, significantly improving the effectiveness of veterinary care. Nanoparticles can also enhance the imaging of diseases, making it easier for veterinarians to detect and diagnose conditions early, when they are most treatable((Bhattarai *et al.*, 2010; Jain, 2001).



**Nanoparticle-Based Imaging Technologies**

Nanoparticles are used in imaging techniques such as MRI contrast agents, which allow for the visualization of internal structures with high precision. These particles can also serve as fluorescent markers, enabling the tracking of disease progression or the effectiveness of treatments in real-time. For example, superparamagnetic nanoparticles can be used for magnetic resonance imaging (MRI), allowing veterinarians to detect tumors, infections, or other abnormalities in animals with exceptional clarity and detail (Cheng *et al.*, 2014; Padhye *et al.*, 2009).

Targeted Drug Delivery

Beyond diagnostic imaging, nanoparticles offer the advantage of targeted drug delivery. Drugs can be encapsulated within nanoparticles and delivered directly to diseased cells or tissues. This precise targeting minimizes the impact of the drug on healthy cells, reducing side effects and improving the overall therapeutic outcome. For instance, nanoparticles are used to deliver chemotherapeutic drugs directly to cancerous tumors, allowing for higher doses of the drug to be administered while minimizing harm to surrounding tissues (Torchilin, 2005). Magnetic nanoparticles, for example, can be controlled externally with magnetic fields, allowing for targeted drug delivery with high spatial accuracy. This is particularly beneficial in treating conditions such as cancer, where conventional treatments often harm healthy cells along with the diseased tissue (Chouly *et al.*, 1996).

Nanotechnology-Based Vaccines

Vaccination is an essential tool in preventing diseases in animals, and nanotechnology is transforming the development of more effective and safer vaccines. Nanotechnology-based vaccines are designed to improve immune responses, increase vaccine stability, and reduce side effects.

Nano-adjuvants

Nano-adjuvants, which are nanoparticles used to enhance the immune response, are incorporated into vaccines to increase their effectiveness. These adjuvants help to stimulate the immune system, ensuring a stronger and longer-lasting immune response. This is particularly valuable in animals, where immune systems may respond less robustly to conventional vaccines (Kumar *et al.*, 2008).

Chitosan-based Nanoparticles

Chitosan, a biopolymer derived from the shells of crustaceans, is used to develop nanoparticles that can enhance the delivery and stability of vaccines. Chitosan-based nanoparticles have been successfully used in vaccines for avian influenza, improving both their stability and effectiveness. These nanoparticles act as carriers that ensure the vaccine reaches the immune cells efficiently (Moore *et al.*, 2012; Patel *et al.*, 2011).

Virus-like Nanoparticles (VLNPs)

Virus-like nanoparticles are engineered to mimic the structure of actual viruses but are devoid of harmful genetic material. When used in vaccines, VLNPs can trigger a strong immune response without causing disease. This approach is especially useful for preventing viral diseases, offering an alternative to traditional vaccines that may require weakened or inactivated forms of the virus (Cui *et al.*, 2016).

Nanoparticle-Mediated Gene Therapy

Gene therapy, which involves altering the genetic material of an organism to treat or prevent disease, is an exciting application of nanotechnology in veterinary medicine. Nanoparticles serve as delivery vehicles for genetic material, allowing for precise targeting of specific cells or tissues (Suri *et al.*, 2016; Singh and Lillard, 2009).

Delivery of DNA and RNA

Nanoparticles can be used to deliver DNA or RNA molecules into animal cells, enabling the correction of genetic disorders or the introduction of therapeutic genes. This technology is particularly useful for treating inherited diseases that were previously untreatable. Nanoparticles made of lipids, polymers, or inorganic materials can carry these genetic materials into cells efficiently, enhancing the overall success of gene therapy (Yang *et al.*, 2014).



**Ramakrishnan et al.,****CRISPR-loaded Nanoparticles**

CRISPR-Cas9 technology has made gene editing more accessible and precise. When combined with nanoparticles, CRISPR can be used to modify specific genes in animals, offering potential cures for genetic diseases. Nanoparticles act as carriers, protecting the CRISPR components and ensuring their delivery to the correct cells. This technology could revolutionize the treatment of genetic disorders in veterinary patients (Harris *et al.*, 2015).

Lipid-based Nanocarriers

Lipid-based nanocarriers are particularly effective for gene therapy due to their ability to encapsulate genetic material and protect it from degradation. These carriers improve the stability and efficiency of gene delivery, allowing for more successful gene therapies in animals. Their use in veterinary medicine could lead to cures for a variety of inherited conditions, including those in companion animals, livestock, and wildlife (Akbarzadeh *et al.*, 2012).

Regenerative Veterinary Medicine

Nanofibers, nanocomposites, and hydrogel scaffolds are being employed in tissue engineering for the repair of bone, cartilage, and skin injuries in animals. These materials support cellular adhesion, proliferation, and differentiation, accelerating healing and functional recovery (Gao *et al.*, 2012).

APPLICATIONS

- Bone graft substitutes in equine orthopedics.
- Wound dressings for companion animals.
- Injectable nanocomposite gels for cartilage repair.

Real-Time Health Monitoring

Nanosensors integrated into wearable devices (like smart collars) allow for continuous monitoring of physiological parameters like temperature, respiration rate, and biomarkers, facilitating early disease detection and improved herd health management (Aziz *et al.*, 2025).

Environmental Applications and Food Safety

Nanoparticles such as zinc oxide and silver have antimicrobial properties and are used in biocides to sanitize farm environments. Moreover, nanosensors help detect contaminants in milk, meat, and poultry products, ensuring food safety (Saeed and Asseel, 2023).

Benefits and Challenges of Nanotechnology in Veterinary Medicine**Improved Drug Delivery and Efficacy**

Nanotechnology offers a significant advantage in the delivery and efficacy of veterinary drugs. Nanoparticles can increase the bioavailability of drugs, ensuring that more of the medication reaches the target tissues. By encapsulating drugs within nanoparticles, they can be released gradually over time, ensuring a consistent therapeutic effect. This can reduce the need for frequent administration, making treatment more convenient for both animals and their caregivers. Furthermore, nanotechnology allows for the development of drugs with improved solubility, stability, and bioavailability. For example, nanogels can enhance the solubility of hydrophobic drugs, which would otherwise be difficult to administer. This results in higher drug concentrations at the site of action, improving the overall treatment outcome (Langer, 1998; Singh *et al.*, 2008).

Targeted Therapy and Personalized Medicine

Nanotechnology opens up the possibility for personalized and targeted therapies in veterinary medicine. By using nanoparticles that respond to specific triggers, such as changes in pH or temperature, drugs can be released only when they reach the diseased tissues. This precision reduces the risk of side effects and increases the effectiveness of treatments. Additionally, the integration of genetic information in veterinary care enables the tailoring of treatments to meet the specific needs of individual animals. Nanotechnology facilitates the delivery of therapies based on an



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animal's genetic profile, ensuring that the treatment is not only targeted but also personalized to maximize therapeutic outcomes.

Toxicity and Safety Concerns

While the potential of nanotechnology in veterinary medicine is vast, there are concerns regarding the safety and toxicity of nanoparticles. Studies have shown that nanoparticles can accumulate in certain organs, such as the liver, kidneys, and spleen, potentially causing long-term health issues. The impact of these particles on animal health and the environment is still not fully understood, necessitating further research. Additionally, there are concerns about the environmental impact of nanoparticles, particularly their release into the environment through animal waste. The fate of nanoparticles in natural ecosystems and their potential effects on wildlife and soil health remain critical areas for investigation.

Thus, the benefits and challenges of nanotechnology in veterinary medicine can be tabulated hereunder (Table:

Future Directions and Opportunities

Nanotechnology and Precision Medicine

The future of veterinary medicine lies in precision medicine, and nanotechnology is poised to play a pivotal role in its development. By integrating genetic data with nanotechnology, veterinarians will be able to tailor treatments specifically for each animal. Nanoparticles can be designed to deliver drugs, genes, or other therapeutic agents directly to the target tissues, increasing treatment effectiveness and minimizing side effects.

Nanotechnology and Regenerative Medicine

Nanotechnology is also advancing the field of regenerative medicine, offering the potential to heal tissues and organs that have been damaged due to injury, disease, or aging. Nanoparticles can deliver stem cells or other regenerative agents to the site of injury, promoting faster and more effective healing. In veterinary orthopedics, nanocomposites and nanofibers are being used to enhance bone and cartilage repair, enabling animals to recover from fractures or joint injuries more efficiently (Yin *et al.*, 2001).

Nanotechnology and Animal Health Monitoring

Real-time health monitoring is a major area where nanotechnology is making strides. Nanosensors, which can be implanted in animals or worn as part of a collar or harness, can continuously track vital signs such as temperature, heart rate, and disease markers. These sensors can detect early signs of illness, allowing for timely interventions and improved health outcomes. Lab-on-a-chip technology also enables rapid disease diagnostics, even in remote locations, providing veterinarians with essential information when and where it is needed most (Zhang *et al.*, 2013; Sahoo and Labhasetwar, 2003).

CONCLUSION

Nanotechnology is undoubtedly transforming veterinary medicine, offering innovative solutions to some of the most pressing challenges in animal health. From disease diagnosis and treatment to the development of vaccines, gene therapies, and regenerative medicine, the potential of nanotechnology is vast. While challenges such as toxicity and safety concerns must be addressed, the continued research and development of nanotechnology will pave the way for a future in which veterinary care is more personalized, efficient, and effective. As this technology continues to evolve, the possibilities for improving the health and well-being of animals seem limitless.

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Declaration of Interest

All authors declare that there exist no commercial or financial relationships that could, in any way, lead to a potential conflict of interest.

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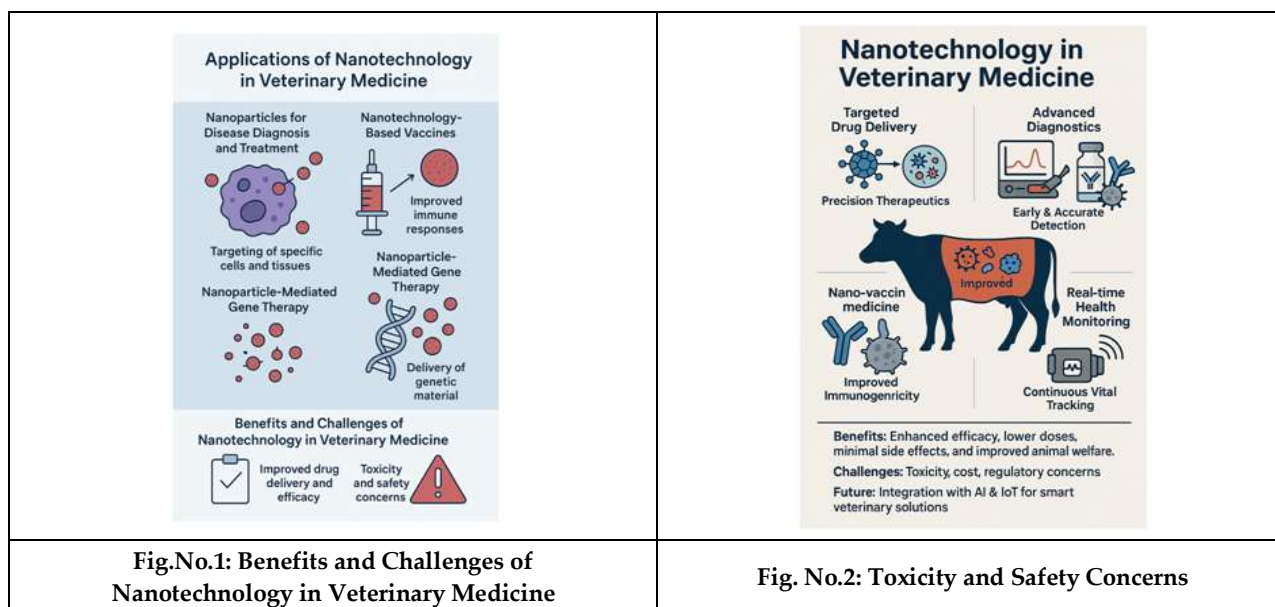


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Table.1: Thus, the Benefits and Challenges of Nanotechnology in Veterinary Medicine can be Tabulated here Under

Advantages	Challenges
Improved bioavailability and targeting	Potential organ accumulation and toxicity
Sustained and controlled drug release	Unknown long-term environmental effects
Reduced drug dosage and side effects	Need for regulatory frameworks
Enhanced immune responses in vaccinations	Lack of standardization in veterinary settings





RESEARCH ARTICLE

Green Synthesis of Silver Nanoparticles using *Zanthoxylum armatum* Seed Extract and Its Characterization, Efficacy on Antioxidant and Antibacterial Properties

V.S. Aakash Gowthaman¹, C.Shobana², D. Rohini³ and B.Usharani^{2*}

¹Student, Department of Biochemistry, Vels Institute of Science Technology and Advanced Studies, (Deemed-to-be University), Pallavaram, Chennai, Tamil Nadu, India.

²Associate Professor, Department of Biochemistry, Vels Institute of Science Technology and Advanced Studies, (Deemed-to-be University), Pallavaram, Chennai, Tamil Nadu, India.

³Assistant Professor, Department of Biochemistry, Vels Institute of Science Technology and Advanced Studies, (Deemed-to-be University), Pallavaram, Chennai, Tamil Nadu, India.

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*Address for Correspondence

B.Usharani

Associate Professor,
Department of Biochemistry,
Vels Institute of Science Technology and Advanced Studies,
(Deemed-to-be University),
Pallavaram, Chennai, Tamil Nadu, India.
E.Mail: usharani.sls@velsuniv.ac.in



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ABSTRACT

Silver nanoparticles are nanosized particle which has antibacterial and antioxidant activity. The present study highlighted a biocompatible and eco-friendly method for the synthesis of nanoparticles through green synthesis using *Zanthoxylum armatum* seed extract. The synthesized nanoparticle was analyzed through analytical techniques. Physically, the presence of AgNPs was confirmed by color change from pale yellow to yellowish-brown color. UV-Visible spectroscopy revealed a peak at 332nm. And the FTIR showed the presence of N-H stretch, O-H stretch, and CN stretch, confirming the phytochemicals reduction and presence of Alkaloids, flavonoids, and Polyphenols. The DLS depicted low PDI values, which indicated the presence of moderate polydispersity. The in vitro antibacterial activity showed the potential of ZAAgNps against bacteria like *Klebsiella pneumoniae*, *S. aureus*, and *E. coli*, with zone of inhibition 19mm, 16mm, and 14mm at their highest concentrations. The antioxidant potency of ZAAgNps was estimated by in vitro assays like DPPH and FRAP, which showed their inhibitory and reducing potential at 79.17% and 78.42%. Compiling these data, it revealed that the synthesized AgNPs from *Zanthoxylum armatum* seed extract have capabilities to be them in biomedical application

Keywords: Silver nanoparticles, *Zanthoxylum armatum*, antibacterial activity, green synthesis





INTRODUCTION

Nanotechnology

In this emerging world, one of the rapidly developing technology or we can say biological weapon is the Nanotechnology. They are the wide range of particles that are sized between 1nm and 100 nm. Based on the overall shape they can be in various form, 0D, 1D, 2D and 3D (Tiwari *et al.*, 2012). They are important as their size can influence the optical properties of a substance. The technology by which these particles are studied are known as Nanotechnology. And it is known as the field of research since last century. During a famous lecture at California Institute of Technology in 1959 “There’s Plenty of Room at the Bottom” Nobel laureate Richard P. Feynman presented “Nanotechnology” and since there happened to be various revolutionary developments in the Nanotechnology field (Feynman, 1960). The Nanoparticles or Nanomaterials aka Nps, are not the simple ones, they are made up of three layers i.e. (a) outer layer which is also known as surface layer which can be functionalized using metal ions, polymers, surfactants and a range of tiny molecules, (b) the shell layer, which differs chemically from the inner or the core layer in every way and the final (c) inner or the core which is the actual Nps itself (Shin *et al.*, 2016).

The Royal Society and Royal Academy of Engineering (2004) have recently defined nanoscience as: “*The study of phenomena and manipulation of materials at atomic, molecular and macromolecular scales, where properties differ significantly from those at a larger scale*” and nanotechnology as: “*the design, characterization, production and application of structures, devices and systems by controlling shape and size at nanometer scale*”. With the help of Nanotechnology, new materials and products are developed at nano-scale and this will eventually lead to great impact on the environment in terms of harm and energy saving. According to the Nanotechnology Products Database (NPD) currently, based on Nanotechnology, there are over 11,149 products available in the markets and 3,910 companies are involved in 68 countries. The various domains of these products are Electronics, Medicine, Construction, Cosmetics, Automobile, Textile, Food, Renewable energies, Agriculture etc.

Types of Nanoparticles

Nanoparticles or the Nanomaterials are classified broadly into various types based on their physical and chemical characteristics, size and morphology. Some of them are discussed below:

Carbon based Nanoparticles

Two significant kinds of Carbon-based nanomaterials are fullerenes and carbon nanotubes (CNTs). Allotropic forms of carbon and other nanomaterials composed of globular hollow cages are seen in fullerenes. Their excellent strength, structure, electron affinity, electrical conductivity and adaptability have generated significant commercial interest (Astefanei *et al.*, 2015). Pentagonal and Hexagonal carbon units are organized in these materials and each carbon is sp^2 hybridised. Carbon nanotubes (CNTs) are elongated tubular structures with diameters ranging from 1 to 2nm (Ibrahim, 2013). Their electrical properties can be classified as either metallic or semiconducting based on their diameter and chirality (Aqel *et al.*, 2012). Structurally, they resemble a graphite sheet that has rolled up. These rolled sheets are classified as single-walled (SWNTs), double-walled (DWNTs), or multi-walled carbon nanotubes (MWNTs) based upon their number of layers. They are primarily produced by depositing carbon precursors, particularly atomic carbon, which is vaporized from graphite through laser ablation or electric arc processes onto metal particles. Recently, carbon nanotubes have also been synthesized using chemical vapor deposition (CVD) techniques (Elliott *et al.*, 2013).

Metal Nps

Metal nanoparticles (NPs) are entirely composed of metallic precursors. Owing to their well-established localized surface plasmon resonance (LSPR) properties, these NPs exhibit distinct optoelectrical features. NPs made from alkali and noble metals, such as copper (Cu), silver (Ag), and gold (Au), demonstrate a broad absorption spectrum in the visible region of the electromagnetic solar spectrum. The controlled synthesis of metal NPs, in terms of facet, size, and shape, is crucial in today's advanced materials research (Dreaden *et al.*, 2012). Thanks to their exceptional optical characteristics, metal NPs are utilized across various research fields. Coating with gold NPs is commonly employed



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for scanning electron microscopy (SEM) sampling to improve the electronic stream, facilitating the acquisition of high-quality SEM images.

Ceramic Nps

Ceramic nanoparticles (Nps) are solid inorganic materials that lack metallic properties and are produced through heating and subsequent cooling processes. They can exist in various forms including amorphous, polycrystalline, dense, porous, or hollow structures (Sigmund *et al.*, 2006). As a result, these Nps are attracting significant attention from researchers due to their potential in numerous applications, such as catalysis, photocatalysis, dye photodegradation and imaging technologies (Thomas *et al.*, 2015).

Polymeric Nps

Nps with an organic base are typically referred to as polymeric nanoparticles (PNPs). Most of them have the shape of nanospheres (Mansha *et al.*, 2017). At the outer edge of the spherical surface, the other molecules are adsorbed, while the former are matrix particles with an overall mass that is typically solid. The solid mass is entirely contained within the particle in the latter instance (Rao and Geckeler, 2011). Numerous applications of PNPs can be found as they are easily functionalized (Abd Ellah and Abouelmagd, 2016).

Lipid based Nps

As the name itself says, these nanomaterials have lipid moieties and they are used in various biomedical applications. The lipid Nps is typically spherical, with a diameter between 10 and 1000nm. Lipid nanomaterials have a solid lipid core and a matrix of soluble lipophilic molecules, just like polymeric Nps. The external core of these nanomaterials where stabilized by surfactants or emulsifiers (Rawat *et al.*, 2011). (Mashaghi *et al.*'s work on lipid nanotechnology, 2013) is a specialized field that focuses on the design and synthesis of lipid nanoparticles for a range of uses including drug delivery and carriers (Puri *et al.*, 2009).

Semiconductor based Nps

Semiconductor Nps are the nanoscale particles that exhibit tunable optical, magnetic, and electronic properties. These nanocrystals, which typically have sizes between 1 and 100 nm are retrieved from bulk materials which act as a bridge between small molecules and large crystals by exhibiting distinct electronic transitions that resemble isolated atoms and molecules and by making it possible to utilize the beneficial qualities of crystalline materials. The composition-dependent band gap energy, which is the bare minimum of energy needed to excite an electron from the ground state valence energy band into the unoccupied conduction energy band, is a characteristic of bulk semiconductors (Smith AM, Nie S, 2010). They are composed of materials like Silicon, Germanium. Various applications of semiconductor nanoparticles are drug delivery, imaging, and biosensors in biomedical field, also used in LEDs, solar cells, batteries. They also act as water and air purification as part of environment treatment.

Synthesis of Nanoparticles

When it comes to Nanomaterials, to achieve the desired results tremendous significance needs to be given to the synthesis part, as it holds the major stake in controlling the size and shape of the desired nanomaterials. There are basically two broad categories onto which various methods are for the synthesis of Nanostructures. The two classes are: (a) Bottom-up type and (b) Top-down type (Wang and Xia, 2004). In Bottom up type, the nanoparticles are formed from the smaller or simpler substances. And in the Top down method, the bigger materials are broken down into sub-micron level particles, which are ultimately the nanostructures. The above-mentioned methods can be broadly put in to three categories which are physical, chemical and biological. Every method has their own advantages and disadvantages and depending upon the availability of the facilities, cost and environmental concerns, the synthesis method is preferred.

Physical Methods

Physical methods for the synthesis of the nanomaterials is the significant approach in the larger field of nanotechnology. It can yield high purity nanomaterials along with minimized contamination. The physical method



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for nanoparticles synthesis typically follow stop-down strategy, where bulk or the large materials are broken down into nanoscale by application of physical forces. There is less chance of contamination because it doesn't call for the use of chemical reagents. The high expense of the laser equipment and the difficulties in expanding the procedure for mass manufacturing, however, continue to be major drawbacks (McNamara *et al.*, 2003; Boulos *et al.*, 2002). Physical Vapor Deposition (PVD) is another pervasively used physical method for coating and thin film applications. PVD method of nanomaterials synthesis follows a vacuum environment in which a material is vaporized and then condensed onto a substrate to form nanoparticle. Several sub-techniques, including sputtering, evaporation, and laser ablation, can do this. PVD is perfect for applications requiring high-quality coatings or thin films because it provides exact control over the content and structure of the particles. However, the process necessitates sophisticated equipment and vacuum chambers, which can be costly and challenging to scale up for mass production (Ohring, 2002; Liu *et al.*, 2005).

Chemical Method

Similar to physical method of synthesis, chemical methods are also one of the commonly approached synthesis methods in the nanotechnology. By monitoring and adjusting various parameters like temperature, pH, reaction time, and concentration it results in the yield of desired size, shape and composition of the nanoparticles. Methods such as Solvothermal, Hydrothermal, Chemical Vapor Deposition (CVD) and Chemical Reduction, Precipitation, Sol-Gel synthesis, Microemulsion are some of the examples of this category. The Solvothermal and Hydrothermal are one of the most widely used methods for the synthesis Nps. As the name itself says, Solvothermal means they use organic solvent and Hydrothermal means they use water instead solvent for the synthesizing of nanomaterials. The key feature of these methods is that they use high-temperature solvents or water to synthesize Nps. Under certain circumstances like proper temperature and pressure, the precursor material is dissolved in the solvent (organic or water) in a sealed container and the reaction is carried out. Under these circumstances, there will be high yield of nanoparticles with uniform size and high crystallinity. These are helpful in the production of inorganic Nps like metal oxides, carbon nanotubes and semiconductors (Feng *et al.*, 2007; Zhao *et al.*, 2008). Another well-known chemical method is the Chemical Reduction Nps synthesis. In this method, metal salts are reduced to metal nanoparticles with the help of reducing agents, hence the name Chemical reduction. Depending on the system, this extremely adaptable process can be run in either the liquid or gas phase. For instance, Silver nanoparticles are formed from silver nitrate which is reduced in the presence of Sodium citrate. By varying the temperature, reaction time, and reducing agent concentration, the nanoparticles size can be regulated. This method is preferred when there is need to synthesize noble metal nanoparticles like gold, silver, and platinum. Nevertheless, the major disadvantage of this method is potential for the formation of agglomerates and this can reduce the efficacy of the nanomaterials (Xie *et al.*, 2015; Daniel and Astruc, 2004). The sol-gel process can be readily adapted for large-scale manufacturing; however, it may necessitate precise control of the reaction parameters to avoid particle aggregation or the development of unwanted phases (Brinker and Scherer, 1990; Aegerter *et al.*, 2011).

Biological Methods

The Nanoparticles synthesized through biological methods are often referred to as Green synthesis and it is regarded as the eco-friendly method for the synthesis of Nps. Unlike chemical and physical methods, they are abstained of using harsh and harmful chemicals that can damage the environment. Instead they prefer living organisms like plants, microorganisms, plant extracts to produce nanoparticles. As this method avoids the use of toxic chemicals and harsh chemical reactions, they are cost-effective, sustainable, biocompatible and has high purity. Due to this, they are used in the field of biomedical and environment.

Plant Mediated Synthesis (Green Synthesis)

Plant extracts are one of the most widely used green synthesis method for the synthesis of nanoparticles due to their ease of availability and cost effective. When extract derived from plants are mixed with metal salt solution and kept at room temperature, the nanoparticles are derived within minutes to hours after completing the reaction. Various metals like silver, gold, platinum is derived in this way. For instance, silver nanoparticle derived from plant extracts has exhibited anti-microbial properties which makes them using in the medical devices and wound healing (Siddiqi



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et al., 2018; Kalishwaralal et al., 2010). The below figure shows the chemical constituents of plants that are involved in the formation of Nps.

Microbial Mediated Synthesis

Another important green synthesis method for the nanoparticles is by use of microorganism. The microorganisms can be bacteria, algae and fungi. The synthesis is similar to the plant extract but one of the major advantages being the availability of whole cell or cell-free extracts. These extracts reduce the metal salt or ions into nanoparticles. Microorganisms like *Aspergillus niger*, *Escherichia coli*, *Bacillus subtilis*, *Streptomyces* and *Trichoderma harzianum* are capable to synthesize nanoparticles. (Bansal et al., 2009; Jha et al., 2009). (Bose and Sahu, 2012).

The Green synthesis of metal nanoparticles have various advantages over the traditional chemical and physical methods. The use of non-toxic chemicals, minimizing the reaction time and reducing the adverse effects of chemicals on environment and majorly biocompatibility has shown the intense and vast usage in the biological and medical fields.

Bacterial Mediated Synthesis

It is another kind of green synthesis method which shows great ability for the nanoparticle formation. This is due to their high metabolic activity and the capacity to produce various reducing agents. Bacteria like *Escherichia coli*, *Staphylococcus*, *Streptomyces*, *Bacillus subtilis* has the ability to reduce metal salt solution to synthesize nanoparticles. The nanoparticles synthesized from bacteria have excellent stability and functionalization potential making them as controlled scalable process which are ideal for the biomedical applications. (Bose and Sahu, 2012).

Biomolecules Mediated Synthesis

In addition to various Microorganisms and plants, biomolecules are also used for the successful synthesis of nanoparticles. Biomolecules such as enzyme, protein and peptides are used as reducing and stabilizing agents for nanoparticles synthesis. For an instance, enzymes can facilitate the reduction of metal ions and stabilization of nanoparticles resulting as efficient route for nanoparticles synthesis. This way of synthesis of nanoparticles is promising for the production of nanoparticles which have complex surface chemistry, and they are used in the applications like drug delivery and bio sensors (Brennan et al., 2015).

Significance of Green Synthesis and Silver Nanoparticles

Though the traditional synthesis methods are effective and widely used, they do result in the environment concern as it involves use of toxic chemicals, harmful environmental byproducts, longer reaction time and complex protocols. This is where the Green synthesis method comes where it minimizes the use of toxic chemicals and are bio compatible unlike the conventional methods. Green synthesis is Eco-friendly alternative, cost-effective and environment sustainable as it involves the use of plant extracts, microorganisms to produce nanoparticles. Reducing agents like Sodium borohydride or hydrazine, are toxic to the environment while natural reducing agents like polyphenols, flavonoids are utilized in green synthesis which are generally found in plant extracts and they also operate under ambient conditions and are low cost making it an ideal method for the synthesis of nanoparticles. Along with this, their enhanced bio compatibility due to the presence of natural capping agents like phytochemicals reduces their toxicity, making it safety and ideal for various bio medical applications. And incorporating this method in the synthesis of silver nanoparticles has ample number of benefits to the world. Silver nanoparticles has been studied extensively as they have shown excellent anti- inflammatory, antimicrobial and antioxidant activities (Raj, M., et al. (2009). Even though they can be synthesized through the conventional methods, biological or the green synthesis has been effective and safe when it is used for the medical purposes. The Phytochemicals like flavonoids, phenolic acids, tannins, alkaloids present in the plant extract acts as natural capping agents making them safe. Due to their exceptional antimicrobial activity, silver nanoparticles are incorporated in medical devices, wound healing and also in agriculture pest control. (Kumar et al., 2019). They also possess antioxidant activity which reduces the oxidative stress by scavenging the free radical. In addition to this, they are also useful in treating conditions like arthritis and wound making them act as anti-inflammatory agents. (Patel et al., 2018). Kumar, R., et al. (2019).



**Aakash Gowthaman et al.,****OBJECTIVES OF THE STUDY**

- To collect the sample and authenticate.
- To perform qualitative and quantitative analyses of the phytochemical present in the extract.
- To synthesize AgNps (Silver Nanoparticles) using the *Zanthoxylum armatum* seed extract.
- To characterize the synthesized nanoparticles.
- To evaluate the biological properties of nanoparticles.

REVIEW OF LITERATURE AI**Green Synthesis of Silver Nanoparticles and its Significance**

Plants are known for their immense medicinal benefits. When chemically synthesized drugs were not available in the early days, people used plants as natural medicine. People generally link them to religious and spiritual thing for many healing and cure. Over the past few years, the environmentally friendly synthesis of silver nanoparticles (AgNPs) has gained significant interest based on their diverse applications and decreased environmental footprint. Traditional physical and chemical synthesis routes, although effective, tend to use harmful chemicals and high amounts of energy. Conversely, green synthesis offers a sustainable, cost-effective, and eco-friendly alternative by using biological species such as plant extracts with a mix of phytochemicals that have the ability to convert silver ions (Ag^+) into silver nanoparticles (Ag^0).

Role of Light Conditions in Nanoparticle Synthesis

Light has been found to have a marked effect on the synthesis and properties of silver nanoparticles. Light can result in photoactivation of silver nitrate, which can be responsible for uncontrolled reduction and nanoparticle agglomeration. Hence, a number of studies have underscored the necessity of carrying out synthesis in the dark to keep the reaction in check and produce uniform nanoparticle properties.

Green Synthesis Using Some plants

In a study by International Journal of Nanomedicine, 2021, ginger (*Zingiber officinale*) extract was utilized for green AgNPs synthesis. The scientists modified the pH to 12 and left the mixture in dark conditions for 24 hours to avoid photoactivation. Dark brown color change indicated nanoparticle formation, which was further confirmed by UV-Vis spectroscopy and other characterization methods. The dark condition enabled a slow and controlled process of reaction, improving the stability and homogeneity of the particles (International Journal of Nanomedicine, 2021). Silver nanoparticles were synthesized in dark conditions using safflower extract according to a rather interesting study published in Heliyon back in 2021. Incubation of reaction mixture in dark conditions prevented unwanted side reactions precipitated by light thereby resulting in significantly improved AgNPs quality. External conditions like light and pH played a pivotal role in nanoparticle synthesis success (Heliyon 2021).

Ferulago macrocarpa extract facilitates green synthesis rather remarkably according to a study published in Journal of Experimental Nanoscience during 2020. They obtained optimal synthesis using 1 mM silver nitrate at pH 11 and keeping mixture in darkness at 80°C for two and half hours. Nanoparticle formation occurred successfully as solution turned brown signifying a rather complex chemical reaction had taken place quietly. Proper reaction conditions especially darkness play a crucial role in green synthesis procedures according to a recent study published in Journal of Experimental Nanoscience in 2020. A study carried on with the green synthesis of silver nanoparticles with *Zanthoxylum armatum* stem extract showed the successful formation of silver nanoparticles having characteristic absorption in UV-Vis Spectroscopy at 385nm (Habib, U., Ahmad khan, A., Rahman, T. U., Zeb, M. A., and Liaqat, W. (2022). The literature also reviewed the further confirmation of nanoparticle by SEM having the size range of 46.66nm to 60.12nm, spherical shape and XRD showed FCC structure. FTIR analysis exhibited the presence of secondary alcohol and phenol groups over the AgNps. The antibacterial activity against the specific bacteria showed zone of inhibition of 21mm for *Staphylococcus aureus*, 17mm for *Pseudomonas aeruginosa*, 18mm for *Salmonella enteric*.



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Though some research have been conducted with different parts of *Z. armatum*, primarily fruits and leaves for nanoparticles synthesis. They have been successfully demonstrated the effectiveness of gold and silver nanoparticles. However, research with seed remain scarce which is highlighted through this study with the hydroalcoholic solvent ratio (70:30). Results from current research on *Zanthoxylum armatum* seed extract in water-ethanol solvent medium which comprises 70% ethanol apply fairly generally. Changes in light exposure and reaction conditions can markedly enhance synthesis yield by drawing cues from experiences garnered through various prior studies.

Zanthoxylum armatum

Zanthoxylum armatum, also known as Timur or tooth ache tree is a traditional medicinal plant which are predominantly grown in Himalayan regions. They are endemic to India, Japan, Korea and China. The different parts of plants are used for various purposes in different parts of region. For an instance, it is used by Bhotiya communities of Uttaranchal for food, medicines and trade. Bhotiyas people of Pithoragarh district of Kumaon region uses fruit while the sticks of *Zanthoxylum armatum* has been collected and traded to the pilgrims of Badrinath, Kedarnath, Yamunotri and Gangotri by peoples of Kamoli district of Garhwal. However, the seeds, barks and leaves are used as condiment in Indian households. Seeds of *Z. armatum* are rich in essential oils, alkaloids, flavonoids, lignans, and fatty acids, making them suitable for nanoparticle synthesis (Shrestha and Jha, 2010). The plant belongs to Rutaceae family and it is an aromatic deciduous, spiny shrub which grows to 3.5 meters in height. It is commonly known as Timur in Nepal, Tejphal, Tumru, Trimal in Hindi. Different varieties of the tree are found in various parts of India such as Jammu and Kashmir, Manipur, Assam, Nepal, Meghalaya, Nagaland, Orissa, Andhra Pradesh.

Taxonomic Classification

Taxonomical Classification of *Zanthoxylum armatum* (Table:1).

MATERIALS AND METHODS

Preparation of Plant materials

Zanthoxylum armatum seeds were bought from the verified local source and they were rinsed with water to remove the dirt or dusts. The seeds were then shade dried at room temperature for several days so that the moisture present in the seed would be eliminated without the loss of phytochemical constituents. Then they were hand grounded into coarse powder using conventional mortar and pestle and stored in zip lock bag or air tight container. Fig:1. *Zanthoxylum armatum* seed powdered sample.

Solvent Preparation

Based on the desired components, the solvent was preferred. For this study, water and ethanol (hydroalcoholic) in the ratio 70:30(v/v). Ethanol dissolves non-polar compounds while water extracts polar components providing a broad spectrum of phytochemicals for nanoparticle synthesis.

Phytoextraction

It was carried out in the ratio 1:10 i.e., for 1gm of sample 10ml of solvent was used. Therefore, 10gm of seed powder was dissolved in 100ml of hydroalcoholic solvent in a 200ml beaker and they were covered with aluminium foil to prevent the vaporization of ethanol. They were boiled at 60°C for 20min and filtered with cheese cloth after cooling. Further, the extraction was kept in the glass beaker sealed with aluminium foil and stored at 4°C in the refrigerator. The extraction mixture is shown below (Fig: 2. An Extracted Sample).

Nanoparticle Synthesis

Silver nitrate procured from Vels University Central Reagent Lab was used for the synthesis process. To synthesize Silver nanoparticles, 1mM aqueous solution of Silver nitrate was prepared by dissolving approximately 169.7mg of silver nitrate in 1000ml of distilled water. From that, 90ml of the solution was transferred into a 200ml beaker and 10ml of the plant extract was added into it, making it as in the ratio (1:10) and the mixture was continuously stirred at



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room temperature. They were sealed with aluminium foil and stored at room temperature in dark conditions to prevent photoreduction. The mixture was monitored for any visible color change. The color change from pale yellow to brown color was observed over 24hrs if there's formation of silver nanoparticles. Reaction mixture after the immediate addition of Seed extract (Fig: 3). Reaction mixture after 24hrs of incubation in dark condition (Fig: 4).

Characterization Techniques

After physically confirming the presence of Silver Nanoparticles with the help of color change from pale yellow to dark yellowish-brown, they were further studied for the characterization. The characterization techniques help in the characterization of the Nps synthesized therefore it is the essential step that can confirm the formation of nanoparticles. They also help to understand their morphology, size and stability. The analytical tools for the characterization of nanoparticles are UV-Visible Spectroscopy, Dynamic Light Scattering, Fourier Transform Infrared Spectroscopy.

UV-Visible Spectroscopy

UV-Vis or Ultraviolet-Visible Spectroscopy is the first and foremost analytical technique used for the confirmation of nanoparticles. It measures the light in the ultraviolet and visible region of the spectrum. It is one of the useful techniques used to analyze the amount of substance present in a sample. This technique is based on the principle of Beer Lambert's Law which states that amount of light absorbed is directly proportional to the concentration or amount of substance present in a sample. It is given by $A = \epsilon bc$ where, A is the absorbance of light, b is path length, c is concentration of absorbing compound and ϵ is the molar absorptivity. The UV-Vis spectrum ranges from 200nm-800nm and each nanoparticle has their own wavelength or to put it scientifically, each metal nanoparticles has a distinct surface plasmon resonance (SPR) band onto which they show peak or spike. Likewise, for AgNps (Silver Nanoparticles) the SPR usually appears between 400nm-450nm due to the continuous oscillation of electrons on the nanoparticles surface when excited by light (Kora and Rastogi, 2013). And peak within this range confirms the presence of AgNps.

Fourier Transform Infrared Spectroscopy

FTIR or Fourier Transform Infrared Spectroscopy is another powerful analytical technique for the characterization of nanoparticles. It helps in the identification of organic and inorganic molecules of the synthesized nanoparticles which are on the surface of nanoparticles after interacting with the plant extract. The principle of FTIR is a beam of infrared radiation is passed through a sample to produce an infrared spectrum, and the transmission percentage of the radiation is recorded as a function of transmitted radiation wave number. A certain portion of infrared radiation is transmitted through the sample and other remaining portion are absorbed. The radiation of infrared absorbed and transmitted by sample produces molecular fingerprint from the spectrum. Two regions can be distinguished in an infrared spectrum. One of them is fingerprint region which is between 1000 and 400 cm^{-1} while another is functional group region where majority of the functional groups exhibit absorption bands in the 4000-1000 cm^{-1} area. These two regions usually detect the molecular vibrations corresponding to various bonds such as O-H, C=O, and N-H where these bonds represents the phytochemicals present in the sample (e.g., alkaloids, phenols, flavonoids). These phytochemicals get participated in the capping and reduction of nanoparticles (Mittal *et al.*, 2013).

Dynamic Light Scattering

Another important analytical technique for the characterization of nanoparticles. Dynamic Light Scattering (DLS) also known as Quasi-elastic light scattering. It helps in the study of size of small particles which ranges from nanometer to sub-micrometer, suspended in a liquid. The fundamentals of DLS is that it is based upon the Brownian movement of particles in a fluid. It determines the hydrodynamic diameter of nanoparticles in suspension by measuring the fluctuations in light intensity scattered by particles undergoing Brownian motion, which are then correlated with particle size. The speed of this motion is inversely proportionally to particle size, i.e., smaller the particle faster they move and inverse. A laser beam is directed at the particle suspension from monochromatic light source. When the laser hits particle in suspension, the light gets scattered in various directions. Overtime, due to the





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particle movement, the intensity of the scattered light gets fluctuated. And these fluctuations are recorded at fixed angle by a detector. The hydrodynamic diameter is calculated using Stokes-Einstein equation

$$D = k_B T / 3 \pi \eta d_H$$

where,

D= diffusion of coefficient

k_B =Boltzmann constant

T= absolute temperature

η = viscosity of the solvent

d_H = hydrodynamic diameter of the particle

It also provides data on the PDI (polydispersity index) indicating the uniformity of particle size in sample.

Antibacterial Activity

The Antibacterial activity was performed in Avigen Biotech Lab, Chrompet, and Armats Biotech Lab, Guindy, Chennai. The Antibacterial activity which is usually done against the bacterial pathogens was carried out by agar well diffusion method (Mosachristas, 2018). The pure culture of *Klebsiella pneumoniae* was obtained and maintained in Nutrient Agar (NA) slant. The bacterial strain of *Klebsiella pneumoniae* were grown overnight in NA liquid medium or broth on a shaking incubator at 37°C at 100rpm. The Mueller-Hinton Agar was prepared and sterilized by autoclaving. The inoculum containing a microbial load of 1×10^5 CFU/ml was then applied to respective agar plates. A 6mm diameter of wells were punched aseptically with sterile well cutter. Then they were loaded with different concentrations of sample (ZAAGNps) (25, 50, 75, 100ug/ml) respectively. Further, 20ul of gentamycin (positive control) into another well which acted as control, 10ug). The plates were incubated at 37°C for 24hrs. Further, zone of inhibition (mm) was measured which are appeared around the wells. For *Staphylococcus aureus* (25923) and *Escherichia coli* (25922) bacteria, Muller-Hinton Agar was prepared and sterilized by autoclaving. The control used was antibiotic tetracycline (50µg/mL). The *E. coli* and *S. aureus* strains were inoculated in the nutrient broth and incubated overnight at 37°C. Then on the sterile MHA plates, *S. aureus* and *E. coli* bacterial culture were uniformly spread on their respective plates and using well cutter four wells (C, 250uL, 500uL, 1000uL) were made in both the plates. Using sterile micropipette, 100uL of sample (ZAAGNps) was added into the wells. The plates were incubated at 37°C for overnight. The next day zone of inhibitions were measured.

Antioxidant Assay

This assay was carried out in Avigen Biotech Lab, Chrompet, Chennai and Armats Biotech Lab, Guindy, Chennai. Antioxidant activity exhibits the potential of sample to scavenge free radicals. To assess the antioxidant activity, DPPH scavenging activity were performed, by using 1,1-diphenyl-2-picrylhydrazyl (Manzocco et al, 1998) and Ferric Reducing Power Assay (FRAP).

DPPH Assay

0.4mM solution of DPPH were prepared using methanol and 2ml of this sample was added to different concentration of the sample ranging from 20ul, 40ul, 60ul, 80ul, and 100ul. And then they were kept at room temperature for 15min. Then, the absorbance was read at 517nm against blank samples. Lower the absorbance of reaction mixture, higher the free radical scavenging activity. The percentage of DPPH radical scavenging is calculated by below equation:

$$\text{Radical scavenging activity/ Inhibition (\%)} = (\text{Abs Control} - \text{Abs sample} / \text{Abs control}) \times 100$$

FRAP Assay

FRAP or Ferric Reducing Antioxidant Power Assay is a method that uses antioxidant as reductants in a redox-linked colorimetric reaction. Different concentrations of the extracts (20 – 120 µg/mL) were mixed with 1 mL of phosphate buffer (0.2 M, pH 6.6) and 1mL of 1% potassium ferric cyanide. The mixture was incubated at 50°C for 20 minutes. Then, 1 mL of 10% trichloroacetic acid was added to the mixture. Further, 1 mL of 0.1% of freshly prepared ferric



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chloride was added and the absorbance of the resultant solution was measured at 700 nm. The percentage of reduction was calculated by the below formula:

$$\% \text{ of reduction} = \frac{\text{Sample} - \text{Control}}{\text{Sample}} \times 100$$

RESULTS AND DISCUSSION

UV-Visible Spectroscopy

The UV-Visible spectroscopy was carried out through Systronics (India) Limited, UV-VIS Spectrophotometer-119. The sample are analyzed in the UV-Visible region or spectrum which ranges from 200nm -800nm. It is the primary technique used to confirm the formation of nanoparticles or any mixture. After the presence of silver nanoparticles (AgNps) by physical confirmation, this technique is specialized to provides insight into the behavior of nanoparticles through surface plasmon resonance (SPR). In the current research carried out with seed extract of *Zanthoxylum armatum*, in the hydroalcoholic solvent ratio 70:30 displayed absorbance at 332nm. The extraction was carried out under 60°C for 20 min and further the extract was mixed with 1mM silver nitrate solution for the synthesis of nanoparticles. However, the solvent used in this research is water and ethanol depicted the peak at 332nm which is not corresponding to the characteristics of silver nanoparticles but the literature [9] carried out with the same plant but different part revealed peak at 385nm and confirming the presence of Silver Nanoparticles. Though, it is not corresponding to the characteristics of AgNp, it may have less stability or could have low concentration of silver nanoparticles in the obtained mixture. The lack of SPR band indicates that either the phytochemical concentration in the extract was insufficient to facilitate reduction or it may also be due to reaction conditions. The below figure. 5 describes the SPR of the synthesized silver nanoparticles.

Fourier Transform Infrared Spectroscopy

FTIR was performed in Vels University Central Instrumentation Laboratory with Spectrum Two FT-IR/Sp10 software model, PERKIN ELMER, USA. Fourier Transform Infrared Spectroscopy is another analytical technique which are used to identify the functional groups in a mixture. They are carried out by the measurement of infrared absorption of molecules present in the compound. It provides important information of the phytochemicals that are present in the plant. During the interaction with metal ions, the phytochemicals of the plants react with them and reduces to form nanoscale structures. The functional groups that are involved in the reducing of metal ions to nanoparticle are analyzed and detected by the infrared spectrum and are portrayed as in the form of peaks with %T (Transmission). In the study conducted with dried seed extract of *Zanthoxylum armatum*, in the hydroalcoholic solvent ratio 70:30 displayed two peaks when analysis was carried out with FTIR in the infrared range 4000 to 400cm⁻¹. The peaks were formed at 3341.89cm⁻¹, 51.66%T and 1636.16cm⁻¹, 72.31%T. These peaks were corresponding to the N-H stretch, C-N stretch, O-H stretch, C=O stretch and these are corresponding to the Alkaloids, Flavonoids and Polyphenols. So, FTIR peaks displayed in the Fig 6, showed the presence of phytochemicals like polyphenols, alkaloids and flavonoids. This shows the confirmation of phytochemicals of the silver nanoparticles of *Zanthoxylum armatum* seed extract.

Dynamic Light Scattering

DLS was performed in Vels University Central Instrumentation Laboratory with Nanotracs Wave II model, Microtrac, Inc. USA. Dynamic Light Scattering is a powerful analytical tool in the characterization of nanoparticles. They analyze the size distribution and stability of nanoparticles suspended in liquid media. It is based upon the Brownian motion of particles suspended in liquid medium. When a beam of light usually laser is made pass through the solution mixture, these get hit by the particles in the solutions due to which fluctuations happen. It measures the fluctuations in the intensity of scattered light caused by Brownian motion of particles in suspension and these fluctuations are used to determine the hydrodynamic diameter of the particle. This gives insights of their distribution, agglomeration and their average size. DLS result of ZAAgNps (Fig:7). The study carried out with *Zanthoxylum armatum* seed extract in the hydroalcoholic solvent ratio 70:30 showed three peaks. This may be due to the solvent preference or the reaction conditions that there's size variability. These were identified using the PDI (Polydispersity index) which tells





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how uniform the sample in the mixture are. The PDI value obtained is 0.24 which indicates there's moderate polydispersity. The lower the PDI values better the quality of particles, i.e., uniformly sized and inverse for the higher PDI values.

Antibacterial Activity

The antibacterial activity was carried out by Agar well diffusion method. The pure culture of bacterial strain *Klebsiella pneumoniae* was obtained and maintained in nutrient agar slant for 37°C. Further, the bacterial strain of *Klebsiella pneumoniae* were grown overnight in NA liquid medium or broth on a shaking incubator at 37°C at 100rpm. The inoculum containing a microbial load of 1×10^5 CFU/ml was then applied to respective agar plates. A 6mm diameter of wells were punched aseptically with sterile cork borer. Then they were loaded with different concentrations of sample (AgNps) (25, 50, 75, 100µL) respectively. Further, 20ul of gentamycin (positive control) into another well which acted as control, 10ug). The plates were incubated at 37°C for 24hrs. Further, zone of inhibition (mm) was measured which are appeared around the wells. After 24hrs of incubation at 37°C, the study carried out with the silver nanoparticles synthesized from *Zanthoxylum armatum* seed extract showed prominent effect or the inhibition was best in the concentration 100ug/ml showing 19mm of zone of inhibition. The positive control used was gentamycin which has the zone of inhibition 20mm against the bacteria *Klebsiella pneumoniae*. And the AgNps of *Zanthoxylum armatum* seed extract had the zone of inhibition in its highest concentration 100ug/ml of 19mm. Higher the concentration, better the zone of inhibition. The test results showed following zone of inhibitions (mm) 0, 14, 17, and 19 in the respective concentrations (µL) 25, 50, 75, and 100 against the pathogen *Klebsiella pneumoniae*. The zone of inhibitions against the bacteria *Klebsiella pneumoniae* are showed in the below. The figure 8 shows the activity of AgNps from *Zanthoxylum armatum* seed extract against the bacteria. For the *Staphylococcus aureus* (25923) and *Escherichia coli* (25922), the positive control used was tetracycline (50µg/mL) which has the standard zone of inhibition value of 35mm and 23mm. For these two bacteria the concentrations used were 250µL, 500µL, and 1000µL respectively. After the incubation at 37°C, there were significant formation of zone of inhibitions. The Zone of Inhibitions for *E. coli* are 11mm, 11mm, 14mm and that for *S. aureus* is 15mm, 16mm, 16mm respectively. Therefore, the highest (mm) of zone of inhibitions in both the bacteria is corresponding to the concentration 1000µL indicating that, higher the concentration higher the amount of zone of inhibitions. The Zone of inhibitions of *E. coli* and *S. aureus* are shown in the figure 9 and figure 10. *S. aureus* had better zone of inhibition when compared to *E. coli*. Table: 2. Result of ZAAgNps against *Klebsiella pneumoniae*. Fig: 8. ZAAgNps (Silver Nanoparticles) activity against *Klebsiella pneumoniae*. Table:3. Result of ZAAgNps against *E. coli* and *S. aureus*.

Antioxidant Assay

DPPH Assay

The antioxidant assay was performed by DPPH (1,1-diphenyl-2-picrylhydrazyl) scavenging activity. 0.4mM solution of DPPH were prepared using methanol and 2ml of this sample was added to different concentration of the sample ranging from 20ul, 40ul, 60ul, 80ul, and 100ul. And then they were kept at room temperature for 15min. Then, the absorbance was read at 517nm against blank samples. Lower the absorbance of reaction mixture, higher the free radical scavenging activity. The study carried out with AgNps of *Zanthoxylum armatum* seed extract, it showed potential effect in the concentration 100ul which had the absorbance of 0.201. The control had the 0% inhibition at absorbance 0.965 but the concentrations (uL) from 20, 40, 60, 80 and 100 showed the inhibitions 4.45, 9.32, 20.93, 45.80, 79.17 with their corresponding absorbance 0.922, 0.875, 0.763, 0.523, 0.201 respectively. The higher the concentration of sample higher the scavenging potential.

The inhibitions were calculated with the formula

Radical scavenging activity/ Inhibition (%) = (Abs Control-Abs sample/ Abs control) x 100

ZAAgNps Results of DPPH antioxidant assay (Table: 4). Chart depicting % of inhibitory activity of ZAAgNps (Chart: 2). DPPH Antioxidant Assay of ZAAgNps (Fig:11).

FRAP Assay

Ferric Reducing Antioxidant Power Assay is a method that uses antioxidant as reductants in a redox-linked colorimetric reaction. Different concentrations were used to assess the reducing potential of ZAAgNps. The study



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carried out with AgNps of *Zanthoxylum armatum* seed extract, it showed potential effect in the concentration 120ul which had the absorbance of 1.400. The control had the 0% inhibition at absorbance 0.302 but the concentrations ($\mu\text{g/mL}$) from 20, 40, 60, 80, 100 and 120 showed the inhibitions (%) 14.44, 55.97, 69.70, 75.84, 76.38 and 78.42 with their corresponding absorbance 0.353, 0.686, 0.997, 1.250, 1.279 and 1.400 respectively. The higher the concentration of sample higher the percentage of inhibitions. The % of inhibitions were calculated with the formula:

% of reduction = $\frac{\text{Sample} - \text{Control}}{\text{Sample}} \times 100$

ZAAgNps Results of FRAP antioxidant assay (Table: 5). Chart depicting % of reducing activity of ZAAgNps (Chart: 2). FRAP Antioxidant Assay of ZAAgNps (Fig:12)

CONCLUSION

The study green synthesis of silver nanoparticles using *Zanthoxylum armatum* seed extract revealed the preliminary indications of reaction like color change, peaks formation in UV-Vis spectroscopy, presence of Alkaloids, flavonoids and polyphenols which are all corresponding to the silver nanoparticles. Though the color change to yellowish-brown suggested some reactions between the seed extract and silver nanoparticles, the characteristic surface plasmon resonance was absent due to which the formed AgNps may have less stability with the solvent preferred with 70:30 hydroalcoholic. suboptimal reagents, or the need for certain conditions like temperature, pH etc. Despite of the lesser stability of ZAAgNps, it showed prominent activity against *Klebsiella pneumoniae* and *S. aureus* with 19mm of zone of inhibition and 16mm in 100ug/ml and 1000 μL concentration. And the DPPH assay resulted their inhibitions of 79.17% at 100uLof concentration and 78.42% of reduction at 120 $\mu\text{g/mL}$ in FRAP Assay.

SUMMARY

The present study was undertaken to explore the green synthesis of silver nanoparticles using *Zanthoxylum armatum* seed extract in the solvent ratio 70:30 hydroalcoholic. The Plant based method offers a biocompatible and environment friendly route compared to traditional methods, making it easily approachable for nanoparticle production. During the study, the reaction mixture showed a visible color change from pale yellow to yellowish-brown color which typically indicates the presence of silver nanoparticles in the initial stage. Further, confirming with the UV-Vis spectroscopy revealed peak at 332nm confirming the presence of silver nanoparticle with reference to the literature [9]. The characterization using FTIR spectroscopy indicated the presence of functional groups hydroxyl and carbonyl with two peaks at 3341.89 cm^{-1} , 51.66%T and 1636.16 cm^{-1} , 72.31%T which played the role in stabilization and reduction process. The DLS results were not conclusively supportive but the PDI values indicated the presence of moderate polydispersity. The antibacterial activity against *E. coli*, *S. aureus* and *Klebsiella pneumoniae*, and antioxidant activity were also promising with the isolated silver nanoparticles using green synthesis of *Zanthoxylum armatum* seed extract.

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Table: 1: Taxonomical Classification of *Zanthoxylum armatum*

Botanical name	<i>Zanthoxylum armatum</i>
Family	Rutaceae
Kingdom	Plantae
Sub kingdom	Viridaeplantae
Domain	Eukaryote
Phylum	Tracheophyta
Sub phylum	Euphyllophytina
Infra phylum	Radiatopses
Class	Magnoliopsida
Sub class	Rosidae
Super order	Rutanae
Order	Spindale
Sub order	Rutineae
Genus	<i>Zanthoxylum</i>

Table.2: Result of ZAAgNps against *Klebsiella pneumoniae*

Pathogens	Zone of Inhibition (mm)				
	Positive Control (C)	25 μ L	50 μ L	75 μ L	100 μ L
<i>Klebsiella pneumoniae</i>	20	0	14	17	19

Table. 3: Result of ZAAgNps against *E. coli* and *S. aureus*

Pathogens	Zone of Inhibition (mm)			
	Positive Control (C)	250 μ L	500 μ L	1000 μ L
<i>E. coli</i>	23	11	11	14
<i>S. aureus</i>	35	15	16	16

Table. 4: ZAAgNps Results of DPPH antioxidant assay

Concentration (μ L)	Absorbance	Inhibition (%)
Control	0.965	0
20	0.922	4.455958549
40	0.875	9.32642487
60	0.763	20.93264249
80	0.523	45.80310881
100	0.201	79.17098446

Table. 5: ZAAgNps Results of FRAP antioxidant assay

S. No.	Conc. (μ g/mL)	Absorbance @700nm	% of Reduction
1.	Control	0.302	-
2.	20	0.353	14.44
3.	40	0.686	55.97
4.	60	0.997	69.70
5.	80	1.250	75.84
6.	100	1.279	76.38
7.	120	1.400	78.42



**Fig. 1. *Zanthoxylum armatum* seed powdered sample****Fig. 2. An Extracted Sample****Fig. 3. Reaction mixture after the immediate addition of Seed extract****Fig. 4. Reaction mixture after 24hrs of incubation in dark condition**



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Fig: 9. ZAAGNPs activity against *E. coli*



Fig: 10. ZAAGNPs activity against *S. aureus*

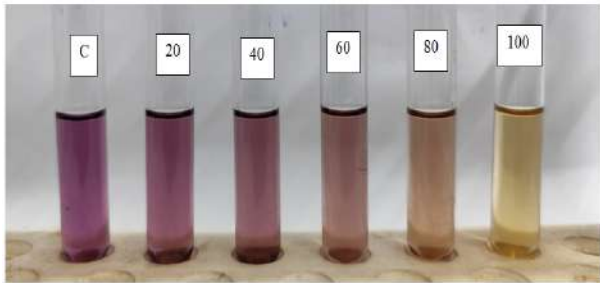


Fig: 11. DPPH Antioxidant Assay of ZAAGNPs

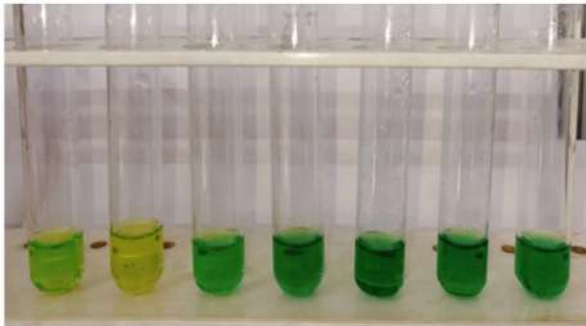


Fig: 12. FRAP Antioxidant Assay of ZAAGNPs

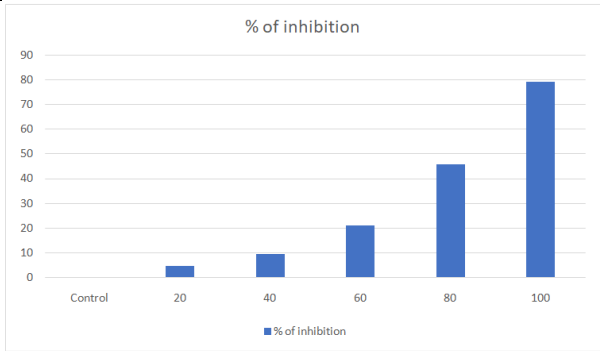


Chart: 1. Chart depicting % of inhibitory activity of ZAAGNPs

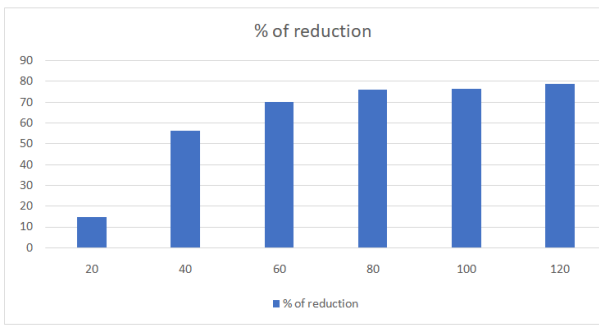


Chart: 2. Chart depicting % of reducing activity of ZAAGNPs





RESEARCH ARTICLE

IoT-Enabled Smart System for Hair Health Analysis and Monitoring

Meenakshi Kashyap^{1*}, Abhinav Kashyap², Muskan Vora³, Kunj Mungra³, Naineel Patel³ and Kunj Mungra³

¹Assistant Professor, Department of Computer Engineering and Information Technology, P P Savani University, Gujarat, India.

²Assistant Professor, Department of Mechanical Engineering and Information Technology, P P Savani University, Gujarat, India.

³Student, Department of Computer Engineering and Information Technology, P P Savani University, Gujarat, India.

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*Address for Correspondence

Meenakshi Kashyap

Assistant Professor,

Department of Computer Engineering and Information Technology,

P P Savani University, Gujarat, India.

E.Mail: meenakshi.kashyap@ppsu.ac.in



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ABSTRACT

This research presents the design and evaluation of an IoT-based system for continuous monitoring and assessment of hair and scalp health. Traditional methods of hair care and diagnostics often lack real-time capabilities and fail to provide comprehensive data. To overcome these challenges, we developed a comb-shaped device equipped with capacitive and environmental sensors to measure key parameters like scalp moisture, temperature and humidity. The Internet of Things integration enables seamless data transmission to a cloud platform, facilitating real-time monitoring and long-term tracking of hair health. This system offers a non-intrusive, cost-effective solution for both personal and clinical use, delivering timely feedback and recommendations through remote access. The proposed IoT-based approach represents a significant advancement in hair care technology, offering enhanced personalization and efficiency in hair health management.

Keywords: Internet of Things (IoT), Scalp health monitoring, Wearable sensors, Arduino.

INTRODUCTION

Human hair, despite its reduced functional role, retains significant emotional and social importance. Its complex keratin-based structure offers strength and flexibility, with properties varying widely across different ethnic groups and individuals. Understanding these variations is essential for developing effective hair care solutions and technologies. Recent advancements in non-invasive technologies, such as capacitive imaging systems, have provided



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valuable insights into hair health and cosmetic conditions. These technologies allow for precise measurement and analysis of hair properties, offering critical data for clinical, cosmetic, and forensic applications. Accurate monitoring of scalp conditions, including temperature and moisture, is vital for maintaining a healthy scalp. This study introduces an IoT-based hair quality detection system—a comb-like device equipped with advanced sensors designed to measure scalp moisture, environmental conditions, dandruff, and hair roughness. By integrating capacitive imaging and various sensor technologies, such as humidity and temperature sensors, the device offers comprehensive data on scalp and hair health [1][2]. The IoT integration enables continuous, real-time monitoring and data transmission to a cloud-based platform, allowing for remote access and long-term tracking of hair and scalp conditions. This innovative approach aims to enhance scalp health management by providing timely, personalized insights, ultimately contributing to more effective hair care solutions.

System Architecture

The IoT-Enabled Hair Health Analyzer measures hair and scalp parameters using multiple sensors connected to a microcontroller and integrated into an IoT platform for real-time analysis. The architecture comprises

Sensor Layer

Capacitive Sensors: Detect hair thickness and surface properties.

Photo-sensor (QRB1114): Measures optical properties like reflectivity and texture of hair.

LM35 Temperature Sensor: Monitors scalp temperature, detecting potential issues.

DHT11/DHT22 Sensor: Tracks ambient temperature and humidity for environmental context.

Processing Layer

Arduino Nano: Central processor that collects and normalizes sensor data, sending it to the IoT platform for analysis.

Communication Layer

Wireless Module (ESP8266/Bluetooth): Facilitates real-time data transmission to the cloud or mobile devices.

IoT Platform Layer

Cloud Platform: Stores, analyzes, and visualizes data, providing insights into scalp and hair health conditions.

User Interface Layer

Mobile/Web Application: Displays real-time data and recommendations to users in a user-friendly interface.

Data Flow:

1. Sensors collect hair and scalp data.
2. Arduino Nano processes and transmits data via a wireless module.
3. IoT platform analyses and stores data.
4. User interface displays results and insights in real-time.

This streamlined system provides continuous, real-time monitoring of hair and scalp health for better care and early issue detection.

LM35/DHT Temperature Sensor

The LM35 is an analog temperature sensor commonly used in various temperature measurement applications. It provides accurate and linear temperature readings and is widely used in both academic and industrial projects. The DHT series (DHT11/DHT22) are digital temperature and humidity sensors commonly used in various environmental monitoring applications. These temperature sensors play an important role in the IoT-Enabled Hair Health Analyzer by providing accurate temperature readings [3][8]. Figure 1: LM35. Figure2: DHT.





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LM35 This sensor delivers highly precise readings of the scalp's temperature. It is perfect for monitoring the scalp environment, as it can directly record the temperature in °C without any additional calibration. In the Hair Health Analyzing system, the LM35 helps in measuring the temperature of the scalp, which can give indications of hair conditions like dryness, excess heat, or other scalp health issues. The collected data is then processed by the Arduino Nano to ensure real-time temperature monitoring, which adds valuable context to overall hair health diagnostics.

DHT11/DHT22: The DHT series sensors are used to measure both temperature and humidity, which makes them most appropriate for environmental data collection. The DHT11 is a basic sensor. It has a moderate accuracy, while the DHT22 provides higher precision. These sensors installed in the Hair Health Analyzer system are used to observe the ambient temperature and humidity around the scalp. These factors are directly related to the hair and scalp health. High humidity levels can lead to moisture buildup, while low levels may cause dryness, both conditions are harmful and play a major role in hair damage[4].

Photo-sensor

The QRB1114 is a reflective object sensor, commonly known as a photo-sensor that is integral to systems requiring precise object detection or measurement, such as the IoT-Enabled Hair Health Analyzer. (Figure 3).

Optical properties of hair like hair thickness, surface texture and reflectivity are very important as per the point of view of hair health. For the assessment of optical properties of hair or to detect hair strands for quality analysis, the QRB1114 can be utilized in the Hair Health Analyzer system. This photo sensor is integrated with the Arduino Nano. The combination of these is used to detect variations in different optical properties. The values of these properties are recorded on the basis of the amount of IR light reflected back from the hair strands [4]. Then we process the collected data for the overall assessment of hair health. The infrared (IR) emitter and phototransistor are combined in a compact package. By measuring the reflected IR light, the combination detects the changes in different surface properties. The addition of the QRB1114 sensor increases the system's capability to capture non-contact measurements, providing accurate, real-time feedback at the same time it is energy-efficient and compact. It increases the precision of the analyser, particularly when applied in such situations where physical contact may affect the hair's natural properties or distort the readings [5].

Arduino-Nano

The Arduino-nano is an open-source microcontroller platform based on hardware and software. It is applied from simple to complex applications during building any electronics based project. The Arduino Nano is a compact, versatile microcontroller board that plays a Crucial role in IoT-based systems, like the IoT-Enabled Hair Health Analyzer[6]. Arduino (Figure 4).

In the Hair Health Analyzer system, the Arduino Nano serves as the controlling. It records data from various connected sensors like capacitive sensors used to detect hair thickness, DHT11/DHT22 for determination of humidity and temperature, and LM35 used for scalp temperature measurements. It is equipped with an ATmega328P microcontroller, which makes it suitable for projects requiring a small footprint, low power consumption, and ease of use. Its features, such as multiple digital and analog pins, allow seamless integration with sensors and other components.

- The microcontroller processes this sensor data and sends it to an IoT platform or user interface for further analysis and visualization, contributing to real-time hair health diagnostics.
- The use of Arduino Nano makes the system easily programmable, reliable sensor communication, and a power-efficient operator, which are essential in portable IoT-enabled solutions.

METHODOLOGY

Sensor Calibration and Validation

Calibration: Each sensor (DHT11, LM35, RGB) is calibrated to ensure accuracy in data collection.



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Validation: Sensor data is validated against known standards to confirm reliability and precision. Flowchart (Figure 5).

Data Analysis Techniques

Descriptive Analytics: Summarizes data to provide a snapshot of current environmental conditions and hair quality.

Predictive Analytics: Utilizes machine learning algorithms (e.g., regression models, neural networks) to predict future hair quality trends based on historical data.

Prescriptive Analytics: Provides actionable recommendations for users based on the analysis of sensor data.

Proposed System

Hair quality is influenced by a variety of factors including environmental conditions, temperature, humidity, and aesthetic elements such as color and shine. The integration of Internet of Things (IoT) technology into hair care presents an opportunity to continuously monitor and analyze these factors to provide actionable insights for personal hair health management. This research proposes an IoT based system that utilize LM35/DHT sensors, along with RGB lighting, to create a comprehensive hair quality analysis framework.

Components used

LM35/DHT Sensor

Purpose: Measures ambient temperature.

Function: Monitors temperature variations affecting hair texture and strength.

Integration: Provides data on temperature extremes that can lead to hair damage, complementing the findings of Kumar et al. [2].

RGB Lighting Sensor

Purpose: Analyzes hair color and shine.

Function: Evaluates aesthetic factors indicative of hair health.

Integration: Captures data on how light reflects off hair, aiding in the evaluation of color and shine as discussed by Sharma et al. [3].

The image is showing the sensor integration and the basic workflow for the IoT-Enabled Hair Health Analyzer. It clearly outlines how various system components interact to measure and analyse different factors for hair and scalp health. The detailed description is as follows:

Proposed Design Flow(Figure 6).

System Workflow Description

Hair Comb: The process is initiated by using hair comb. The primary function of comb is to prepare the hair for analysis. It ensures that the hair is free of tangles or obstructions, which enables sensors to collect accurate data.

Sensors: The sensor array includes various sensors crucial for the evaluation of hair and scalp properties

LM35 Temperature Sensor: Detects any hair related issues by Measuring the scalp's temperature.

DHT11/DHT22 Sensor: Used to Monitors the surrounding environment by measuring the ambient temperature and humidity levels, factors that can impact hair and scalp health.

Capacitive Sensors: Detects the different physical characteristics of hair like thickness and surface properties.

QRB1114 Photosensor: It is used to Analyze the optical properties of the hair, such as surface texture and reflectivity.

Sensing Mechanism: With the integrated sensor array, data pertaining to the condition of both the hair and scalp is sampled in real time using the sensing mechanism. The sensors, when used in combination, provide complete physical, thermal and environmental analysis of the health of the hair.

Hair Health Analysis: The received sensor data is utilized for further examination of the hair and scalp. This data is processed to develop insights on hair's condition, issues with the scalp, and other factors which may correlate to the health of the hair. These insights can be accessed through a mobile or web application for monitoring purposes.



**Meenakshi Kashyap et al.,****Overall System Flow**

The process starts with the user commencing their hair routine of combing their hair, then moves on to the collection of data through sensors regarding the user's scalp and hair. This is all captured in the final sensing step, which integrates all the collected information for further analysis on the user's health. This covers the information IoT systems provide on real time, effortless, and precise monitoring of one's hair and scalp injuries. The objective's integration of various sensors guarantees for the best results on the hair's health condition and gives the users opportunity to make the correct choice at the right moment.

Proposed Schematic (Figure 7).

Proposed Design Circuit (Figure 8).

Data Collection and Transmission**Real-Time Monitoring**

Sensors continuously collect data on temperature, humidity, and hair color.

Data is transmitted to a controller unit via networking protocols (e.g., MQTT or HTTP).

Data Processing

Collected data is processed using cloud-based analytics.

User Interface**Mobile Application**

Displays real-time data from sensors.

Provides visual representations of environmental conditions and hair quality metrics.

Offers personalized recommendations based on sensor data.

Alerts and Notifications

Users receive alerts when sensor data indicates potential issues (e.g., high/low humidity or temperature).

Recommendations are provided to mitigate adverse conditions and improve hair health.

System Integration**IoT Connectivity**

Utilizes IoT platforms for data transmission and management.

Ensures remote accessibility and control over the hair quality monitoring system.

Cloud Storage and Analysis

Data is securely stored in the cloud.

Cloud-based analytics processes large volumes of sensor data, enabling scalable and efficient analysis.

CONCLUSION

The incorporation of photo-sensors and temperature sensors in an IoT-based hair quality analysis system shows great promise in evolving technology within the personal care domain. These sensors capture real time information from the environment, such as temperature and humidity, which are critical for maintaining good health of the hair [5]. Studies emphasize the need for controlling these variables to avoid hair damage and ensure general well-being. Enhanced real-time data processing allows the system to automatically track and adapt to the changes in the environment, which optimizes the management of hair care practices. The inclusion of RGB lighting in conjunction with DHT11 and LM35 sensors further enriches the system by enabling the evaluation of aesthetic factors, including hair color and shine. This multifaceted approach not only assesses environmental influences but also provides insights into the visual quality of hair. The synergy between these technologies contributes to a comprehensive understanding of hair health, allowing for personalized recommendations and refined hair care routines [3]. Advancements in sensor technology and real-time analytics are pivotal in enhancing the accuracy and effectiveness



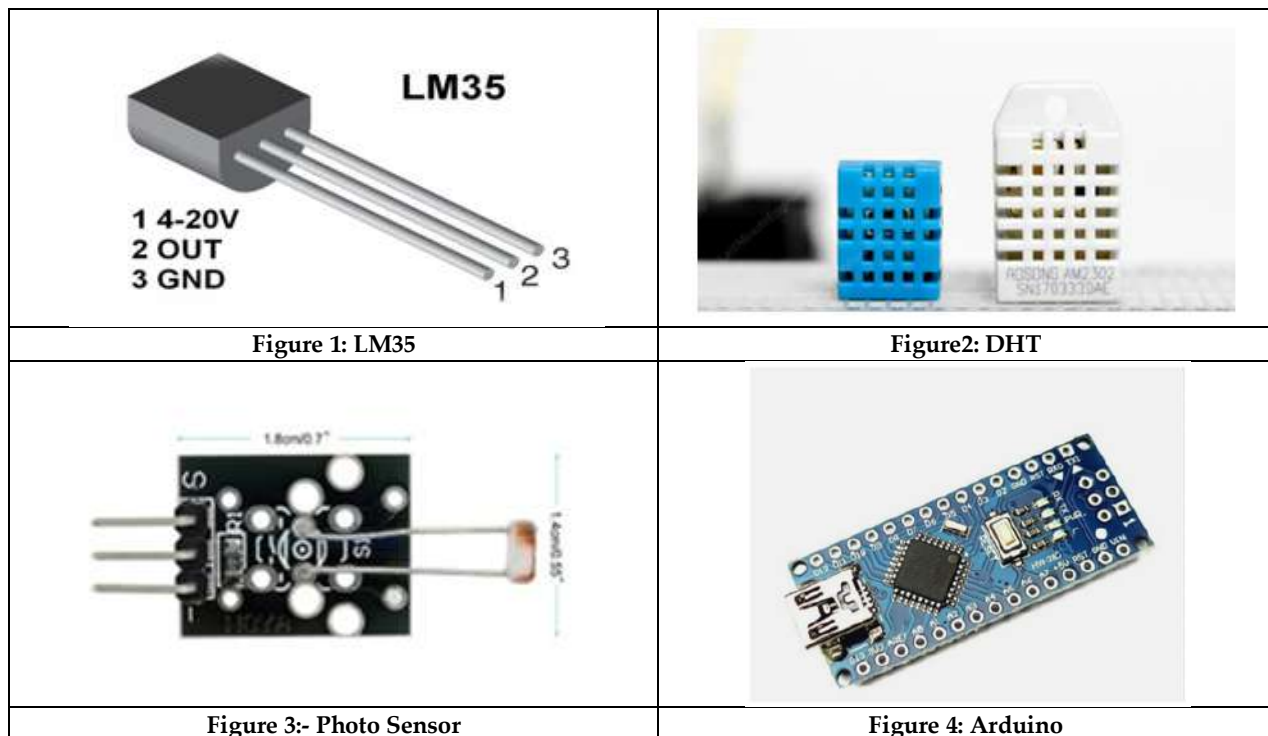


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of hair quality analysis. Future research is anticipated to focus on improving sensor precision and developing more sophisticated IoT-based systems [7]. These developments are expected to offer even more accurate and actionable insights, thereby expanding the capabilities of hair care management solutions. In summary, the proposed IoT-based hair quality analysis system represents a significant leap forward in personal care technology. By integrating DHT11 and LM35 sensors with RGB lighting, the system provides a holistic approach to monitoring and managing hair health. The combination of real-time data processing and personalized feedback empowers users to make informed decisions about their hair care routines, leading to improved hair quality and overall health. Future research will continue to advance sensor technologies and data analysis techniques, further enhancing the system's functionality and effectiveness.

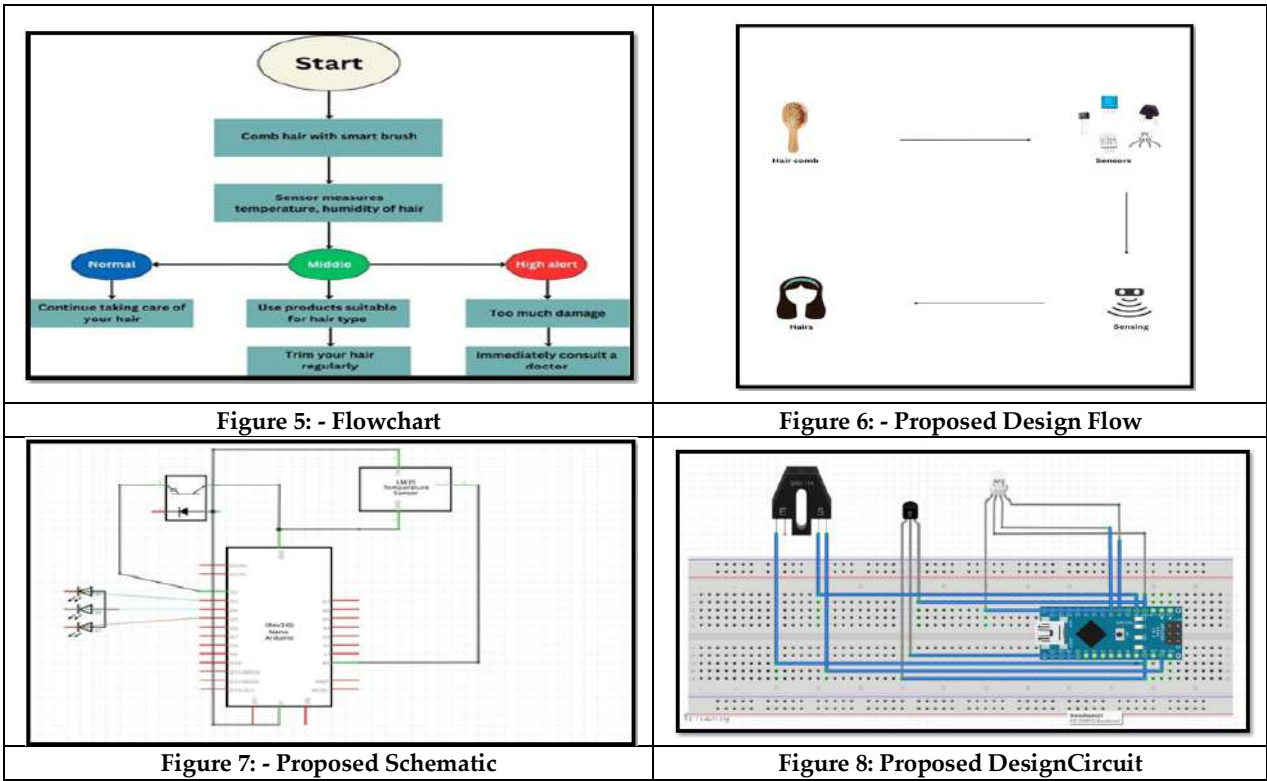
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RESEARCH ARTICLE

A Feature Fusion based CNN for Fern Classification

Shajin Yesu Raj S^{1*} and T.C. Rajakumar²

¹Research Scholar (Reg. No.: 19211282281015), Department of Computer Science, St. Xavier's College (Autonomous), Palayamkottai, (Affiliated to Manonmaniam Sundaranar University), Tirunelveli, Tamil Nadu, India.

²Associate Professor, Department of Computer Science, St. Xavier's College (Autonomous), Palayamkottai, (Affiliated to Manonmaniam Sundaranar University), Tirunelveli, Tamil Nadu, India.

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*Address for Correspondence

Shajin Yesu Raj S

Research Scholar (Reg. No.: 19211282281015),
Department of Computer Science,
St. Xavier's College (Autonomous), Palayamkottai,
(Affiliated to Manonmaniam Sundaranar University),
Tirunelveli, Tamil Nadu, India.
E.Mail: selvashajin@gmail.com



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ABSTRACT

Ferns are non-flowering, seedless vascular plants. Ferns can be used as food source, medicine and as ornamental plants. There are numerous ongoing taxonomic studies which aim at classifying ferns based on their botanic traits. Other than traits, appearance of different parts of ferns can also be used to identify them. Deep learning models such as Convolutional Neural Networks (CNN) can aid botanists in fern classification. In most of the CNN architectures, the height and width of the input images are reduced in order to reduce computational cost. Fern leaves have compound structure. While resizing the images of compound leaves, there is a chance of losing important morphological features. To overcome this, images of fern leaflets are used in this study. Few fern species may look similar in adaxial view. Abaxial view of fern leaflets can highly distinguish them, since most of these plants have sori underneath their leaflets. Arrangement of sori and venation can help the deep learning models to classify them accurately. Morphology of fern leaves may vary in different stages. Sequential CNN architectures may not be efficient for classifying such leaves. To address this, a feature fusion based CNN model is proposed. This CNN architecture has two input layers, each input layer is followed by two convolution and two pooling layers. A fully connected layer along with an output layer is employed to classify the concatenated featuremaps obtained from the convolution and pooling layers. The proposed model is efficient and it could classify 15 terrestrial ferns with an accuracy of 98.09%. This study recommends to use images of leaflets, especially the abaxial view of the leaflets to classify them.

Keywords: Fern Identification, Leaf Classification, Deep Learning, CNN, Feature Fusion, Multi-Input CNN



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INTRODUCTION

Ferns are non-flowering vascular plants. Ferns do not produce any flower, fruits and seed. As they cannot bear any fruits and seeds, ferns reproduce using spores. Spores are tiny parts developed under various regions of ferns, mostly under their leaves. Ferns use vascular tissue to transport nutrients to various parts of the plant. Ferns can be found in variety of natural environments. Few ferns can be used as medicine[1], food, bio-fertilizer, livestock feed, and as ornamental plants. There were more than 12,000 fern species, few of them are extinct. A study held in 2016 reported 10,578 extant species of ferns[2]. There are ongoing fern taxonomic studies. Pteridologists utilize the botanical characteristics of ferns to distinguish them. Morphological characteristics of fern leaves can also help them to distinguish ferns[3]. These morphological characteristics include, shape, size and colour of various parts such as frond, stipe, lamina, apex and pinna. Different species of ferns may have similar appearance. In such situations, arrangement of pinna and sori can also be considered. Depending on the sori forming stage, ferns belonging to same species may exhibit dissimilarity in appearance. It requires expertise to identify the ferns based on their morphological characteristics. CNN is a supervised deep learning algorithm[4] which is better at classifying images. It learns only the appropriate features from input images which make it an efficient algorithm for image classification. A CNN model is comprised of few convolution layers, pooling layers and fully connected layers. It can have few other layers and hyper-parameters which are adjusted depending on the classification problem. Most of the CNN based models follow sequential architectures. These models work well when the intra-class dissimilarity is low. These models are prone to error when the images belonging to same classes have higher degree of dissimilarity. To overcome this issue, this research article presents a feature fusion based CNN model. This model combines the features learned from dissimilar images belonging to the same class. It makes the model classify ferns more accurately than the sequential architectures.

RELATED WORK

Recent studies utilized the morphology of various organs to classify plants. Among them, the morphology of leaves highly distinguished plants. Fatihah *et al* [6] compared the classification accuracy of a CNN model with different datasets. In this work, a classification model is trained using flower and leaf images separately. The comparison showed that images of plant leaves provide better accuracy than flowers. Mostly, the classification models are trained using the adaxial view of leaf images. In few cases, leaves of different plants may look similar adaxially but dissimilar abaxially. To address this issue, Bambil *et al* [7] created a dataset of trees and shrubs. This dataset had leaf images with both adaxial and abaxial view. While comparing, images captured with adaxial view produced a better accuracy than the abaxial view. In earlier days, machine learning models were used to solve plant classification problems. These models require feature extractors and feature selectors. Pushpa *et al* [8] classified plants using Multiple Support Vector Machine (MSVM). For this work, the authors extracted texture and morphological features such as leaf area, aspect ratio, circularity, eccentricity, perimeter, major axis length and minor axis length. For this, the authors used separate algorithms. Before extracting features, segmentation is necessary to remove unnecessary regions from the images. Patil *et al* [9] suggested a method for medicinal plant classification. In this work, the images were segmented to extract only the necessary portion from the image. Then important features such as texture and shape were extracted from the segmented images. These features were then trained and classified using Support Vector Machine (SVM). Combining the features extracted using two different feature extractors can improve accuracy of classification. Janahiraman *et al* [10] combined the features extracted using Local Binary Pattern (LBP) and Histogram of Oriented Gradients (HOG) to form a final feature vectors. These feature vectors were classified using SVM. Combining the result of two or more classifiers can reduce misclassification. Mittal *et al* [11] proposed a plant classification method which combines the results of different classifiers. In this work, the results of SVM, Naïve Bayes and Decision tree were combined using majority voting technique to form a combined classifier. For these classification models, there is a need of feature extractor and feature selector. Hence the accuracy of classification depends on the feature extractor also. In the past years, deep learning is widely used for image classification. Among the deep learning models, CNN exhibits accurate classification and it does not require a separate feature extractor.



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Alimboyong *et al* [12] classified plants using a CNN architecture. This CNN architecture had five convolution layers, two fully connected layers and an output layer. Along with convolution, pooling and fully connected layers, few other layers can also be included in the network. Akter *et al* [13] proposed a CNN architecture which included gaussian noise layer, batch normalization layer, and dropout layer. Bisen *et al* [14] proposed a CNN architecture to classify 15 plants from Swedish leaf dataset. This architecture had four convolution layers and three maxpooling layers, a fully connected layer and a dropout layer. Accuracy of classification can be improved by adjusting the input shape, number of layers, arrangement of layers, number of filters, kernel size, data augmentation and learning rate etc. Mokeev *et al* [15] tried to improve a CNN based plant classification model by adjusting the hyper-parameters. Training a CNN based classifier can be a time consuming task. To reduce the training time, Bahri *et al* [16] suggested a method in which CNN is used only for feature extraction. In this method, classification is done using Locality Sensitive Hashing (LSH). The LSH function hashes the leaf signatures so that similar leaves fall in the same cluster with high probability. These CNN models are simple and could classify plants where inter-class similarity is too low. Few researchers created efficient architectures which solved complex classification problems. These architectures became famous as they are good at classifying numerous objects with varying background, Creating CNN architectures similar to such architectures could help in accurate classification. Dileep *et al* [17] designed a medicinal plant classification model named AyurLeaf. The number of layers, filters and neurons present in this model are similar to the AlexNet architecture. Mahmudul *et al* [18] classified plants using a CNN which is similar to AlexNet. It had 5 convolution, 3 max-pooling and 3 fully connected layers. In this CNN architecture, pooling layers were placed next to the first, second and fifth convolution layers. First and second fully connected layers had 4096 neurons.

Altering the hyper parameters of an existing architecture is another efficient way to achieve accurate classification. Liu *et al* [19] proposed a CNN model for plant classification. In terms of layer arrangement, this architecture is similar to the LeNet architecture. It varies in other aspects such as, input size, kernel shape, number of filters used in convolution operations, number of neurons present in fully connected layers and activation functions used. Among these models, the model suggested by Liu *et al* [19] is simple yet it could classify the plants accurately. Other models had too much of parameters which can lead to overfitting when the dataset does not have large number of images. Transfer learning is an efficient approach which helps to reduce time and resource utilization. Zahoor *et al* [20] classified different species of crops and weeds using a pre-trained CNN model named DenseNet. Pudaruth *et al* [21] designed a mobile application that classifies few medicinal plants. In this work, pre-trained inception v3 model is utilized. For improving accuracy, an additional layer is added to the inception v3 model. Features extracted using convolution and pooling layers are flattened before passing them to fully connected layers. Instead of flattening, Global Average Pooling layer can be used. Geerthana *et al* [22] classified medicinal plants using Inception v3 model. In this model, Global Average Pooling (GAP) layer is utilized instead of flattening. Most of the pre-trained models have a large number of parameters which makes them time consuming. Freezing few layers of these models can reduce the number of parameters. Ahmed *et al* [23] utilized pre-trained DenseNet201 model to classify grapevine leaves. Few layers of this architecture were froze in order to reduce computational cost. As pre-trained models are better at feature extraction, multiple pre-trained models can be employed to extract features from the input data. Van *et al* [24] extracted features from leaf images using four different models namely Resnet50V2, Inception Resnet V2, MobilenetV2, and VGG16. The extracted features were then classified using SVM and k-Nearest Neighbors (KNN). Ayumi *et al* [25] classified medicinal plants using pre-trained models VGG16, VGG19, and MobileNetV2. The authors fine tuned these models to obtain accurate classification. Among these models, the fine tuned MobileNetV2 model performed very well. Rachburee *et al* [26] tried classifying lotus species using three pre-trained models named VGG16, ResNet152V2, and MobileNetV2. The research findings stated that the MobileNetV2 model outperformed other two models with a good classification accuracy. When comparing with other models discussed in this section, pre-trained models are good at classifying plants. Still these models make inaccurate classification when the inputs have higher degree of dissimilarity between images within same class.

Multi-View Fusion CNN

Most of the deep learning models discussed in section II performed plant classification using a sequential CNN architecture. This type of architectures are efficient when the classification problem is simple. In case of fern





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identification, the following challenges need to be considered. While utilizing CNN models for image classification, the height and width of the input images needs to be reduced in order to reduce time and resource consumption. Fern leaves are also called as fronds[5] and they have compound structure. The size of fronds of different fern species may vary comparably. Fronds of few fern species can grow upto 10 feet long. While resizing the images of such fronds, there is a chance of losing important morphological features. If the image of a 7 feet long frond is resized into 128x128 image, it may lose the clear-cut morphology of the frond. Fig. 1(a) shows the morphology of a frond of *Christella dentata* (Forssk.) Brownsey and Jermyspecies. Fronds contain smaller units called pinna (leaflets)[5]. Fig. 1(b) shows the morphology of a pinna of *Christella dentata* (Forssk.) Brownsey and Jermy species. When comparing Fig. 1(a) and 1(b), the image of pinna highly distinguishes the fern. Morphology of these pinna is sufficient for classifying ferns. Hence images of pinna is used in this study. The morphology of pinna of different fern species can be similar in adaxial (top) view. But their abaxial (bottom) view will be dissimilar. Fig. 2(a) and 2(b) compares abaxial and adaxial views of *Blechnopsis orientalis* (L) C. Persl and *Lindsaea ensifolia* Sw. species. Most of the ferns produce spores underneath or along the margin of their pinna. And also, the costa (midrib of pinna)[3] can be seen clearly in the abaxial view. Sori and costa can aid in accurate classification. Hence, the abaxial view of pinna is used in this study. Ferns produce sori during a particular stage of their growth. Until that stage, their leaves will not have sori. This is another challenge to overcome. If a model is trained using leaves with sori, it may not be able to classify leaves without sori. To overcome this, images of leaves with and without sori are combined and trained. This gives another challenge, that is, the leaf morphology of same species differs when they have sori and when they have no sori. Fig. 3(a) and 3(b) compares *Lygodium flexuosum* (L.) Sw.species with and without sori. Fig. 3(a) and 3(b) shows that pinna of same species can look dissimilar depending on the presence of sori. In such cases, sequential architectures may suffer from inaccuracy. In order to overcome this, the proposed model performs feature fusion. This architecture has two input layers. One input layer receives the images of ferns with sori. Another input layer receives the images of ferns without sori. These two layers extract different visual features from the leaves and pass them to the next layers. After extracting visual features using different convolution and pooling layers, all these feature maps are concatenated and passed to the fully connected layers. Finally a fully connected layer with softmax activation function is employed to classify the ferns. The proposed CNN architecture is illustrated in Fig 4. The input convolution layers receive input images of size $62 \times 62 \times 3$. These convolution layers had 6 filters with the kernal size 3×3 . These layers are followed by maxpooling layers with pool size 2×2 . Each of these pooling layers are followed by a convolution layer and a maxpooling layer. The convolution layers had 16 filters with kernels of size 3×3 . The pooling layers had a pool size of 2×2 . ReLU is the activation function used in the convolution layers. It introduces non-linearity into the network, allowing it to learn complex patterns from data. The mathematical formula of ReLU is

$$f(x) = \max(0, x) \quad (1)$$

Where, x is the input to the activation function.

The concatenated feature maps are flattened and passed to a fully connected layer with 204 units. The output layer had 15 units as it classifies 15 terrestrial ferns. Softmax is the activation function used in the output layer. It converts the output scores into probabilities that sum to 1, making them interpretable as class likelihoods. The mathematical formula of softmax is:

$$\text{softmax}(z_i) = \frac{e^{z_i}}{\sum_{j=1}^k e^{z_j}} \quad (2)$$

Where, z_i = input score for the i^{th} class and k = total number of classes.

Experiment and Analysis

Data Collection

A total of 2,100 images of 15 different fern species were collected. These images were captured using smartphone camera. Most of the smartphones have AI mode which enhances the image captured. It may alter the original information. Therefore, AI mode was turned off. To avoid unnecessary noise, plain background was used while capturing the images. All these images were collected from few selected regions of Killiyoor, Kanyakumari District, Tamilnadu. Table 1. shows the fern species that are collected. Fig. 5 shows few images of collected ferns. The images with label (a) are fern species without sori and (b) are same species with sori.





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Image Preprocessing

Even the images were captured with plain background, it may have few noisy regions. To avoid those noises, background was removed using threshold based segmentation. For generating segmentation mask, binary threshold method is used. After segmentation, the images contained only leaflets with black background. After preprocessing, the images were augmented. Images can be captured with different angle, with varying sizes and their clarity may vary. If the network is trained with only a particular angle and size, it will not be able to classify new images with varying angle and size. To overcome this, the input images were augmented. It makes the network learn necessary parameters. Rotation, horizontal flipping, are the augmentation performed on the preprocessed data.

Training and evaluation

For training and evaluation, the dataset was divided into training and validation sets. 80% of the dataset were utilized for training and 20% were used for validation. Epoch was set to 100 with 24 steps per epoch. Batch size was set to 70. Other hyper-parameters such as stride, padding, initializers were set to default. On every epoch, different accuracy and loss were observed. While training the CNN model, accuracy increased gradually and loss also decreased. It was observed that the training and validation accuracy were improving almost similarly. This shows that the model learnt the necessary parameters and there were no overfitting nor underfitting happened. Fig. 6 shows the training and validation accuracy and Fig. 7 shows training and validation loss obtained throughout the training. To stabilize the learning and to avoid overfitting, callback methods such as reduce learning rate on plateau and early stopping were used. The network learnt optimal weights and the accuracy did not improve after the 66th epoch. Learning was stopped at 70th epoch.

Analysis of the proposed method

The network was evaluated on the validation dataset. Fig 8 shows the confusion matrix obtained while evaluating the trained model. The confusion matrix provides a clear breakdown of correct and incorrect predictions obtained for each class. It shows how well the model distinguishes between classes. It reveals both the true positives and true negatives, as well as any false positives and false negatives. While evaluation, the network exhibited a good performance with the metrics such as accuracy, precision, recall, f1-score and specificity.

$$\text{Accuracy} = \frac{\text{TN} + \text{TP}}{\text{TP} + \text{TN} + \text{FP} + \text{FN}} = 0.9809 \quad (3)$$

$$\text{Precision} = \frac{\text{TP}}{\text{TP} + \text{FP}} = 0.9844 \quad (4)$$

$$\text{Recall} = \frac{\text{TP}}{\text{TP} + \text{FN}} = 0.9833 \quad (5)$$

$$\text{f1 score} = 2 \times \frac{\text{Precision} \times \text{Recall}}{\text{Precision} + \text{Recall}} = 0.9825 \quad (6)$$

$$\text{Specificity} = \frac{\text{TN}}{\text{TN} + \text{FP}} = 0.9986 \quad (7)$$

The model is highly reliable, with 98.09% accuracy, 98.44% precision, 98.33% recall, 98.25% F1 score, and 99.86% specificity. This model made a very few mistakes in both positive and negative predictions. These metrics confirm that the trained model generalizes well on unseen data and it indicates near-perfect classification performance of the proposed model.

Comparison with State-of-the-Art Methods

From the models discussed in section II, three models were chosen for training on the fern dataset. Each of them were described as best performing models in each category. A simple CNN model proposed by Bisen *et al* [14], a model similar to AlexNet proposed by Mahmudul *et al* [18] and a pre-trained model suggested by Rachburee *et al* [26] are those three models. While comparing the accuracy of prediction, the proposed model outperforms those three models. Table 2 compares the accuracy of the above said models with the proposed model.





CONCLUSION

The proposed multi view fusion based CNN is proposed for the identification of terrestrial ferns. This model is comprised of two input layers and an output layer. These input layers receive images of fern pinna with and without sori. Feature learning is done on these two branches of the network. The learnt features are concatenated and flattened then passed to the fully connected layers. The output layer classifies 15 ferns with a good accuracy. This model is proposed to overcome an issue related with morphology of fern pinna during various stages. And it could outperform other sequential/single input models evaluated in this paper. Hence this study suggests the use of multiple input and feature fusion for classifying plants having dissimilar morphology within the same species.

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Table 1. Collected fern species

Sl. No.	Name of the fern species
1	<i>Achrostichum aureum</i> L.
2	<i>Adiantum caudatum</i> L.
3	<i>Adiantum latifolium</i> Lam.
4	<i>Adiantum philippense</i> subsp. <i>Philippense</i>
5	<i>Blechnopsis orientalis</i> (L) C. Persl
6	<i>Christella dentata</i> (Forssk.) Brownsey and Jermy
7	<i>Cyclosorus interruptus</i> (Willd.) H.Itô
8	<i>Dicranopteris linearis</i> (Burm.f.) Underw.
9	<i>Lindsaea ensifolia</i> Sw.
10	<i>Lygodium flexuosum</i> (L.) Sw.
11	<i>Nephrolepis brownii</i> (Desv.) Hovenkamp and Miyam.
12	<i>Pityrogramma calomelanos</i> (L.) Link
13	<i>Pteris ensiformis</i> Burm.f.
14	<i>Pteris otaria</i> Bedd.
15	<i>Pteris vittata</i> L.

Table 2. Comparison of proposed model with state-of-the-art methods

Model	Accuracy	Precision	Recall	F1 Score
Proposed model	0.980	0.983	0.980	0.980
Pre-Trained MobileNet V2[26]	0.973	0.976	0.973	0.973
Model similar to AlexNet[18]	0.869	0.882	0.869	0.862
Simple CNN[14]	0.885	0.906	0.885	0.877





Fig. 1(a): Morphology of a frond	Fig. 1(b): Morphology of a pinna	Fig. 2(a) : abaxial and adaxial view of <i>Blechnopsis orientalis</i> (L) C. Persl	Fig. 2(b) : abaxial and adaxial view of <i>Lindsaea ensifolia</i> Sw.
		<pre> graph TD subgraph Path1 [Abaxial View Path] C1[Conv2D: input (None, 62, 62, 3), output (None, 60, 60, 6)] --> M1[MaxPooling2D: input (None, 60, 60, 6), output (None, 30, 30, 6)] M1 --> C2[Conv2D: input (None, 30, 30, 6), output (None, 28, 28, 16)] C2 --> M2[MaxPooling2D: input (None, 28, 28, 16), output (None, 14, 14, 16)] end subgraph Path2 [Adaxial View Path] C3[Conv2D: input (None, 62, 62, 3), output (None, 60, 60, 6)] --> M3[MaxPooling2D: input (None, 60, 60, 6), output (None, 30, 30, 6)] M3 --> C4[Conv2D: input (None, 30, 30, 6), output (None, 28, 28, 16)] C4 --> M4[MaxPooling2D: input (None, 28, 28, 16), output (None, 14, 14, 16)] end M2 --> Concat[Concatenate: input [(None, 14, 14, 16), (None, 14, 14, 16)], output (None, 14, 14, 32)] M4 --> Concat Concat --> Flatten[Flatten: input (None, 14, 14, 32), output (None, 6272)] Flatten --> D1[Dense: input (None, 6272), output (None, 204)] D1 --> D2[Dense: input (None, 204), output (None, 15)] </pre>	
Fig. 3(a) : <i>Lygodium flexuosum</i> (L.) Sw.without sori.	Fig. 3(b) : <i>Lygodium flexuosum</i> (L.) Sw.with sori.	Fig 4. Proposed CNN architecture	
1(a)	1(b)	2(a)	2(b)
3(a)	3(b)	4(a)	4(b)





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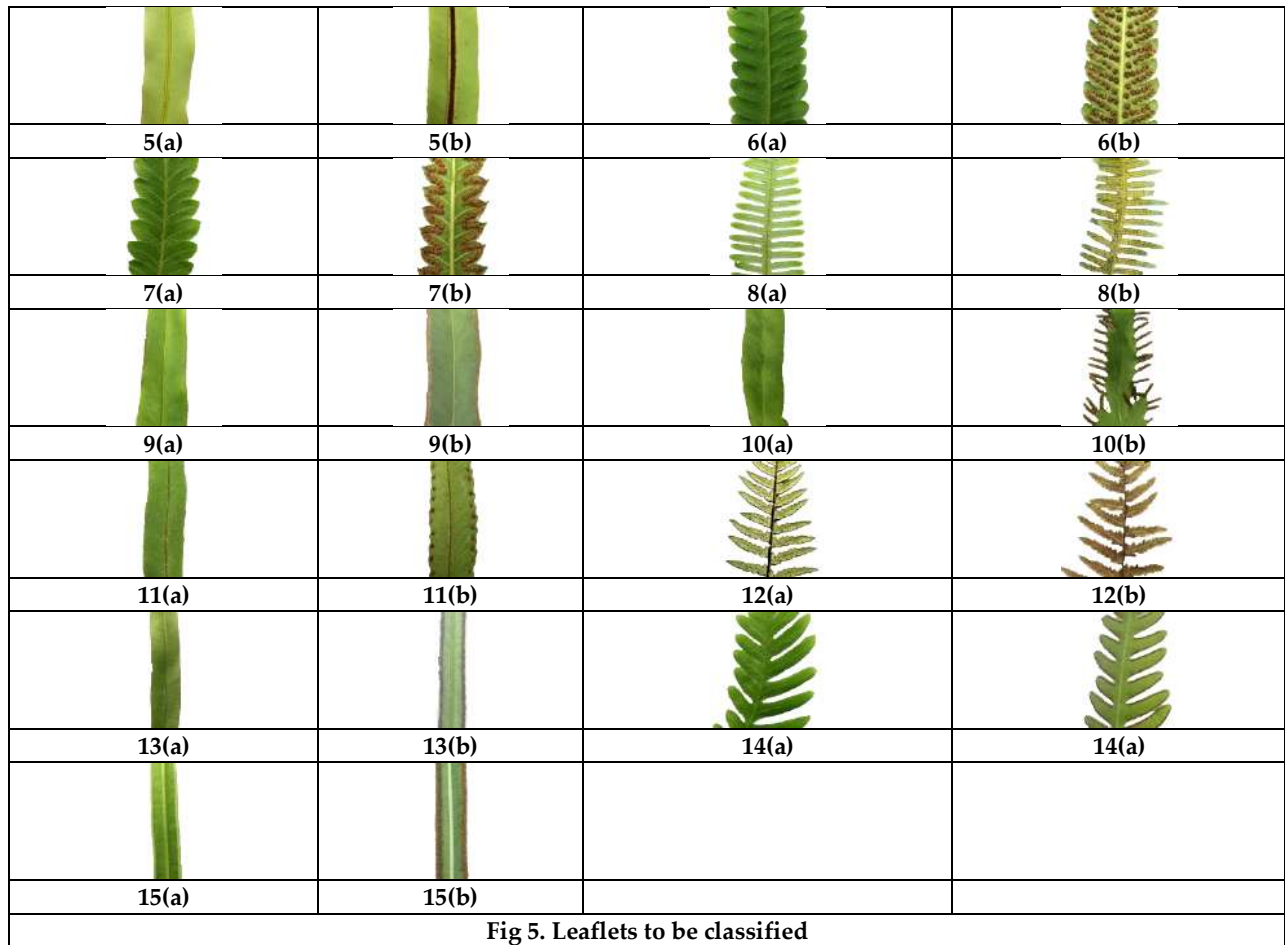


Fig 5. Leaflets to be classified

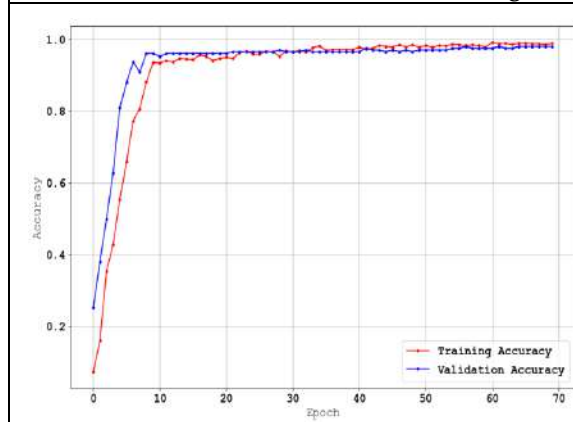


Fig. 6: training and validation accuracy

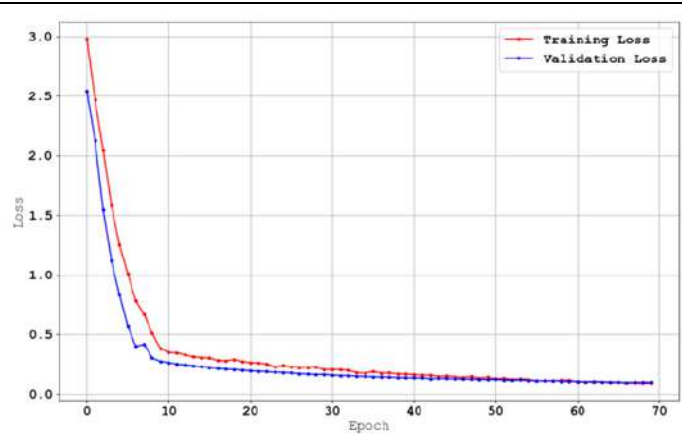


Fig. 7: training and validation loss





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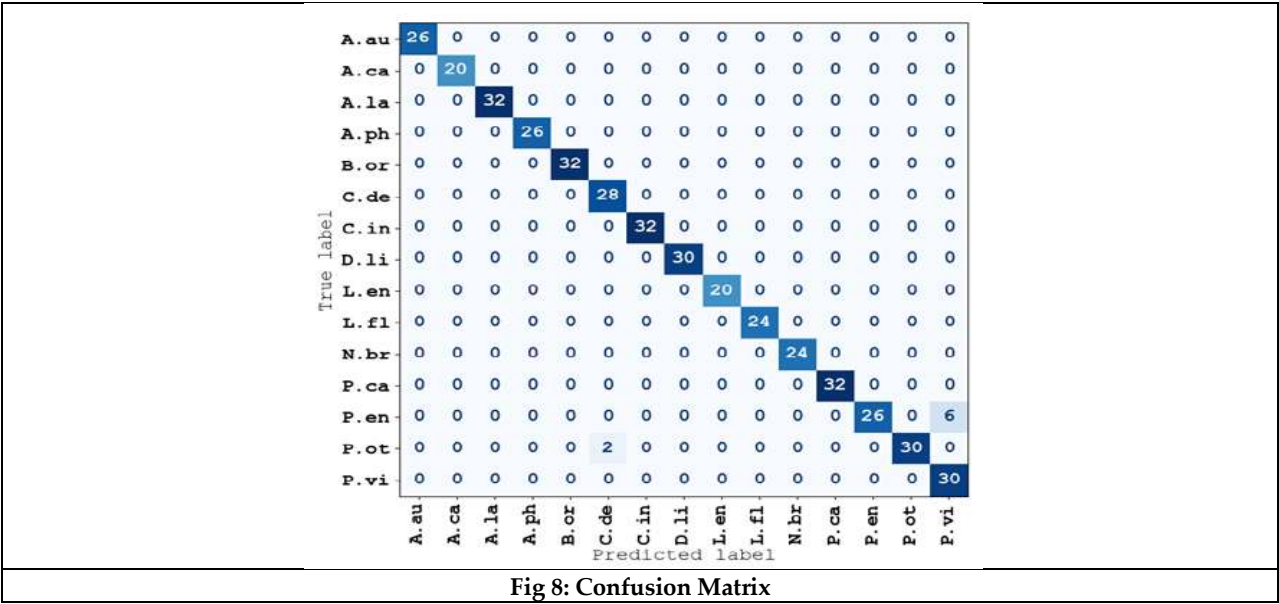


Fig 8: Confusion Matrix





RESEARCH ARTICLE

Determining Positive Integers with Specific Conditions using Recurrence Relations, Generating Functions and Z transforms

S. Radhakrishnan¹ and R. Sivaraman^{2*}

¹Assistant Professor, Post Graduate and Research Department of Mathematics, Dwaraka Doss Goverdhan Doss Vaishnav College, Arumbakkam, (Affiliated to University of Madras) Chennai, Tamil Nadu, India.

²Associate Professor, Post Graduate and Research Department of Mathematics, Dwaraka Doss Goverdhan Doss Vaishnav College, Arumbakkam, (Affiliated to University of Madras) Chennai, Tamil Nadu, India.

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*Address for Correspondence

R. Sivaraman

Associate Professor,

Post Graduate and Research Department of Mathematics,

Dwaraka Doss Goverdhan Doss Vaishnav College, Arumbakkam,

(Affiliated to University of Madras) Chennai,

Tamil Nadu, India.

E.Mail: rsivaraman1729@yahoo.co.in



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ABSTRACT

The main objective of this paper to determine all possible positive integers n such that $n \pm 2$ and $\frac{n \pm 1}{2}$ are perfect squares. A similar problem for finding natural numbers such that both $n + 2$ and $\frac{n + 1}{3}$ are perfect squares was solved completely. The solutions were obtained using linear difference equation method, generating function method, Z transforms and were verified by a suitable python program.

Keywords: Perfect Squares, Positive Integer Solutions, Linear Difference Equation, Generating Function, Z transforms.

INTRODUCTION

Right from the beginning of 2 CE, for past two millennia, mathematicians have been keen to solve equations whose solutions are natural numbers, since such solutions can be applied for their day to day life needs. The Greeks, Egyptians, Romans, Chinese, Indians have contributed a lot towards solving all sorts of equations whose solutions must be in integers. In particular, ancient Greek mathematician Diophantus gave methods for solving equations whose solutions are integers and due to this, today we call such equations as Diophantine Equations. Mathematicians like Brahmagupta, Bhaskara II, Leonhard Euler, Lagrange were considered as masters in solving Diophantine Equations. Euler particularly adopted method of continued fractions to solve several types of Diophantine equations.





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In this paper, we will consider certain nice problems which in turn would get converted to particular Diophantine equations which we have solved in detail.

Solving the Problem using linear difference equations

Theorem 1: There exists infinitely many natural numbers n , such that $n \pm 2$ is a perfect square

Proof: Since by hypothesis, we have $n \pm 2$ are perfect squares,

$$n \pm 2 = x^2, \text{ for some integer } x$$

$$n = x^2 \mp 2 \quad (1)$$

Since by our assumption $\frac{n \pm 1}{2}$ is a perfect square

$$\frac{n \pm 1}{2} = y^2, \text{ for some integer } y$$

$$n \pm 1 = 2y^2$$

$$n = 2y^2 \mp 1 \quad (2)$$

From (1) and (2) we get

$$x^2 \mp 2 = 2y^2 \mp 1$$

$$x^2 - 2y^2 = \pm 1 \quad (3)$$

$$\text{First, let us consider the equation } x^2 - 2y^2 = -1 \quad (4)$$

$(x_0, y_0) = (1, 1)$ and $(x_1, y_1) = (7, 5)$ are two initial solutions of (4).

To get further solutions for (x, y) , we consider the recurrence relations

$$x_{n+2} - 6x_{n+1} + x_n = 0 \text{ and } y_{n+2} - 6y_{n+1} + y_n = 0$$

For $x_{n+2} - 6x_{n+1} + x_n = 0$ the auxiliary equation is $a^2 - 6a + 1 = 0$

$$a = 3 \pm 2\sqrt{2}$$

$$\text{Hence the solution of } x_{n+2} - 6x_{n+1} + x_n = 0 \text{ is } x_n = A(3 + 2\sqrt{2})^n + B(3 - 2\sqrt{2})^n \quad (5)$$

Put $n = 0$ in (5)

$$x_0 = A + B$$

$$1 = A + B \quad (6)$$

Put $n = 1$ in (5)

$$\begin{aligned} x_1 &= A(3 + 2\sqrt{2}) + B(3 - 2\sqrt{2}) \\ 7 &= A(3 + 2\sqrt{2}) + B(3 - 2\sqrt{2}) \end{aligned} \quad (7)$$





Solving (6) and (7) we obtain $A = \frac{\sqrt{2}+2}{2\sqrt{2}}, B = \frac{\sqrt{2}-2}{2\sqrt{2}}$

$$\text{Therefore, the solution is } x_n = \frac{\sqrt{2}+2}{2\sqrt{2}}(3+2\sqrt{2})^n + \frac{\sqrt{2}-2}{2\sqrt{2}}(3-2\sqrt{2})^n \quad (8)$$

Similarly for $y_{n+2} - 6y_{n+1} + y_n = 0$, we have

$$y_n = C(3+2\sqrt{2})^n + D(3-2\sqrt{2})^n \quad (9)$$

Put $n = 0$ in (9)

$$y_0 = C + D$$

$$1 = C + D \quad (10)$$

Put $n = 1$ in (9)

$$y_1 = C(3+2\sqrt{2}) + D(3-2\sqrt{2})$$

$$5 = C(3+2\sqrt{2}) + D(3-2\sqrt{2}) \quad (11)$$

Solving (10) and (11) we have

$$C = \frac{\sqrt{2}+1}{2\sqrt{2}}, D = \frac{\sqrt{2}-1}{2\sqrt{2}}$$

Therefore, the solution of $y_{n+2} - 6y_{n+1} + y_n = 0$ is

$$y_n = \frac{\sqrt{2}+1}{2\sqrt{2}}(3+2\sqrt{2})^n + \frac{\sqrt{2}-1}{2\sqrt{2}}(3-2\sqrt{2})^n \quad (12)$$

$$\text{From (8) and (12), we obtain } (x_n, y_n) = (1,1), (7,5), (41,29), (239,169), \dots \quad (13)$$

forming solutions of $x^2 - 2y^2 = -1$

Similarly for $x^2 - 2y^2 = 1$ the solutions are given by

$$x_n = \frac{4-2\sqrt{2}}{2\sqrt{2}}(3+2\sqrt{2})^n + \frac{3\sqrt{2}-4}{2\sqrt{2}}(3-2\sqrt{2})^n \quad (14)$$

$$y_n = \frac{3}{2\sqrt{2}}(3+2\sqrt{2})^n + \frac{2\sqrt{2}-3}{2\sqrt{2}}(3-2\sqrt{2})^n \quad (15)$$

From (14) and (15), we obtain $(x_n, y_n) = (3,2), (17,12), (99,70), (577,408), \dots$ (16) forming solutions of $x^2 - 2y^2 = 1$. From (13) and (16), we notice that there are infinitely many pairs satisfying the equations $x^2 - 2y^2 = -1$ and $x^2 - 2y^2 = 1$ respectively. From each such pair, we obtain corresponding value of n satisfying the given conditions. In particular, from (13), the required natural numbers are provided by the following tabular column (Table: 1). Thus the values of n given by 3, 51, 1683, 57123, ... are such that $n-2$ are perfect squares and $\frac{n-1}{2}$ are also perfect squares. Similarly, from (16), the required natural numbers are provided by the following tabular column (Table: 2). Thus the values of n given by 7, 287, 9799, 332927, ... are such that $n+2$ are perfect squares and $\frac{n+1}{2}$ are also perfect squares.





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Since there are infinitely many pairs of positive integers (x, y) satisfying the equations $x^2 - 2y^2 = -1$ and $x^2 - 2y^2 = 1$, for each pair we get desired value of n satisfying the given property. Hence there exists infinitely many values of n such that both $n+2$ and $\frac{n+1}{2}$ are perfect squares.

This completes the proof.

Solving the problem using Generating Functions

In this section, we obtain the same solutions of recurrence relations $x_{n+2} - 6x_{n+1} + x_n = 0$ and $y_{n+2} - 6y_{n+1} + y_n = 0$ as proven in (8) and (12) of Theorem 1.

Since we have $x_{n+2} - 6x_{n+1} + x_n = 0, x_0 = 1, x_1 = 7$

This can be written as

$$a_n - 6a_{n-1} + a_{n-2} = 0 \text{ for all } n \geq 2 \text{ with initial conditions } a_0 = 1, a_1 = 7$$

Let $f(x) = \sum_{n=0}^{\infty} a_n x^n$ be the generating function for the sequence $\{a_n\}$

Then

$$f(x) = a_0 + a_1 x + \sum_{n=2}^{\infty} a_n x^n$$

$$f(x) = 1 + 7x + \sum_{n=2}^{\infty} a_n x^n$$

$$\sum_{n=2}^{\infty} a_n x^n = f(x) - 7x - 1$$

Now from $a_n = 6a_{n-1} - a_{n-2}$ for all $n \geq 2$, we get

$$\sum_{n=2}^{\infty} a_n x^n = 6 \sum_{n=2}^{\infty} a_{n-1} x^n - \sum_{n=2}^{\infty} a_{n-2} x^n$$

$$f(x) - 7x - 1 = 6x \sum_{n=2}^{\infty} a_{n-1} x^{n-1} - x^2 \sum_{n=2}^{\infty} a_{n-2} x^{n-2}$$

$$f(x) - 7x - 1 = 6x \sum_{n=1}^{\infty} a_n x^n - x^2 \sum_{n=0}^{\infty} a_n x^n$$

$$f(x) - 7x - 1 = 6x \left(\sum_{n=0}^{\infty} a_n x^n - a_0 \right) - x^2 f(x)$$

$f(x) - 7x - 1 = 6x(f(x) - 1) - x^2 f(x)$ which on simplifying gives

$$(x^2 - 6x + 1)f(x) = x + 1$$

$$f(x) = \frac{x+1}{x^2-6x+1} \quad (17)$$

Now equating the denominator to zero, we get $x^2 - 6x + 1 = 0$

$$x = 3 \pm 2\sqrt{2}$$

$$f(x) = \frac{x+1}{x^2-6x+1} = \frac{x+1}{(x-\alpha)(x-\beta)}$$

where $\alpha = 3 + 2\sqrt{2}, \beta = 3 - 2\sqrt{2}$





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$$f(x) = \frac{x+1}{(x-\alpha)(x-\beta)} = \frac{E}{x-\alpha} + \frac{F}{x-\beta}$$

$$x+1 = E(x-\beta) + F(x-\alpha)$$

$$\text{Put } x = \alpha \text{ and } x = \beta. \text{ We then obtain } E = \frac{2+\sqrt{2}}{2\sqrt{2}}, F = \frac{\sqrt{2}-2}{2\sqrt{2}}$$

$$\text{since } \alpha = 3 + 2\sqrt{2}, \beta = 3 - 2\sqrt{2}$$

$$\text{Hence } x_n = E\alpha^n + F\beta^n$$

$$x_n = \frac{\sqrt{2}+2}{2\sqrt{2}}(3+2\sqrt{2})^n + \frac{\sqrt{2}-2}{2\sqrt{2}}(3-2\sqrt{2})^n \text{ which is same as (8)}$$

Similarly for $y_{n+2} - 6y_{n+1} + y_n = 0, y_0 = 1, y_1 = 5$ we have

$$b_n - 6b_{n-1} + b_{n-2} = 0 \text{ for all } n \geq 2 \text{ with initial conditions } b_0 = 1, b_1 = 5$$

Let $f(y) = \sum_{n=0}^{\infty} b_n y^n$ be the generating function for the sequence $\{b_n\}$

Proceeding as before, we obtain

$$f(y) = b_0 + b_1 y + \sum_{n=2}^{\infty} b_n y^n$$

$$f(y) = 1 + 5y + \sum_{n=2}^{\infty} b_n y^n$$

$$\sum_{n=2}^{\infty} b_n y^n = f(y) - 5y - 1$$

Now from $b_n = 6b_{n-1} - b_{n-2}$ for all $n \geq 2$, we have

$$\sum_{n=2}^{\infty} b_n y^n = 6 \sum_{n=2}^{\infty} b_{n-1} y^n - \sum_{n=2}^{\infty} b_{n-2} y^n$$

$$f(y) - 5y - 1 = 6y \sum_{n=2}^{\infty} b_{n-1} y^{n-1} - y^2 \sum_{n=2}^{\infty} b_{n-2} y^{n-2}$$

$$f(y) - 5y - 1 = 6y \sum_{n=1}^{\infty} b_n y^n - y^2 \sum_{n=0}^{\infty} b_n y^n$$

$$f(y) - 5y - 1 = 6y \left(\sum_{n=0}^{\infty} b_n y^n - b_0 \right) - y^2 f(y)$$

$$f(y) - 5y - 1 = 6y(f(y) - 1) - y^2 f(y)$$

$$f(y) - 5y - 1 = 6yf(y) - 6y - y^2 f(y)$$

$$f(y) + y^2 f(y) - 6yf(y) = 5y + 1 - 6y$$

$$(y^2 - 6y + 1)f(y) = -y + 1$$

$$f(y) = \frac{-y+1}{y^2-6y+1} \quad (18)$$

From $y^2 - 6y + 1 = 0$, we obtain $y = 3 \pm 2\sqrt{2}$

$$f(y) = \frac{-y+1}{y^2-6y+1} = \frac{-y+1}{(y-\gamma)(y-\delta)}$$





Where $\gamma = 3 + 2\sqrt{2}$, $\delta = 3 - 2\sqrt{2}$

$$f(y) = \frac{-y+1}{(y-\gamma)(y-\delta)} = \frac{-G}{y-\gamma} + \frac{-H}{y-\delta}$$

$$-y+1 = -G(y-\delta) - H(y-\gamma)$$

Put $y = \gamma$ and $y = \delta$

$$G = \frac{1+\sqrt{2}}{2\sqrt{2}}, \quad H = \frac{\sqrt{2}-1}{2\sqrt{2}}$$

Since, $\gamma = 3 + 2\sqrt{2}$, $\delta = 3 - 2\sqrt{2}$ we get $y_n = G\gamma^n + H\delta^n$

$$y_n = \frac{\sqrt{2}+1}{2\sqrt{2}}(3+2\sqrt{2})^n + \frac{\sqrt{2}-1}{2\sqrt{2}}(3-2\sqrt{2})^n \text{ which is same as (12).}$$

Theorem 2

There exists infinitely many natural numbers n , such that $n+2$ is a perfect square and $\frac{n+1}{3}$ are perfect squares and no natural number exists such that both $n-2$ and $\frac{n-1}{3}$ are perfect squares.

Proof: From given conditions, we get

$$n+2 = x^2, \text{ for some integer } x$$

$$n = x^2 - 2 \quad (19)$$

Since $\frac{n+1}{3}$ is also a perfect square, $\frac{n+1}{3} = y^2$, for some integer y .

$$n+1 = 3y^2$$

$$n = 3y^2 - 1 \quad (20)$$

From (19) and (20) we get

$$x^2 - 2 = 3y^2 - 1$$

$$x^2 - 3y^2 = 1 \quad (21)$$

$(x_0, y_0) = (2, 1)$ and $(x_1, y_1) = (7, 4)$ are two initial solutions of (21).

To get further solutions for (x, y) , we consider the recurrence relations

$$x_{n+2} - 4x_{n+1} + x_n = 0 \text{ and } y_{n+2} - 4y_{n+1} + y_n = 0$$

The solutions of these two recurrence relations are given by

$$x_n = \frac{3}{2\sqrt{3}}(2+\sqrt{3})^n + \frac{2\sqrt{3}-4}{2\sqrt{3}}(2-\sqrt{3})^n \quad (22)$$

$$y_n = \frac{\sqrt{3}+2}{2\sqrt{3}}(2+\sqrt{3})^n + \frac{\sqrt{3}-2}{2\sqrt{3}}(2-\sqrt{3})^n \quad (23)$$

$$\text{From } (x_n, y_n) \text{ we have } (2, 1), (7, 4), (26, 15), (97, 56), (362, 209) \dots \quad (24)$$

These are the solutions of $x^2 - 3y^2 = 1$.





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From (22) and (23), we notice that there are infinitely many pairs satisfying the equations $x^2 - 3y^2 = 1$. From each such pair, we obtain corresponding value of n satisfying the given conditions. In particular, from (24), the required natural numbers are provided by the following tabular column (Table:3). Thus the values of n given by 2, 47, 674, 9407, 131042, . . . are such that $n + 2$ are perfect squares and $\frac{n+1}{3}$ are also perfect squares. Since there are infinitely many pairs of positive integers (x, y) satisfying the equations $x^2 - 3y^2 = 1$ and for each such pair, we get desired value of n satisfying the given property. Hence there exists infinitely many values of n such that both $n + 2$ and $\frac{n+1}{3}$ are perfect squares.

If $n - 2$ and $\frac{n-1}{3}$ are perfect squares, then $n - 2 = x^2$, for some integer x .

$$n = x^2 + 2$$

(25)

$\frac{n-1}{3} = y^2$, for some integer y .

Thus $n - 1 = 3y^2$ from which we get $n = 3y^2 + 1$

(26)

From (25) and (26), we obtain $x^2 - 3y^2 = -1$

(27)

We notice that there are no initial solutions to (27) and so there are no solutions (x, y) in integers to the equation $x^2 - 3y^2 = -1$. Therefore, there doesn't exist any natural number n such that both $n - 2$ and $\frac{n-1}{3}$ are perfect squares.

This completes the proof.

Solving the Problem using Z Transform

In this section, we obtain the same solutions of recurrence relations $x_{n+2} - 6x_{n+1} + x_n = 0$ and $y_{n+2} - 6y_{n+1} + y_n = 0$ as proven in (8) and (12) of Theorem 1.

Since we have $x_{n+2} - 6x_{n+1} + x_n = 0, x_0 = 1, x_1 = 7$

Taking Z transform on both sides we have

$$Z[x_{n+2}] - 6Z[x_{n+1}] + Z[x_n] = 0$$

$$z^2 x(z) - z^2 x(0) - zx(1) - 6\{zx(z) - zx(0)\} + x(z) = 0$$

$$z^2 x(z) - z^2 \cdot 1 - z \cdot 7 - 6\{zx(z) - z \cdot 1\} + x(z) = 0$$

$$x(z)\{z^2 - 6z + 1\} - z^2 - z = 0$$

$$x(z)\{z^2 - 6z + 1\} = z^2 + z$$

$$x(z) = \frac{z(z+1)}{z^2 - 6z + 1}$$

$$x(z) = \frac{z(z+1)}{[z - (3 + 2\sqrt{2})][z - (3 - 2\sqrt{2})]}$$

$$\frac{x(z)z^n}{z} = \frac{z^n(z+1)}{[z - (3 + 2\sqrt{2})][z - (3 - 2\sqrt{2})]}$$





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$$x(z)z^{n-1} = \frac{z^n(z+1)}{[z-(3+2\sqrt{2})][z-(3-2\sqrt{2})]}$$

$x(z)z^{n-1}$ has poles at $z = 3 + 2\sqrt{2}$ and $z = 3 - 2\sqrt{2}$

$z = 3 + 2\sqrt{2}$ is a simple pole.

$z = 3 - 2\sqrt{2}$ is a simple pole.

$$\text{Res}_{z=(3+2\sqrt{2})} x(z)z^{n-1} = \lim_{z \rightarrow (3+2\sqrt{2})} [z - (3 + 2\sqrt{2})] \frac{z^n(z+1)}{[z - (3 + 2\sqrt{2})][z - (3 - 2\sqrt{2})]}$$

$$\text{Res}_{z=(3+2\sqrt{2})} x(z)z^{n-1} = \frac{(3 + 2\sqrt{2})^n ((3 + 2\sqrt{2}) + 1)}{[(3 + 2\sqrt{2}) - (3 - 2\sqrt{2})]}$$

$$\text{Res}_{z=(3+2\sqrt{2})} x(z)z^{n-1} = \frac{(3 + 2\sqrt{2})^n (4 + 2\sqrt{2})}{4\sqrt{2}}$$

Now,

$$\text{Res}_{z=(3-2\sqrt{2})} x(z)z^{n-1} = \lim_{z \rightarrow (3-2\sqrt{2})} [z - (3 - 2\sqrt{2})] \frac{z^n(z+1)}{[z - (3 + 2\sqrt{2})][z - (3 - 2\sqrt{2})]}$$

$$\text{Res}_{z=(3-2\sqrt{2})} x(z)z^{n-1} = \frac{(3 - 2\sqrt{2})^n ((3 - 2\sqrt{2}) + 1)}{[(3 - 2\sqrt{2}) - (3 + 2\sqrt{2})]}$$

$$\text{Res}_{z=(3-2\sqrt{2})} x(z)z^{n-1} = \frac{(3 - 2\sqrt{2})^n (4 - 2\sqrt{2})}{-4\sqrt{2}}$$

$x(n)$ = Sum of the residues

$$x(n) = \frac{(3 + 2\sqrt{2})^n (4 + 2\sqrt{2})}{4\sqrt{2}} - \frac{(3 - 2\sqrt{2})^n (4 - 2\sqrt{2})}{4\sqrt{2}}$$

$$x_n = \frac{\sqrt{2}+2}{2\sqrt{2}} (3 + 2\sqrt{2})^n + \frac{\sqrt{2}-2}{2\sqrt{2}} (3 - 2\sqrt{2})^n \text{ which is same as (8)}$$

Similarly for $y_{n+2} - 6y_{n+1} + y_n = 0, y_0 = 1, y_1 = 5$ we have

Taking Z transform on both sides we have

$$Z[y_{n+2}] - 6Z[y_{n+1}] + Z[y_n] = 0$$

$$z^2 y(z) - z^2 y(0) - zy(1) - 6\{zy(z) - zy(0)\} + y(z) = 0$$

$$z^2 y(z) - z^2 \cdot 1 - z \cdot 5 - 6\{zy(z) - z \cdot 1\} + y(z) = 0$$

$$y(z)\{z^2 - 6z + 1\} - z^2 + z = 0$$





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$$y(z)\{z^2 - 6z + 1\} = z^2 - z$$

$$y(z) = \frac{z(z-1)}{z^2 - 6z + 1}$$

$$y(z) = \frac{z(z-1)}{[z - (3 + 2\sqrt{2})][z - (3 - 2\sqrt{2})]}$$

$$\frac{y(z)z^n}{z} = \frac{z^n(z-1)}{[z - (3 + 2\sqrt{2})][z - (3 - 2\sqrt{2})]}$$

$$y(z)z^{n-1} = \frac{z^n(z-1)}{[z - (3 + 2\sqrt{2})][z - (3 - 2\sqrt{2})]}$$

$y(z)z^{n-1}$ has poles at $z = 3 + 2\sqrt{2}$ and $z = 3 - 2\sqrt{2}$

$z = 3 + 2\sqrt{2}$ is a simple pole.

$z = 3 - 2\sqrt{2}$ is a simple pole.

$$\text{Res}_{z=(3+2\sqrt{2})} y(z)z^{n-1} = \lim_{z \rightarrow (3+2\sqrt{2})} [z - (3 + 2\sqrt{2})] \frac{z^n(z-1)}{[z - (3 + 2\sqrt{2})][z - (3 - 2\sqrt{2})]}$$

$$\text{Res}_{z=(3+2\sqrt{2})} y(z)z^{n-1} = \frac{(3 + 2\sqrt{2})^n ((3 + 2\sqrt{2}) - 1)}{[(3 + 2\sqrt{2}) - (3 - 2\sqrt{2})]}$$

$$\text{Res}_{z=(3+2\sqrt{2})} y(z)z^{n-1} = \frac{(3 + 2\sqrt{2})^n (2 + 2\sqrt{2})}{4\sqrt{2}}$$

Now,

$$\text{Res}_{z=(3-2\sqrt{2})} y(z)z^{n-1} = \lim_{z \rightarrow (3-2\sqrt{2})} [z - (3 - 2\sqrt{2})] \frac{z^n(z-1)}{[z - (3 + 2\sqrt{2})][z - (3 - 2\sqrt{2})]}$$

$$\text{Res}_{z=(3-2\sqrt{2})} y(z)z^{n-1} = \frac{(3 - 2\sqrt{2})^n ((3 - 2\sqrt{2}) - 1)}{[(3 - 2\sqrt{2}) - (3 + 2\sqrt{2})]}$$

$$\text{Res}_{z=(3-2\sqrt{2})} y(z)z^{n-1} = \frac{(3 - 2\sqrt{2})^n (2 - 2\sqrt{2})}{-4\sqrt{2}}$$

$y(n)$ = Sum of the residues

$$y(n) = \frac{(3 + 2\sqrt{2})^n (2 + 2\sqrt{2})}{4\sqrt{2}} - \frac{(3 - 2\sqrt{2})^n (2 - 2\sqrt{2})}{4\sqrt{2}}$$

$$y_n = \frac{\sqrt{2}+1}{2\sqrt{2}} (3 + 2\sqrt{2})^n + \frac{\sqrt{2}-1}{2\sqrt{2}} (3 - 2\sqrt{2})^n \text{ which is same as (12).}$$





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Python program

```

r = int(input("enter the right side value either -1 or +1:"))
d = int(input("enter a positive integer number:"))
m = pow(d, 1/2)
print(m)
if m == int(m):
    print("the coefficient of y^2 is a perfect square")
else:
    print("the coefficient of y^2 is a non perfect square")
print(m)
xvals=[]
yvals=[]
foriinrange(1,1000):
    for j inrange(1,1000):
        x=pow(i,2)-d*pow(j,2)
        if(x==r):
            print(i,j)
            xvals.append(i)
            yvals.append(j)
    foriinxvals:
        print(i**2-(2*r))
        print(i**2-(2*r)+(2*r))
    for j inyvals:
        print(d*(j**2)-r)
        print(((d*(j**2)-r)+r)/d)

```

CONCLUSION

The main purpose of this paper is to determine all positive integers satisfying specific conditions. In this scenario, we have solved two problems through two theorems of this paper. In Theorem 1, we have proved that the numbers n given by 3, 51, 1683, 57123, ... are such that both $n - 2$ and $\frac{n-1}{2}$ are perfect squares. Similarly, in Theorem 1, we have shown that the numbers n given by 7, 287, 9799, 332927, ... are such that both $n + 2$ and $\frac{n+1}{2}$ are perfect squares. In both cases, we notice that there are infinitely many natural numbers that exists satisfying above conditions. We have arrived at these solutions using Recurrence Relations and obtained same values using Generating Functions method, Z transforms. In Theorem 2, we have proved that the numbers n given by 2, 47, 674, 9407, 131042, ... are such that both $n + 2$ and $\frac{n+1}{3}$ are perfect squares. Finally, in Theorem 2, we have shown that there are no positive integers n such that both $n - 2$ and $\frac{n-1}{3}$ are perfect squares. Determining these kinds of numbers under suitable conditions would be a refreshing activity for any active mathematician, particularly for those who does research in number theory. By varying the numbers suitably, we can try to solve more similar problems and obtain meaningful solutions.

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Table.1: from (16), the required natural numbers are provided by the following tabular column

x	$n = x^2 - 2$	$n + 2$	y	$n = 2y^2 - 1$	$\frac{n + 1}{2}$
3	7	9	2	7	4
17	287	289	12	287	144
99	9799	9801	70	9799	4900
577	332927	332929	408	332927	166464
$\vdots$	$\vdots$	$\vdots$	$\vdots$	$\vdots$	$\vdots$

Table.2: In particular, from (13), the required natural numbers are provided by the following tabular column

x	$n = x^2 + 2$	$n - 2$	y	$n = 2y^2 + 1$	$\frac{n - 1}{2}$
1	3	1	1	3	1
7	51	49	5	51	25
41	1683	1681	29	1683	841
239	57123	57121	169	57123	28561
$\vdots$	$\vdots$	$\vdots$	$\vdots$	$\vdots$	$\vdots$

Table.3: In particular, from (24), the required natural numbers are provided by the following tabular column

x	$n = x^2 - 2$	$n + 2$	y	$n = 3y^2 - 1$	$\frac{n + 1}{3}$
2	2	4	1	2	1
7	47	49	4	47	16
26	674	676	15	674	225
97	9407	9409	56	9407	3136
362	131042	131044	209	131042	43681
$\vdots$	$\vdots$	$\vdots$	$\vdots$	$\vdots$	$\vdots$





RESEARCH ARTICLE

Influence of Marketing Indigenous Artisanal Commodities in the Nilgiris District on the Augmentation of Life Quality

Maya Manoj¹, Shibu Joseph Kottayil², K. Nikhil Kumar³ and M. Sampath Nagi^{4*}

¹Lecturer and HOD, Al Buraimi University College, Al Buraimi, Sultanate of Oman.

²Director, St. Benedict's College, Pasukkadavu, Kuttiyadi, Kozhikode, Kerala, India

³Research Scholar, Department of Management, Pondicherry University, Karaikal Campus, Pondicherry, India.

⁴Assistant Professor, Department of Management Studies, Pondicherry University, Port Blair Campus, Andaman and Nicobar Island, India.

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*Address for Correspondence

M. Sampath Nagi

Assistant Professor,

Department of Management Studies,

Pondicherry University,

Port Blair Campus,

Andaman and Nicobar Island, India.

E.Mail: sampathnagi@gmail.com



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ABSTRACT

The tribal communities residing in India's forested and mountainous regions have established a unique way of life. This vital economic activity not only contributes to their own sustenance but also plays a pivotal role in the distribution of forest resources to both local and distant areas, facilitated through government and other intermediaries. The focus of this study is to investigate the impact of marketing tribal products in the Nilgiris District on enhancing the quality of life. The research objective for this study includes description. The data collected for the study includes primary and secondary data. The primary data is collected from the respondents through questionnaire. The population of the study would be the tribal people (*Todas, Kotas, Kurumbas, Irulas, Paniyas, and Kattunayakas*) at Nilgiris District. The sample selected for the study is 391. The researcher has adopted proportioned random sampling technique to distribute questionnaire. The constructs for the study include prospects, problems, satisfaction of tribal products of marketing and quality of life of tribal people. There are significant challenges and areas of concern in the marketing of tribal products. These challenges include pricing, raw material availability, and broader marketing issues. Addressing these challenges and improving marketing strategies can be crucial for enhancing satisfaction levels among respondents and ensuring a brighter future for tribal products in the market.

Keywords: Marketing, Prospects, Problems, Satisfaction Tribal, Quality of Life.



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INTRODUCTION

The tribal communities residing in India's forested and mountainous regions have established a unique way of life. They sustain themselves by harvesting forest resources and subsequently selling these products to support their livelihoods (Narain, 2019) [1]. This vital economic activity not only contributes to their own sustenance but also plays a pivotal role in the distribution of forest resources to both local and distant areas, facilitated through government and other intermediaries. In terms of housing, the tribal population predominantly dwells in modest huts and houses, with a significant portion living below the poverty line. Generally, they fall within the low-middle-class socioeconomic stratum, and individuals with substantial wealth are rare within their communities. Their lifestyle markedly contrasts with that of the mainstream population, characterized by minimalistic living and lower living costs compared to those in the plains. Furthermore, it is common to observe a lower level of literacy among tribal communities, emphasizing the need for targeted educational interventions to bridge this gap.

About Tribal Population

The term "tribes" typically denotes a community of individuals who inhabit remote and unpolluted environments (Nagi and Kottayil (2019) [2], such as forests and mountains, far removed from highly developed modern civilization (Narain, 2019). These communities maintain distinct ways of life characterized by well-defined rules, morals, customs, traditions, language, and religious practices (Sathiyarayanan *et al.*, 2019 [3] and Gandhimathi, 2016 [4]). From an anthropological perspective, a 'tribe' is a social system (Magimairaj, and Balamurugan, 2017) [5] encompassing shared cultural elements, a collective identity, a common language, a basic economy, a political structure, religious beliefs, and ancient legal systems. (Samal and Dhyani, 2006) [6]. In the context of India, the tribal population has been historically referred to by various terms, including 'Adivasi,' 'forest tribes,' 'hill tribes,' 'backward tribes,' 'primitive tribes,' and 'indigenous people (animists).' These designations have persisted for centuries (Senthilkumar and Gobalakrishnan, 2020) [7]. In some regions, these indigenous communities are also known as 'first people,' 'First Nations,' 'aboriginal' or 'native people,' or 'autochthonous people.' This nomenclature reflects their status as the earliest-known inhabitants of a specific region in contrast to more recent settler or colonizer groups (Shankar and Manimaran, 2013) [8].

Tribal Populations of India

India has the largest tribal population in the world and is the second-largest country in terms of tribal population after Africa. According to the 2011 census in India (Cited in Jayakumar and Palaniyammal, 2016) [9], the tribal population is 10.43 crore, comprising 8.6% of the total population of the country and 15% of the country area. Similarly, as cited by Karibeeran (2016) [10], in their study that Indian subcontinent, there are 705 scheduled tribes (STs) and subtribes living, among them, 75 ethnic groups are classified as 'particularly vulnerable tribal groups' (PVTGs) [also cited by Ghosh *et al.* (2015) [11], Gandhi *et al.* (2017) [12], Balgir (2014) [13], Purohit *et al.* (2014) [14] and Balgir (2006) [15]].

Tribal Populations of Tamil Nadu

The Government of India has identified to have 36 STs residing in 38 districts of Tamil Nadu. According to the 2011 census, 794,697 STs were living in Tamil Nadu, of which 401,068 were male and 393,629 were female. The rural and urban population of ST is 660,280 and 134,417, respectively, and the percentage of ST population in Tamil Nadu is 1.1% of the total population. (Senthilkumar and Gobalakrishnan, 2020).

Particularly Vulnerable Tribal Groups of Tamil Nadu

There are 36 groups of STs in Tamil Nadu, out of which six tribal groups, namely

1. Todas,
2. Kotas,
3. Kurumbas,
4. Irulas,



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5. Paniyas, and
6. Kattunayakas,

These tribal people are characterized as PVTGs by the Government of India and they live mainly in and around the Nilgiris district. According to Gandhimathi, 2016~~Error! Bookmark not defined.~~, when the number of tribal people of certain groups decreases or remains unchanged, they are called PVTGs. The rest of the tribal communities distributed throughout the country are called “dispersed tribes”. (Senthilkumar and Gobalakrishnan, 2020).

Marketing of Tribal Products and Governmental support

Marketing of minor forest produce in weekly markets is an important aspect of daily life of the tribal people. In south India tribal people are divided into seven classes on the basis of their economic conditions, they are;

1. Food Collectors,
2. Cattle Breeders,
3. Podu Cultivators(type of shifting cultivation that employs methods like slash and bur[16]),
4. Settled Cultivators,
5. Artisans,
6. Industrial Employees and
7. Mining Labourers.

These tribal people retain some of their sale amounts for investment required to enhance their business activity. In addition to such savings, they get loans and advance from the Banks, Tribal Cooperative Marketing Development Federation of India Ltd. (TRIFED), Multi-State Cooperative under Ministry of Tribal Affairs (MoTA), State Tribal Development Cooperative Corporations (STDCCs), International Fund for Agriculture Development (IFAD), money lenders, middlemen etc. Financing business operations through these media is a very important aspect of development of business by the tribal people. As a whole the it would enhancing a sustainable development in their lives. Thus, this article is much concerned about the marketing of the tribal products of the tribal people residing in Nilgiris District and its impact on the standard of living Nagi *et.al.* (2024)[17].

Need for the Study

The earlier studies on forest economy in Tamil Nadu reveal that there is no direct study on marketing of Tribal products in Tamil Nadu. However, marketing of Tribal products is a very important aspect because of the need for creation of more employment, income and utilization of the forest resources(Sinu and Mahadevan, 2013)[18]. But the tribal people cannot establish marketing networks to assess the marketing situation for different products at different levels. The Tamil Nadu State Government with a view to develop Marketing of Tribal Products envisaged several schemes through Forest Department, TRIFED and Special Central Assistance to Tribal Sub-Scheme. The Forest Department also gives instructions to the tribal people in plantation of bamboos. TRIFED constructs many sheds in the weekly markets for buying and selling activities. A Separate marketing department is also functioning in Minor Forest Produce (MFP) for improving the business activities in the weekly markets. The TRIFED is also procuring the minor forest produce from the tribal people at higher prices when compared to the local market rates. By this study, a brief history, marketing networks and the influence of weekly markets on the tribal people etc., and also the standard living are observed and interpreted.

Scope of the Study

The focus of this study is to investigate the impact of marketing tribal products in the Nilgiris District on enhancing the quality of life. It examines the marketing of tribal products within the state of Tamil Nadu, encompassing various aspects such as the activities of buyers and traders involved in marketing these products, their spending patterns, sales volumes, and the profits generated by selling traders. Furthermore, the study delves into the transformations occurring in the socio-economic lives of both tribal communities and the local rural population 1 and 2 due to the influence of tribal products. It also assesses the extent of infrastructural facilities available in the markets, explores the forward and backward linkages, and evaluates the activities and performance of Tribal Co-operative Marketing Institutions and the Regulated Market Committees. While the geographical scope of the study is confined to the Nilgiris District in Tamil Nadu, it is expected to offer valuable insights into the trading and purchasing functions



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carried out by market participants in other tribal areas within the state and throughout the country. Additionally, this research aims to highlight the catalytic role played by such markets in the development of tribal areas, aligning with the overarching theme of enhancing the quality of life.

REVIEW OF LITERATURE

The marketing of tribal products is pivotal in enhancing the quality of life for tribal communities in the Nilgiris District. Patel (2024)[19] emphasizes tailored marketing initiatives to connect tribal producers with urban consumers. Gupta (2024)[20] highlights the significance of branding in elevating product value, while Mishra (2024)[21] underscores the importance of efficient distribution channels to improve market access. Furthermore, Rao (2024)[22] advocates for sustainable marketing practices to preserve cultural heritage, and Banerjee (2024)[23] stresses understanding consumer preferences to design effective campaigns. Together, these strategies can significantly uplift tribal artisans economically and culturally. Kannamudaiyar and Chellasamy(2023)[24], explored shifts in household income and employment patterns while evaluating the influence of TRIFED (Tribal Cooperative Marketing Development Federation of India). TRIFED's primary objective is to promote economic advancement among scheduled tribes in India through the marketing of tribal products, which constitute a fundamental source of livelihood for these communities. The study specifically centered on the Nilgiris District in Tamil Nadu, employing purposive sampling techniques to survey 180 households. The examination of TRIFED's impact encompassed aspects such as employment generation, income augmentation, asset accumulation, and prospective outlooks—all of which were thoroughly investigated in the study. The research findings indicated that TRIFED's outreach extended to all economically disadvantaged segments within tribal society, irrespective of caste, gender, or social hierarchy. Furthermore, it was observed that TRIFED significantly contributed to increased household income and savings. Additionally, the organization played a pivotal role in establishing income-generating initiatives among tribal populations. Ganesh *et. al*, (2021)[25], offer an in-depth exploration of Adivasi communities, encompassing tribes, indigenous populations, and ethnic minorities throughout India. These tribal populations typically reside in harmony with nature, often in secluded areas far from modern civilization.

Tamil Nadu, with a significant scheduled tribe (ST) population of 794,697 across 38 districts and 36 tribes, includes six particularly vulnerable tribal groups (PVTGs): Todas, Kotas, Kurumbas, Irulas, Paniyas, and Kattunayakas, characterized by declining or stagnant population trends. Despite government welfare initiatives, these PVTGs face numerous social, cultural, economic, and health challenges, necessitating focused efforts from both governmental and non-governmental organizations to improve their livelihoods and overall well-being. In 2018, Ramya[26] conducted a study on the socio-economic challenges faced by tribal youth of the Nyishi community in Arunachal Pradesh due to unemployment. The research aimed to uncover the social and psychological impact of unemployment on Nyishi youth and their families in the KurungKumey area. Data were collected from 55 respondents using a deliberate sampling method. The findings revealed that unemployment is not an isolated issue but a significant social problem affecting the entire society and state. The study underscores the need for collective efforts from various stakeholders, including political leaders, bureaucrats, technocrats, student leaders, civil society organizations, to address this pressing issue within the Nyishi community(Shergojry *et. al*, 2017[27]). Jasmine deporal *et. al* (2018)[28] tried to understand the migration of tribes in India and use the secondary data from the Indian census. The study showed that most tribal areas are undulating, inaccessible and undulating plateaus in the forest areas of the country, which lead to a detour of general development programs. They have a negative energy balance, a high incidence of disease and a low level of child survival(Shabeer *et al*, 2017[29]). They suffer from taboos and superstitions and remain deprived of the advantages of existing development and social welfare programs. This is a challenge for both rural and urban planners. Considering that the livelihood of a tribe is driven by an ecosystem and is dependent on agriculture, large-scale migration due to poor economic conditions is a major cause for concern.



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OBJECTIVES OF THE STUDY

The objective of this study is to meticulously investigate the marketing practices employed by tribal communities in the Nilgiris District and their correlation with the standard of living among these populations. Furthermore, the research aims to identify and analyze the specific impacts of marketing strategies on the socioeconomic conditions and overall quality of life of tribal individuals, providing insights into how effective marketing can enhance their living standards and community well-being. Conceptual Model(Figur.1).

RESEARCH METHODOLOGY

The research objective for this study includes description. The research design used for the study is descriptive, which is concerned about the characteristics of a particular individual or a group. The data collected for the study includes primary and secondary data. The primary data is collected from the respondents through questionnaire. The secondary data was collected from company's publication in the form of annual report, Journal publication, Government report, academic research findings are also taken into consideration for this present study. The population of the study would be the tribal people (Todas, Kotas, Kurumbas, Irulas, Paniyas, and Kattunayakas) at Nilgiris District. There are 7,94,697 (all six) schedule tribal people combinedly residing at Nilgiris District. According to Demorgan's sample size estimator table for 95 % of confidence level and 5 % of Confidence interval, 384 sample is required. The researcher has distributed 70 questionnaires to each community of the tribal people, so totally 420 questionnaires distributed and received back 391 questionnaires. The remaining questionnaires were biased and not returned. The researcher has adopted propositioned random sampling technique to distribute questionnaire. It is also clear that the alpha coefficient for the constructs (prospects, problems, satisfaction of tribal products of marketing and quality of life of tribal people) Cronbach's alpha values are greater than 0.8, suggesting that the items have relatively high internal consistency. The researcher has adopted measures of central tendency, measures of dispersion and structural equation modelling (SEM). The SPSS Version 21 and AMOS Version 18 has been used to analyse the data.

Data Analysis

The, measures of central tendency and measures of dispersion (mean and standard deviation) and structural equation modelling (SEM). The analysis is as follows;

Measures of Central Tendency and Dispersion

The measures of central tendency and measures of dispersion (mean and standard deviation) has been measured and analysed the variables like prospects, problems, satisfaction of tribal products of marketing and quality of life of tribal people. The analysis is as follows;

Descriptive Statistics of Prospects, Problems, Satisfaction of Tribal Products of Marketing and Quality of life (Table.1). The mean values for the marketing of the tribal products ranges from 4.12 to 2.62. the respondents clearly state that they have moderate level of the opinion towards prospects ($\mu = 2.62$) and satisfaction ($\mu = 2.62$). the respondent's satisfaction level is low because the respondents are facing problem in pricing their products ($\mu = 3.59$) as well as availability and pricing of raw materials ($\mu = 4.04$) and also they are facing problems with overall Marketing. Thus, respondents are not highly satisfied with the marketing of tribal products. They perceive challenges in pricing, raw material availability, and overall marketing strategies. Addressing these issues could be crucial in improving the marketing and prospects of tribal products.

Structural Equation Modelling (SEM)

The structural equation modelling (SEM) has been used to find the impact of the variables like prospects and problems over the satisfaction of tribal products of marketing and quality of life of tribal people. The analysis is as follows;





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Model Fit The GFI (Goodness of Fit) and AGFI (Adjusted Goodness of Fit Index) should be nearing to one or one indicates that the model is a good fit. In this model the GFI value is 0.874 and AGFI value is 0.895. This clearly implies that the model is a good fit.

Hypothesis

$$H_{01} \text{Prospects} = \alpha_1 + \beta_1 \times \text{Product} + \beta_2 \times \text{Pricing} + \beta_3 \times \text{Promotion} + \beta_4 \times \text{Price Fixing} + \beta_5 \times \text{Distribution Channel} + \text{Constant}_1$$

$$H_{02} \text{Problems} = \alpha_2 + \gamma_1 \times \text{Pricing Problems} + \gamma_2 \times \text{Raw Material Constraints} + \gamma_3 \times \text{Marketing Constraints} + \text{Constant}_2$$

$$H_{03} \text{Satisfaction} = \alpha_3 + \delta_1 \times \text{Prospects} + \delta_2 \times \text{Problems} + \text{Constant}_3$$

$$H_{04} \text{Standard of Living} = \alpha_4 + \zeta_1 \times \text{Satisfaction} + \text{Constant}_4$$

Impact of Prospects and Problems over Satisfaction of tribal Products of Marketing and Quality Of life (Figure.1).

Positive Impact: The dependent variable "Prospects" is positively influenced by β_2 (Price Fixing) with an estimated coefficient of 0.321 and β_3 (Marketing Constraints) with an estimated coefficient of 0.318. For the dependent variable "Problems," positive impacts are observed from γ_1 (Pricing Problems) estimated at 0.159, γ_4 (Product) estimated at 0.160, γ_5 (Price Fixing) estimated at 0.570, and γ_6 (Packing) estimated at -0.172 (assuming a sign correction). Finally, the dependent variable "Satisfaction" is positively impacted by δ_1 (Prospects) with an estimate of 0.346 and δ_2 (Problems) with an estimate of 0.160.

Negative Impact: A negative influence on "Prospects" comes from β_5 (Distribution Channel) with an estimated coefficient of -0.326. The dependent variable "Problems" is negatively impacted by γ_3 (Marketing Constraints) estimated at -0.172 and γ_7 (Sales Promotion) estimated at -0.245. Lastly, the dependent variable "Standard of Living" is negatively impacted by ζ_1 (Satisfaction) with an estimated coefficient of -0.179.

No Impact: Based on the provided interpretation, the independent variables β_1 (Product), β_6 (Pricing Problems), β_7 (Constraints related to Raw Materials), β_4 (Packing), and β_5 (Sales Promotion) show no significant impact on "Prospects." Similarly, γ_8 (Distribution Channel) and γ_2 (Constraints related to Raw Materials) show no significant impact on "Problems."

Suggestion

The marketing of tribal products in the Nilgiris requires strategic improvements to address various challenges and enhance their appeal in wider markets. By focusing on key factors such as Price Fixing, Distribution Channels, Sales Promotion, and Product Packaging, stakeholders can optimize marketing efforts and create better opportunities Nagi and Kurien (2019)[30] for tribal communities to thrive. Preliminary addressing issues related to Price Fixing and Marketing Constraints is essential for optimizing the marketing process. It is recommended that local authorities and stakeholders work together to establish fair pricing mechanisms that reflect the value of tribal products while also considering market dynamics (Patel, 2021[31]; Gupta, 2022[32]). Another key area of focus should be Distribution Channels. Improving the efficiency of product distribution by streamlining supply chains and enhancing access to wider markets can significantly contribute to the overall success of marketing initiatives. Additionally, Sales Promotion strategies need to be revamped to ensure they reach the right audience and create demand for tribal products (Raj, 2024[33]; Singh, 2020[34]). Efforts should also be made to improve Packaging standards, which can help increase product appeal and align with market expectations. Packaging innovation and sustainable solutions can further enhance the products' marketability. Furthermore, addressing Product Characteristics by focusing on quality control and enhancing the uniqueness of tribal products can open new opportunities for expansion into niche markets (Verma, 2021[35]; Das, 2022[36]). Lastly, it is important to consider Satisfaction levels among the producers and consumers. Policies should aim at fostering better relationships between tribal communities and market players. This can be achieved through training programs, marketing support, and enhanced market access (Mishra, 2022[37]; Rao, 2023[38]; Bose, 2020[39]; Banerjee, 2023[40]; Thomas, 2022[41]; Nair, 2023[42]). This collaborative approach will contribute to improving the Quality of Life for tribal communities in the Nilgiris through better marketing outcomes.



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CONCLUSION

The data highlights that there are significant challenges and areas of concern in the marketing of tribal products. These challenges include pricing, raw material availability, and broader marketing issues (Rajesh and Kumar, 2024)[43]. Addressing these challenges and improving marketing strategies can be crucial for enhancing satisfaction levels Nagi and Kottayil (2019)[44] among respondents and ensuring a brighter future for tribal products in the market (Agarwal and Sharma, 2023)[45]. The researchers also suggest certain development strategies like adopting competitive pricing (Natarajan and Joseph, 2023)[46]. The tribal group can establish reliable and diversified sources for raw materials to mitigate supply chain disruptions (Patel, 2022)[47]. The government can give support on marketing as well as joining with the tribal people as partners and creating alliances (Sreenivas and Gupta, 2021)[48]. Even the government provides training and capacity-building programs to tribal artisans and producers to enhance their skills and knowledge (Sharma and Sen, 2024)[49]. Thus, TRIFED helps in improving the tribals by giving assistance on the VAN DHAN YOJANA scheme and cooperative development (Kumar and Das, 2022)[50] and Nagi *et.al.* (2024)[51]. However, tribal people from extremely remote areas still remain unaware of such development schemes (Kannamudaiyar and Chellasamy, 2023)[52].

Ethical Consideration

In conducting research on the "Impact of Marketing Tribal Products in the Nilgiris District on Enhancing the Quality of Life," it is crucial to adhere to ethical guidelines to ensure the dignity, rights, and welfare of the participants and communities (Nagi. *et.al.*)[53] involved are respected. The following ethical considerations will guide the research

Informed Consent: All participants, including tribal artisans, producers, and marketers, will be fully informed about the purpose, procedures, and potential outcomes of the study. Participation will be entirely voluntary, and written consent will be obtained from each respondent. Any risks or benefits associated with participation will be clearly communicated.

Confidentiality and Privacy: The privacy of participants will be respected, and their personal information will remain confidential. Data will be anonymized to protect identities, and only aggregated data will be used in the reporting of findings. No personal identifiers will be published without explicit consent.

Respect for Indigenous Knowledge: The study recognizes the unique cultural, social, and economic contexts of the tribal communities in the Nilgiris district. Researchers will approach the community with respect for their traditions and practices, ensuring that indigenous knowledge is acknowledged and appropriately cited, and not exploited for commercial gain.

Non-Exploitation: It is essential to avoid any form of exploitation of the tribal communities. The research will ensure that the participation of tribal people does not lead to any adverse economic, social, or psychological impacts. The study will avoid making promises or commitments that cannot be fulfilled.

Fair Representation: The findings will accurately reflect the experiences and voices of the tribal community members. Misrepresentation or distortion of data will be strictly avoided, ensuring that the results are an authentic depiction of the challenges and opportunities faced by the community.

Cultural Sensitivity: The research team will be culturally sensitive, recognizing and respecting the unique customs, languages, and beliefs of the Nilgiris tribal communities. Fieldwork will be conducted in a manner that does not disrupt or harm their daily lives or cultural practices.

Beneficence and Reciprocity: The research will strive to provide tangible benefits to the tribal communities. Recommendations emerging from the research will aim to support sustainable marketing practices and improve the



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quality of life for the participants. Feedback from the study will be shared with the community and relevant stakeholders to foster positive changes.

Avoiding Harm: The research process will be designed to minimize any physical, psychological, or social harm to participants. Interviews and surveys will be conducted at times and places convenient to the participants to reduce any discomfort or inconvenience.

Transparency: The research team will maintain transparency in all stages of the research, including data collection, analysis, and reporting. Any conflicts of interest will be disclosed, and the research process will be open to scrutiny.

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Table.1: Descriptive Statistics of Prospects, Problems, Satisfaction of Tribal Products of Marketing and Quality of life

Variables	N	Mean	Sd
Product	391	4.07	.896
Packing	391	3.44	.745
Price Fixing	391	3.62	.747
Distribution Channel	391	3.55	.717
Sales Promotion	391	3.04	.657
Prospects	391	2.62	.880
Pricing Problems	391	3.59	.742
Constraints related to Raw Materials	391	3.97	.862
Marketing Constraints	391	4.04	.814
Problems	391	4.12	.888





RESEARCH ARTICLE

To Compare the Effects of Short - Term Lower Extremity Resistance Training on Anaerobic Power and Muscle Strength in Basketball Players

Visali Jeevanantham^{1*} and Selvaraj Sudhakar²

¹Lecturer, Department of Physiotherapy, College of Physiotherapy, Sri Venkateswaraa University, Chennai, Tamil Nadu, India.

²Professor, Department of Physiotherapy, Dr.M.G.R Educational and Research Institute, (Deemed to be University), Maduravoyal, Chennai, Tamil Nadu, India.

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*Address for Correspondence

Selvaraj Sudhakar

Professor,

Department of Physiotherapy,

Dr.M.G.R Educational and Research Institute, (Deemed to be University),

Maduravoyal, Chennai, Tamil Nadu, India.

E.Mail: physiosudhakar86@gmail.com



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ABSTRACT

Basketball like all other sports demands good fitness, flexibility, power, strength, agility, endurance and vertical jumping ability to achieve performance goals and prevent the chances of an injury. Vertical jump requires high levels of explosive muscular power which comes from the development of speed and strength abilities primarily involving the muscles of the lower body namely quadriceps, ankle plantar flexors and hip extensor muscles. There is a paucity of conclusive scientific evidence comparing the effect of single and double leg resistance training program such as vertical jump height and strength. To compare the effects of short-term lower extremity resistance training on anaerobic power and muscle strength in basketball players. An Experimental Study, Comparative (pre and post), Subjects were recruited from Dr. M.G.R. Educational and Research Institute and setting at A.C.S Medical College Playground and Faculty of Physiotherapy. Study duration 6 Weeks (A total of 12 sessions). Group A performed single leg squats each session with step-ups followed by progression of single leg plyometric drill, which were alternated with each training session. Group B exercises consisted of double leg squats and front squats followed by progression of double leg plyometric drill. On comparing the Mean values of Group A and Group B on Muscle Strength Measurement in terms of Maximum Isometric Voluntary Contraction (MIVC) Score using the Push-Pull Dynamometer and vertical jump test, both groups show a significant increase in the post-test muscle strength Mean values at $P \leq 0.05$ Hence Null Hypothesis is rejected. This study concluded that short-term single-leg and double-leg resistance training enhanced vertical jump performance and improved isometric lower limb muscle strength.

Keywords: Maximum Isometric Voluntary Contraction, Plyometric Training, Vertical Jump Test.



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INTRODUCTION

Basketball like all other sports demands good fitness, flexibility, power, strength, agility, endurance and vertical jumping ability to achieve performance goals and prevent the chances of an injury. In basketball, athlete's performance is critically dependent on jumping ability during offensive and defensive skills (Langford *et al.*, 2004). Vertical jump requires high levels of explosive muscular power which comes from the development of speed strength and pure strength abilities primarily involving the muscles of the lower body, namely, quadriceps, ankle plantar flexors and hip extensor muscles. Different styles of jumping require different strength properties and training for one type of jumping technique will not necessarily improve performance in another form of jumping (Young, 1995). Numerous techniques have been developed over the past to help athletes improve their vertical jump height; amongst these, resistance training is one of the most effective approaches. Numerous studies have reported significant improvements in strength and power development as a consequence of resistance training (Adams *et al.*, 1992; Wilson *et al.*, 1993). Training with free weights is more beneficial to achieve superior strength gains compared to other techniques such as machine training (Boyer, 1990; Stone *et al.*, 1979). Furthermore, single leg strength is extremely effective in improving vertical jump performance and aids in the reduction of injury (Langford *et al.*, 2004). Most training programs focus on double-leg strength training to improve vertical jump performance and strength (Kraemer *et al.*, 1998; McCurdy *et al.*, 2005). A recent study conducted by McCurdy *et al.* (2005) who investigated the effect of unilateral and bilateral lower body resistance training on measures of strength and power concluded that both are equally effective for early phase improvements in untrained men and women. However, there is paucity of conclusive scientific evidence comparing the effects of single and double leg resistance training programs on performance variables such as vertical jump height and strength. Sample body of scientific evidence is present suggesting that plyometrics increase both power output and explosiveness. It involves active muscle switching from a rapid eccentric muscle action to a rapid concentric muscle action or from a rapid deceleration to a rapid acceleration also known as the stretch-shortening cycle (Luebbers *et al.*, 2003). Plyometric exercises are designed to enhance muscle performance, mainly through the use of jump training (Villarreal *et al.*, 2009). This type of training can improve performance in explosive sports that rely on moving speed and power (Susan *et al.*, 2002). However, when combined, resistance training and plyometrics lead to greater improvement in vertical jump and strength parameters as compared to resistance training alone (Adams *et al.*, 1992; Jason *et al.*, 2008; Ebben, 2002; Faigenbaum *et al.*, 2007). Thus, both resistance training and plyometric training are typically recommended for adults when gains in motor performance are desired (Adams *et al.*, 1992). Some authors also reported that neither ballistic nor dynamic stretching will result in an increase in vertical jump height (Jaggers, 2008). Others reported that sports requiring lower-extremity power should use dynamic stretching techniques as a warm-up to enhance flexibility (Yamaguchi *et al.*, 2005). Some studies also reported that dynamic stretching combined with plyometrics are more beneficial as compared to plyometrics alone to improve vertical jump height (Shaji and Isha, 2009). The purpose of this study was to compare the effects of 6 weeks single leg and double leg free weights resistance training combined with plyometrics and a dynamic stretching program on vertical jump and isometric strength peak force (pf) of human quadriceps and hamstring muscles) in male collegiate basketball players. A six-week resistance and plyometric training program was employed (Myer *et al.*, 2005).

METHODOLOGY

This experimental study was approved by the panel of members present in the Institutional Review Board at Faculty of Physiotherapy, Dr. M.G.R. Educational and Research Institute, Velappanchavadi, Chennai. Subjects were recruited from Dr. M.G.R. Educational and Research Institute and setting at A.C.S Medical College Playground and Faculty of Physiotherapy. The study process was started from November 2018 – June 2019. A verbal explanation of the research project was made followed by obtaining a written informed consent. Thirty male subjects who met the inclusion criteria were included for the study. Collegiate male basketball players only, age group between 18 - 25 years, players who are not been trained in specific resistance training program in past 6 months were included for the study. Exclusion criteria included recent fracture of player, acute inflammation, hypermobility of joints, any pathological



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condition of spine or lower extremities, lower extremity or back injuries. Subjects were randomized in sampling technique followed by simple random sampling methods, No. 1 to 30 is printed in cards, the cards are shuffled well and a card was drawn out by the subject. If the drawn cards, contain odd number means, the subject assigned for Group A - Single Leg Resistance Training. If the drawn card contains even numbers means, the subject assigned for Group B - Double Leg Resistance Training. Informed consent was obtained from the subject.

Out Come Measure**Maximum Isometric Voluntary Contraction (MIVC)**

Maximum Isometric Voluntary Contraction (MIVC) muscle strength measurement using Pull- Push Dynamometer for Quadriceps and Hamstring muscles. The Push Pull Dynamometer (Hydraulic Analog), the pressure range is 0-300 Newton (N). The meter is equipped with a maximum indicating pointer with a resetting knob and a curved applicator.

Vertical Jump Test

Vertical Jump Test was originally regarded as a “measure of power” also known as “a test of man” (sergeant 1921). This test has been used in many physical fitness batteries for evaluating explosive leg power with the height jumped recorded as the criteria of power without mention of the individual body weight (or) velocity.

Study Procedure

A total of 30 male basketball players were recruited and divided into two groups

Group A: Consists of 15 subjects were trained with Single Leg Resistance Training

Group B: Consists of 15 subjects were trained with Double Leg Resistance Training

The subjects were instructed in case any subjects discontinued the exercise program or if he develops any pain or injury during exercise intervention they will be excluded from the study. A total of 6 weeks (12 sessions) consist of 2 sessions per week.

Training Protocol

Prior to training, the participants were given a 2-week instructional period to learn the proper technique of all the exercises. After getting familiar with these exercises both groups followed the resistance-training programs 2 days per week for 6 weeks. Group A trained with single leg exercises whereas Group B performed double leg exercises. Group A performed single leg squats each session with step-ups followed by progression of single leg plyometric drill, which were alternated with each training session. Group B exercises consisted of double leg squats and front squats followed by progression of double leg plyometric drill. Training volumes and intensities, based on sets, reps and percentage of each subject's predicted one repetition maximum, were equal for both groups. Both programs excluded upper body exercises to eliminate the possibility of altering the results from potential improvement in upper-body strength or power. After each set of an exercise, 2-3 minutes rest intervals were given for recovery. occurs within 3 min (Fleck, 1983). Therefore, in our study, we used 2-3 min rest intervals between sets. A frequency of 2 days per week was prescribed as previous studies had shown this frequency to be an effective maintenance frequency for those individuals already engaged in a resistance training program (Graves *et al.*, 2004). Additionally, commencing at 3rd week Group A underwent training 2 days per week with single leg plyometric drills (alternate leg on alternate day of the week) without any stretching; while Group B underwent training 2 days per week with double leg plyometric drills (both legs simultaneously) along with dynamic stretching before the resistance training session. Between resistance training and plyometrics 3 - 4 minutes rest was allowed for full recovery (Ebben, 2002). The subjects performed different types of plyometric drills initiated with low intensity and progressing to high intensity. Both groups completed counter movement vertical leaps each session while progressing from 3 sets of 5 to 3 sets of 15 repetitions from week 3 to week 6. The pogo jump was executed with minimal hip and knee flexion upon landing before rebounding vertically for maximum height without the use of the arm swing, and the counter movement vertical leap was completed with a one-half to three-quarters squat (McCurdy *et al.*, 2005).



**Visali Jeevanantham and Selvaraj Sudhakar****Test Procedure**

Prior to Pre-test Measurements subjects from both the groups under gone 8 minutes of warm up protocol includes 5 minutes of stretching (lower limb group muscles) and 3 minutes of jogging (Allen 2001). The Subjects instructed to wear comfortable clothing during the test. Pre-test was conducted in four sessions. The First session included an Introduction of the testing protocols to the subjects. The Second session included the Measurements of Quadriceps and Hamstrings Muscle Strength in the dominant leg. In the Third session, anaerobic power was determined by the Vertical Jump Test. There was a 24-hour pause between the testing sessions (Sporis2001). Pre-test measurements were measured a week before commencement of the 1st training session for both the Group A and Group B. Post test measurements were recorded after 3 days of the 12th session.

Measurement of vertical jump test

In this procedure the individual's standing height was determined by having the subject stand with the side of his dominant hand next to the wall, and heels together on the floor. With chalked finger-tips the subject reaches upward as high as possible and marks the wall. The individual then assumes a position next to the wall with both feet on the floor. From this position the subject gather himself in a semi-squat position and jumps, making a chalk mark on the wall at the peak of the jump. Subjects were not allowed to hop, go off of one foot, or walk into the jump. The height jumped is measured distance between the standing reach height and the jumping height. Measurements were recorded in centimeters. Each subject received 3 trails jumps in succession, with approximately 15 to 30 seconds recovery between jumps and the best of the 3 jumps was used to calculate the individual's score(McLaren 1999).

Maximum Isometric Voluntary Contraction (MIVC)

The Push Pull Dynamometer (Hydraulic Analog), the pressure range is 0-300 Newton (N). The meter is equipped with a maximum indicating pointer with a resetting knob and a curved applicator. For quadriceps muscle strength measurement, Subject Position - High Sitting, Dynamometer placement- just proximal to the ankle joint. For Hamstrings muscle strength measurement, Subject Position - Prone Lying, Dynamometer placement- just proximal to the posterior aspect of ankle joint.

Data Analysis

The collected data were tabulated and analyzed using both descriptive and inferential statistics. All the parameters were assessed using statistical package for social science (SPSS) version 24. Paired t-test was adopted to find the statistical difference within the groups and Independent t-test (Student t-Test) was adopted to find the statistical difference between the groups.

RESULT

On comparing the Mean values of Group A and Group B on Muscle Strength Measurement in terms of Maximum Isometric Voluntary Contraction (MIVC) Score using Push Pull Dynamometer, both the groups shows significant Increase in the post test Mean values but (Group B - Double Leg Exercises) Quadriceps 25.90 pounds and Hamstrings 25.50 pounds which has the higher Mean value in Quadriceps and Hamstrings Muscle Strength is effective than (Group A - Single Leg Exercises) Quadriceps 23.50 pounds and Hamstrings 23.96 pounds at $P \leq 0.05$ Hence Null Hypothesis is rejected. On comparing the Mean values of Group A and Group B on Vertical Jump Test for anaerobic power, both the groups shows significant increase in the post test Mean values but (Group A - Single Leg Exercises) 49.29 centimeters which has the higher Mean value is more effective than (Group B - Double Leg Exercises) 44.93 centimeters at $P \leq 0.001$. Hence Null Hypothesis is rejected. On comparing Pre test and Post test within Group A and Group B on Maximum Isometric Voluntary Contraction (MIVC) and Vertical Jump Test shows highly significant difference in Mean values at $P \leq 0.001$



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DISCUSSION

The results of the study highlighted that six weeks of single and double leg resistance training significantly improved vertical jump performance within both groups. Power represents the amount of work done by a muscle or a group of muscles per unit of time (Adams *et al.*, 1992) and since vertical jump has long been used as a measure of power; therefore, in the present study vertical jump was used to access power. The results of the study demonstrate that upon inter-group comparison significant improvements were observed for all the variables of vertical jump between the single leg in comparison to the double leg group. The possible explanation for the same is likely due to the differences attributed to the subject selection. Scientific literature cites that it is easy to find the difference in unilateral and bilateral strength and power in untrained (McCurdy *et al.*, 2005) as compared to the conditioned athlete. Upon intra-group comparison, significant percentage improvement was observed for all the variables of vertical jump in the single leg group in-comparison to the double leg group. Since, during a vertical jump, high amount of eccentric forces are generated when one dips down, and the ability to absorb and stabilize these forces is an important step in developing great plyometric power (Kelly Baggett, 2005); this accounts for the improvement in vertical jump variables in both the groups. However, a greater improvement for all variables of vertical jump was observed in the single leg group as compared to the double leg group. This may be attributed to the specific activities or exercises employed in the single leg resistance training protocol. Furthermore, it has been demonstrated that the force absorption training (the ability to absorb and stabilize high eccentric or negative forces) helps the athlete to improve the vertical jump height. Since single leg resistance training leads to better force absorption by the lower limb musculature in comparison to the double leg resistance training which leads to better force production, it can be deduced that single leg exercises account for significant improvements in the vertical jump as compared to double leg resistance exercises. The bilateral deficit serves as another possible explanation. It has been described by Sale (1992) as the difference between the force output when the left and right sides act simultaneously and the sum of the forces produced by the left and right limbs acting alone. Training may either increase or reduce the deficit, as suggested by the fact that rowers, who train bilaterally, are stronger in the bilateral leg press than when summing their single leg presses, whereas cyclists, who normally alternate leg actions, display greater summed strength than bilateral strength (Sale, 1992) Hence, it is better to train basketball players with single leg exercises. The vertical jump height achieved in the single leg group was higher as compared to the double leg group what may be neuromuscular in nature (Coyle, 2001). In a previous study, both groups were trained and tested with free weights but in the present study free weights were used for training but not for testing. In the present study, the effect of isometric strength on maximum voluntary contraction of the dominant quadriceps and hamstrings were measured in isometric mode rather than the isotonic or isokinetic modes, because studies have demonstrated that high correlations exists among the three testing (Kanapik *et al.*, 1983). On comparing the Mean values of Group A and Group B on Muscle Strength Measurement in terms of Maximum Isometric Voluntary Contraction (MIVC) Score using Push Pull Dynamometer, both the groups shows significant Increase in the post test Mean values but (Group B - Double Leg Exercises) Quadriceps 25.90 pounds and Hamstrings 25.50 pounds which has the higher Mean value in Quadriceps and Hamstrings Muscle Strength is effective than (Group A - Single Leg Exercises) Quadriceps 23.50 pounds and Hamstrings 23.96 pounds at $P \leq 0.05$. On comparing the Mean values of Group A and Group B on Vertical Jump Test for anaerobic power, both the groups shows significant increase in the post test Mean values but (Group A - Single Leg Exercises) 49.29 centimeters which has the higher Mean value is more effective than (Group B - Double Leg Exercises) 44.93 centimeters at $P \leq 0.001$.

CONCLUSION

This study concluded that short term single leg and double leg resistance training enhanced vertical jump performance and improved isometric lower limb muscle strength. The findings suggest that to design a sports specific double leg resistance training programs, coaches and players should include single leg plyometric drills to increase the vertical jump performance and single leg resistance training is an effective method to improve double



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leg jump performance and also double leg resistance training should be incorporate in the training protocol to improve significant lower limb muscle strength.

LIMITATION

- Only male players selected for the study.
- The study was performed in the age group of 18-25 years,
- The study was done with smaller samples,
- Short duration study,
- Lower body weights of the subjects were controlled.
- Positional demands of the players are limited.

RECOMMENDATION

Further studies need to be conducted to prove the efficacy of the procedure involved in this study with

- Female athletes.
- Different Age Groups
- Larger samples.
- Different fields of players and sports.
- Different positional demands of individual can be studies

DISCLOSURE STATEMENT

No potential conflict of interest was reported by the authors.

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Table. 1: Comparison of Maximum Isometric Voluntary Contraction (MIVC) of Quadriceps and Hamstring Muscles between Group – A and Group - B in Pre Test

#Muscle Strength (POUNDS)	#GROUP – A		#GROUP - B		t - Test	Df	Significance
	Mean	S.D	Mean	S.D			
Quadriceps	20.25	.486	20.47	.359	-1.40	28	.570*
Hamstrings	19.68	.106	19.58	.346	1.07	28	.594*

(* - $P > 0.05$)

The above table reveals the Mean, Standard Deviation (S.D), t-test, degree of freedom(df) and p-value of the Maximum Isometric Voluntary Contraction (MIVC) between (Group A) and (Group B) in pre test.

This table shows that there is no significant difference in pre test values of the Maximum Isometric Voluntary Contraction (MIVC) of Quadriceps and Hamstrings Muscles between Group A and Group B ($*P > 0.05$).

Table. 2: Comparison of Maximum Isometric Voluntary Contraction (MIVC) of Quadriceps and Hamstring Muscles Between Group – A and Group - B in Post Test

#Muscle Strength (Pounds)	#Group - A		#Group - B		t - Test	df	Significance
	MEAN	S.D	MEAN	S.D			
Quadriceps	23.50	.207	25.90	.460	-8.46	28	.004**
Hamstrings	23.96	.423	25.50	.365	-10.70	28	.003**

(** - $P \leq 0.05$)

The above table reveals the Mean, Standard Deviation (S.D), t-test, degree of freedom(df) and p-value of the Maximum Isometric Voluntary Contraction (MIVC) between (Group A) and (Group B) in post test.

This table shows that there is a significant difference in post test values of the Maximum Isometric Voluntary Contraction (MIVC) of Quadriceps and Hamstrings Muscles between Group A and Group B ($***P \leq 0.05$).

Table. 3: Comparison of Vertical Jump Test Between Group – A and Group - B in Pre and Post

#VJT	#Group - A		#Group - B		t - TEST	df	Significance
	MEAN	S.D	MEAN	S.D			
Pre Test	41.80	3.74	42.13	3.02	.268	28	.790*
Post Test	49.29	4.25	44.93	3.14	3.07	28	.000***

(* - $P > 0.05$), (** - $P \leq 0.001$)

The above table reveals the Mean, Standard Deviation (S.D), t-test, degree of freedom(df) and p-value between (Group A) and (Group B) in pre test and post test weeks.

This table shows that there is no significant difference in pre test values between Group A and Group B ($*P > 0.05$).

This table shows that statistically highly significant difference in post test values between Group A and Group B ($***P \leq 0.001$).

Table. 4: Comparison of Vertical Jump Test Within Group – A and Group – B

#VJT	Pre Test		Post Test		t - Test	Significance
	Mean	S.D	Mean	S.D		
Group- A	41.80	3.74	49.26	4.25	24.30	.000***
Group- B	42.13	3.02	44.93	3.14	16.03	.000***

(*** - $P \leq 0.001$)

The above table reveals the Mean, Standard Deviation (S.D), t-value and p-value between pre-test and post-test within Group – A and Group – B

There is a statistically highly significant difference between the pre test and post test values within Group A and Group B ($***P \leq 0.001$).





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Table. 5: Comparison of Dependent Variables within Group – A Between Pre and Post Test Values

#Group - A	Pre Test		Post Test		t - TEST	Significance
	Mean	S.D	Mean	S.D		
Quadriceps	20.25	.486	23.50	.207	-25.37	.000***
Hamstrings	19.68	.106	23.96	.423	-34.24	.000***

(***- $P \leq 0.001$)

The above table reveals the Mean, Standard Deviation (S.D), t-value and p-value of the Dependent variables between pre-test and post-test within Group – A.

In the above table, Dependent variables shows that there is a statistically highly significant difference between the pre test and post test values within Group A

(***- $P \leq 0.001$).**TABLE. 6: Comparison of Dependent Variables within Group – B between Pre and Post Test Values**

#Group - B	Pre Test		Post Test		t - Test	Significance
	Mean	S.D	Mean	S.D		
Quadriceps	20.40	.359	25.90	.460	-36.98	.000***
Hamstrings	19.58	.346	25.50	.365	-46.22	.000***

(***- $P \leq 0.001$)

The above table reveals the Mean, Standard Deviation (S.D), t-value and p-value of the Dependent variables between pre-test and post-test within Group – B

In the above table, Dependent variables shows that there is a statistically highly significant difference between the pre test and post test values within Group B

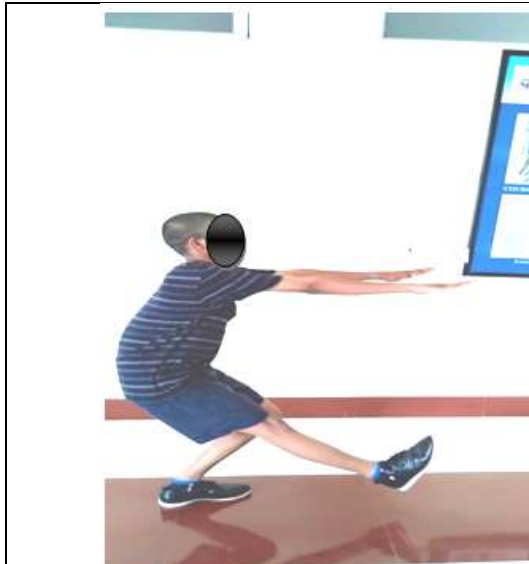
(***- $P \leq 0.001$).**Fig 1: Single Leg Squat****Fig 2: Single Leg Line Hop Forward and Backward**



Fig 3: Double Leg Line Hop Forward and Backward



Fig 4: Double Leg Line Continuous Hop



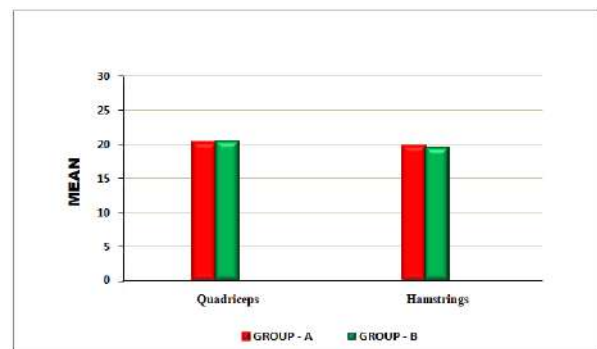
Fig. 5 (a): Stand and Reach Height



Fig. 5 (b): Vertical Jump Height



Fig. 6: MIVC Measurement of Quadriceps and Hamstrings Using Push Pull Dynamometer

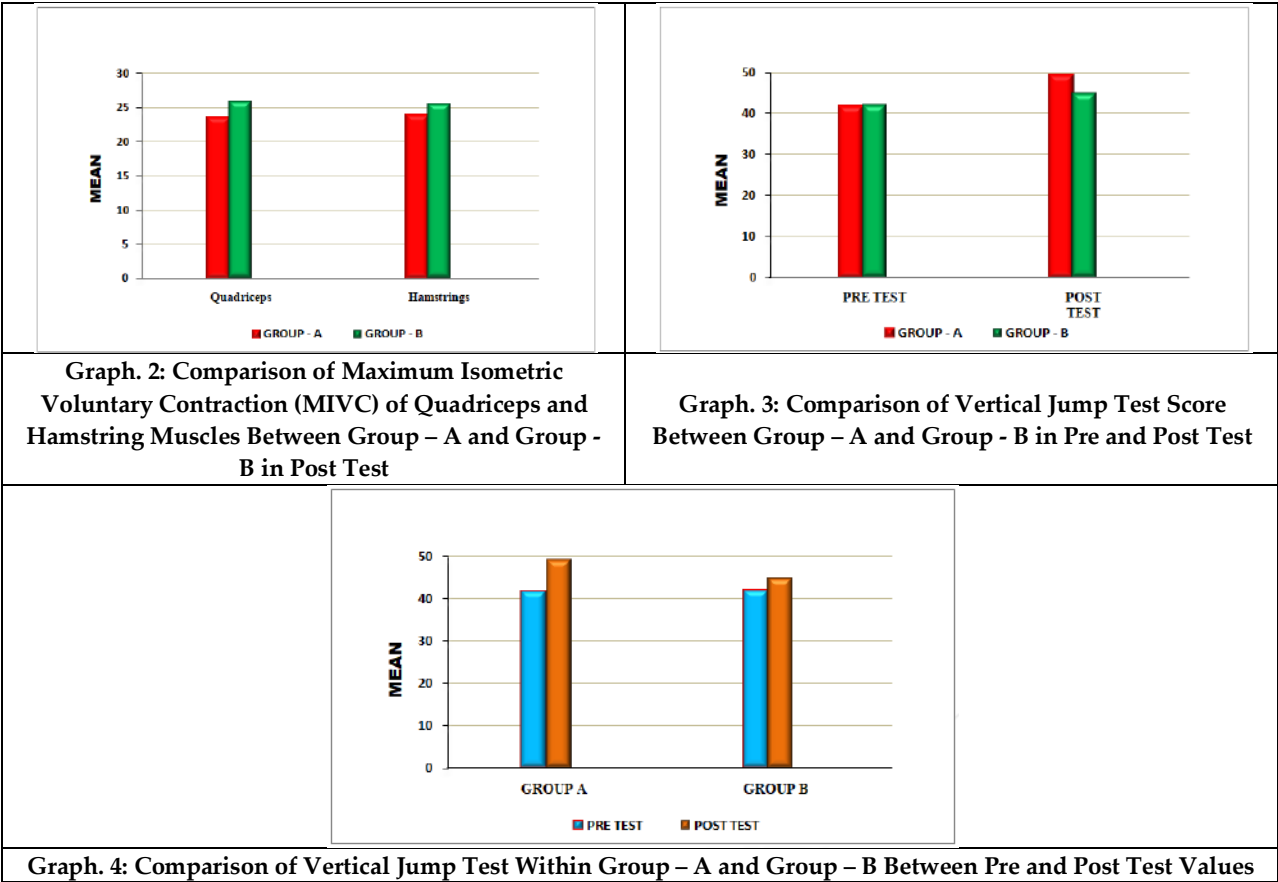


Graph 1: Comparison Of Maximum Isometric Voluntary Contraction (MIVC) of Quadriceps and Hamstring Muscles Between Group – A and Group - B in Pre Test





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RESEARCH ARTICLE

Exploring 2-Odd, Minimal and Maximal Labeling Strategies for Bull, Star and Some Related Graphs

K. Priya^{1*} and J. Jayapriya²

¹Research Scholar, Sathyabama Institute of Science and Technology (Deemed to be University), Chennai, Tamil Nadu, India.

²Associate Professor, Sathyabama Institute of Science and Technology (Deemed to be University), Chennai, Tamil Nadu, India.

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*Address for Correspondence

K. Priya

Research Scholar,

Sathyabama Institute of Science and Technology (Deemed to be University),

Chennai, Tamil Nadu, India.

E.Mail: priyakiyalath@gmail.com



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ABSTRACT

Labeling a graph entails allocating integers to its edges, vertices, or both, depending on its specific prerequisites. A function which is injective, $f: V(G) \rightarrow \mathbb{Z}$ with a two odd labeling of G is defined so that the number $|f(v) - f(u)|$, indicating the affirmative difference of any adjacent nodes u and v , is either $2n \pm 1$; $n \in \mathbb{N}$ or precisely 2. A graph G with vertex set $V(G)$ and edge set $E(G)$ then $|V(G)| \leq |E(G)|$ is called a minimal label graph $\text{MinL}(G)$. If there exist an edge labelling $f: E(G) \rightarrow \{1, 2, \dots, r\}$ such that the induced vertex labelling $f^*(v) = \min\{f(e), e \text{ is incident on } v\}$ and for any two distinct vertices $u, v \in V(G)$, $f^*(u) \neq f^*(v)$. The intention of this article is to explore the notions of minimal and maximal labelling, two odd labeling on graphs produced by applying different graph operations.

Keywords: 2 odd labeling, Star graph, Middle graph, Total graph, Bull graph, Minimal and Maximal labeling.

INTRODUCTION

Labeling strategies in graph theory are essential tools for studying the properties and structure of graphs. These strategies involve assigning labels, usually integers, to the vertices, edges, or both, of a graph according to specific rules. The resulting labeled graph can reveal important insights about graph characteristics, symmetries, and underlying patterns. In this paper, we explore two - odd, minimal, and maximal labeling strategies for a selection of specific graph structures, namely the bull graph, the star graph, and some related graphs. These graphs serve as foundational examples in graph theory and provide a rich context for investigating various labeling techniques.





METHODOLOGY

Research Design and Graph Selection

The research design typically involves defining the types of graphs under study and specifying the particular labeling scheme. This research aims to identify and analyze the two odd labelling, minimal and maximal labeling of some specified graphs. Graph types were chosen due to their distinct structural properties, which facilitate the examination of minimal and maximal labeling schemes under various conditions.

Definitions

Definition 1: The graph with vertex set $V(G) \cup E(G)$ is called the middle graph [8] $M(G)$ of a graph G . Two vertices in this graph are adjacent if and only if they are either adjacent edges of G or one vertex of G and the other is an edge incident on it.

Definition 2: The total graph [8] $T(G)$ of a graph G is the graph whose vertex set is $V(G) \cup E(G)$ and two vertices are adjacent whenever they are either adjacent or incident in G .

Definition 3: The splitting graph [8] $S'(G)$ of a graph G is obtained by adding a new vertex v' corresponding to each vertex v of G such that $N(v) = N(v')$ where $N(v)$ and $N(v')$ are the neighborhood sets of v and v' respectively.

Definition 4 : A function which is injective, $f: V(G) \rightarrow \mathbb{Z}$ with a two odd labeling of G is defined so that the number $|f(v) - f(u)|$, indicating the affirmative difference of any adjacent nodes u and v , is either $2n \pm 1$; $n \in \mathbb{N}$ or precisely 2

Definition 5: A graph G with vertex set $V(G)$ and edge set $E(G)$ then $|V(G)| \leq |E(G)|$ is called a minimal label graph $\text{MinL}(G)$ [18] If there exist an edge labelling $f: E(G) \rightarrow \{1, 2, \dots, r\}$ such that the induced vertex labelling $f^*(v) = \text{Min}\{f(e), e \text{ is incident on } v\}$ and for any two distinct vertices $u, v \in V(G)$, $f^*(u) \neq f^*(v)$.

Definition 6: A graph G with vertex set $V(G)$ and edge set $E(G)$ then $|V(G)| \leq |E(G)|$ is called a maximal label graph $\text{MaxL}(G)$ [18] If there exist an edge labelling $f: E(G) \rightarrow \{1, 2, \dots, r\}$ such that the induced vertex labelling $f^*(v) = \text{Max}\{f(e), e \text{ is incident on } v\}$ and for any two distinct vertices $u, v \in V(G)$, $f^*(u) \neq f^*(v)$.

Definition 7: An n -vertices star graph is a complete bipartite [5] graph of the manner $K_1, n-1$. If every vertex in a star graph is part of one set and every other vertex is part of the other set, then the graph is considered full bipartite. Star graph S_n (Figure 1).

Definition 8: 'Forming a triangle with two discontinuous pendant edges, the Bull graph [15] is a planar, undirected graph with five vertices and five edges'. Bull graph (Figure 2).

MAIN RESULTS

Theorem 1

Star graph S_n admits 2 odd labeling.

Proof

Star graph S_n has a central node connected to n leaves. Let the central node be labeled as v_0 and the leaves be labeled as $v_1, v_2, \dots, v_m$. Now define a function which is injective $f: L(S_m) \rightarrow \mathbb{Z}$ as given

Say $f(v_0) = 0$

$f(v_m) = 2m - 1, 1 \leq m \leq n$

Then, $|f(v_0) - f(v_m)|$ are odd numbers.





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Hence f induces required 2-odd labeling of S_n .
Star graph S_3 (Figure 3).

Theorem 2

The S_n middle graph, or $M(S_n)$ admits two odd labeling.

Proof

Let $M(S_n)$ be the middle graph of S_n .

Let vertices of $M(S_n)$ are $N(M(S_n)) = \{v_1, v_2, \dots, v_n, e_1, e_2, \dots, e_n\}$. Now define a function which is injective, $f: N(M(S_n)) \rightarrow \mathbb{Z}$ such that $f(v_m) = 2m - 1$, $0 \leq m \leq n$, $f(e_m) = 2m$, $1 \leq m \leq n$.

Then $|f(v_i) - f(e_i)|$ and $|f(e_i) - f(e_j)|$, $i \neq j$ is odd number or exactly 2.

Hence $M(S_n)$ allows 2 odd labeling.

Middle graph of S_3 (Figure 4).

Theorem 3

Total graph of S_n , ie $T(S_n)$ allows 2-odd labeling.

Proof

Say, $T(S_n)$ defines the middle graph of S_n .

So, the vertices of $T(S_n)$ be $N(T(S_n)) = \{v_1, v_2, \dots, v_n, l_1, l_2, \dots, l_n\}$

Now, specify a function which is injective $f: N(T(S_n)) \rightarrow \mathbb{Z}$ such that

$$f(N_0) = 0$$

$$f(N_m) = 2m - 1, 1 \leq m \leq n$$

$$f(l_i) = 2m + 1, 1 \leq m \leq n$$

We can observe that f induces required 2-odd labeling of $T(S_n)$.

Total graph of S_3 (Figure 5).

Theorem 4

The splitting graph $S'(S_n)$ allows 2-odd labeling.

Proof

The neighborhood set of each peripheral node N_i in S_n is N_0 and the neighborhood set of each corresponding new vertex N'_i in $S'(S_n)$ is also N_0 since we are adding new vertex in which case that $N(n) = N(n')$.

Now define an 'injective function $f: N(S'(S_n)) \rightarrow \mathbb{Z}$ as given

$$f(N_0) = 0$$

$$f(N'_0) = 1$$

$$f(N_m) = 2m, 1 \leq m \leq n$$

$$f(N'_m) = 2m + 1, 1 \leq m \leq n$$

We can observe that f induces required 2-odd labeling of $S'(S_n)$.

Splitting graph $S'(S_3)$ (Figure 6).

Theorem 5

A star graph admits a 2-odd labeling if and only if there exists an injective function $f: V(G) \rightarrow \mathbb{Z}$ such that the absolute difference between the labels of any two adjacent vertices is either an odd number or exactly 2.

Proof

Assume for the moment that a star graph G allows for 2-odd labeling. Afterwards, applying the definition, it becomes evident that a function which is injective $f: V(G) \rightarrow \mathbb{Z}$ exists in a possibility that ensures that the absolute distinction among the labels of neighbouring nodes is precisely two or an odd number.





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Case 1: For $n = 1$

We have $N(G) = \{v_0, v_1\}$. We can find a function which is injective $f: N(G) \rightarrow Z$ such that $f(v_0) = 0, f(v_1) = 3$ then, $|f(v_0) - f(v_1)| = 3$. This contradicts our assumption.

Hence, S_2 is a 2- odd labeling.

Case 2: For $n = 2$

We have $N(G) = \{v_0, v_1, v_2\}$. We can find a function which is injective $f: N(G) \rightarrow Z$ such that $f(v_0) = 0, f(v_1) = 3$ and $f(v_2) = 5$ then, $|f(v_0) - f(v_1)| = 3$ and $|f(v_0) - f(v_2)| = 5$. This contradicts our assumption.

Hence, S_3 is a 2- odd labeling.

Let us continue this process up to n .

Case n : We have $N(G) = \{v_0, v_1, v_2, \dots, v_n\}$

Then there is a function which is injective $f: N(G) \rightarrow Z$ such that $f(v_0) = 0, f(v_m) = 2m+1, 1 \leq m \leq n$

We can observe that f induces required 2-odd labeling which contradicts our assumption.

Hence S_n is 2- odd labeling.

On the other hand, imagine that there isn't a function which is injective $f: N(G) \rightarrow Z$ that makes the absolute variation amongst the labels of neighbouring nodes equal to precisely two or an odd integer.

But in all the above considered cases, the graph S_n allows 2- odd labeling.

Hence the proof.

Theorem 6

Bull graph G admits 2 odd labeling.

Proof:

Say G be a bull graph with $N(G) = N_1 \cup N_2$ Where $N_1 = \{u_1, u_2\}$ and $N_2 = \{v_i, 1 \leq i \leq n\}$

Now specify a function which is injective $f: N(G) \rightarrow Z$ as given

Let $f(u_1) = 1$ and $f(u_2) = -1$

Let $f(v_m) = 2m, 1 \leq m \leq n$

Now we can observe that $|f(u_1) - f(u_2)| = 2, |f(u_1) - f(v_i)|$ and $|f(u_2) - f(v_i)|$ are also odd numbers

Hence f is the required 2-odd labeling of Bull graph G .

Figure 6: Bull graph

Theorem 7

A Bull graph's middle graph does not allow for two odd labelings.

Proof

'The number of nodes of the middle graph of a Bull graph is 10 and the number of links is 17.

Say the nodes of middle graph of a Bull graph of $G = V_1 \cup V_2$ Where $V_1 = \{v_1, v_2, v_5\}$ and $V_2 = \{e_1, e_2, \dots, e_5\}$.

Now define an injective function $f: V(G) \rightarrow Z$ as given

Let $f(e_m) = 2m+1, 1 \leq m \leq n$

$f(v_m) = 2m, 1 \leq m \leq n$

$|f(e_m) - f(v_m)|$ satisfies conditions of 2- odd labeling.

But the middle graph does not fully satisfy the 2- odd labeling condition for the differences between vertices corresponding to edge 1 and other four vertices corresponding to edges.

Hence the proof.

Bull graph and its Middle graph (Figure 7).

Theorem 8

A bull graph's total graph does not allow for two odd labeling.





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Proof

Say the nodes of Total graph of a Bull graph of $G = V_1 \cup V_2$ Where $V_1 = \{v_1, v_2, v_3\}$ and $V_2 = \{e_1, e_2, \dots, e_5\}$. A Bull graph contains 10 vertices and 22 edges in its whole graph.

Now define an injective function $f: V(G) \rightarrow Z$ as given

Let $f(e_m) = 2m + 1, 1 \leq m \leq n$

$f(v_m) = 2m, 1 \leq m \leq n$

$|f(e_m) - f(v_m)|$ are odd numbers, $|f(v_i) - f(v_o)| \neq 0, 1 \leq i \leq n, 1 \leq o \leq n$ is exactly 2

In $|f(e_i) - f(e_o)| \neq 0, 1 \leq i \leq n, 1 \leq o \leq n$ some adjacent differences violate the condition of 2- odd labeling.

Hence the proof

Figure 8: Bull graph and its Total graph

Theorem 9

Middle graph of S_n , ie $M(S_n)$ admits minimal and maximal labeling.

Proof

Let vertices of middle graph of S_n are $V(M(S_n)) = \{V_{11}, V_{12}, \dots, V_{1n}, e_1, e_2, \dots, e_n\}$

Now define the function $f: E(M(S_n)) \rightarrow Z$, then the induced vertex function is specified as $f^*: V(M(S_n)) \rightarrow Z$ such that,

The nodes are labelled as follows.

$f^*(V_i) = \{f(e_i) \text{ incident on } V_i, 1 \leq i \leq n\}$, no two vertices must share same minimum edge

Hence middle graph of S_n , ie $M(S_n)$ admits minimal labeling. Similarly we can prove $M(S_n)$ admits maximal labeling.

Figure 9 : Middle graph of Star S_3

Theorem 10

Total graph of S_n , i.e. $T(S_n)$ admits minimal and maximal labeling.

Proof

Let the nodes of $T(S_n)$ be $V(T(S_n)) = \{v_0, v_1, \dots, v_n, e_0, e_1, \dots, e_n\}$. Now, we define a function, $f: E(T(S_n)) \rightarrow Z$, then the induced vertex function is defined as, $f^*: V(T(S_n)) \rightarrow Z$ as follows:

$f^*(v_i) = \min\{f(e_i) | e_i \text{ incident on } v_i\}$

By the construction, $f^*(v_i)$ are distinct for all the nodes and satisfying minimal labeling. Similarly we can prove $T(S_n)$ admits maximal labeling.

Hence the proof.

Theorem 11

Bull graph admits minimal and maximal labeling.

Proof

Bull graph is an undirected planar graph with five vertices $V = \{v_1, v_2, v_3, v_4, v_5\}$ and five edges $E = \{e_1, e_2, e_3, e_4, e_5\}$.

Define a function $f: E \rightarrow Z$, then the induced vertex labeling $f^*: V \rightarrow Z$ defined by

$f^*(v_i) = \min\{f(e_i) | e_i \text{ incident on } v_i\}$

Guarantees that the minimum edge is not shared by any two nodes. i.e. For each leaf node v_i , $f^*(v_i) = \min\{f(e_i) | e_i \text{ incident on } v_i\} = i$. The rest of the vertices form a cycle. We know that cycle admits minimal labeling. Similarly we can prove Bull graph admits maximal labeling.

Hence the proof.

Figure 10: Minimal graph of Bull

Theorem 12

Splitting graph of S_n , i.e. $S'(S_n)$ admits minimal and maximal labeling.



**Proof**

Let $S'(S_n)$ has $2n$ vertices. i.e. $V(S'(S_n)) = \{v_1, v_2, \dots, v_n\} \cup \{v'_1, v'_2, \dots, v'_n\}$ and $E(S'(S_n))$ include all edges E' connecting to v'_i to the neighbours of v_i . Now, define a function $f: E(S'(S_n)) \rightarrow Z$, then the induced vertex function is defined as follows:

For vertex v_i , $f^*(v_i) = \min\{f(e_k) | e_k \text{ is incident on } v_i\}$

For vertex v'_i , $f^*(v'_i) = \min\{f(e_k) | e_k \text{ is incident on } v'_i\}$

Ensures that no two vertices share the same minimum edge. Thus, the splitting graph $S'(S_n)$ admits minimal labeling. Similarly we can prove $S'(S_n)$ admits maximal labeling.

Theorem 13

The middle graph of bull graph admits minimal and maximal labeling.

Proof

Let the vertices of middle graph of a bull graph of G , $N(M(G)) = N(G) \cup L(G)$. i.e. $N(M(G)) = \{n_{11}, n_{12}, n_{13}, n_{14}, n_{15}, l_{11}, l_{12}, l_{13}, l_{14}, l_{15}\}$ and $L(M(G)) = \{l'_1, l'_2, \dots, l'_{17}\}$.

Now, define a function, $f: E(M(G)) \rightarrow Z$. Then, the induced vertex function is defined as follows:

$f^*(v_i) = \min\{f(e'_k) | e'_k \text{ is incident on } v_i\}$

$f^*(e_i) = \min\{f(e'_k) | e'_k \text{ is incident on } v_i\}$

Construction shows that middle graph of bull graph admits minimal labeling. . Similarly we can prove middle graph of bull graph admits maximal labeling.

Theorem 14

The total graph of bull graph admits minimal and maximal labeling.

Proof

Assume that the vertices of a bull graph of G 's total graph, $N(T(G)) = N(G) \cup L(G)$. i.e. $N(T(G)) = \{n_{11}, n_{12}, n_{13}, n_{14}, n_{15}, l_{11}, l_{12}, l_{13}, l_{14}, l_{15}\}$ and $L(T(G)) = \{l'_1, l'_2, \dots, l'_{22}\}$.

Now, define a function, $f: E(T(G)) \rightarrow Z$. Then, the induced vertex function is defined as follows:

$f^*(v_i) = \min\{f(e'_k) | e'_k \text{ is incident on } v_i\}$

$f^*(e_i) = \min\{f(e'_k) | e'_k \text{ is incident on } v_i\}$

Thus, each vertex in $T(G)$ has a distinct minimum label. Hence, the total graph of bull graph admits minimal labeling. Similarly we can prove total graph of bull graph admits maximal labeling.

We suggest that you use a text box to insert a graphic (which is ideally a 300 dpi TIFF or EPS file, with all fonts embedded) because, in an Word document, this method is somewhat more stable than directly inserting a picture.

To have non-visible rules on your frame, use the MSWord "Format" pull-down menu, select Text Box > Colors and Lines to choose No Fill and No Line.

CONCLUSION

In this paper, we have thoroughly investigated 2- odd, minimal and maximal labeling strategies for bull, star, and related graphs. Investigating such labelings for the graph or similar graphs that allow such labelings is both highly intriguing and demanding, as not all of the graphs are 2-odd labeling or minimal and maximal labeling graphs. Through our investigation, we have contributed some new discoveries here. This is a field of investigation into whether graph families may or may not permit 2-odd, minimal and maximal labelling.

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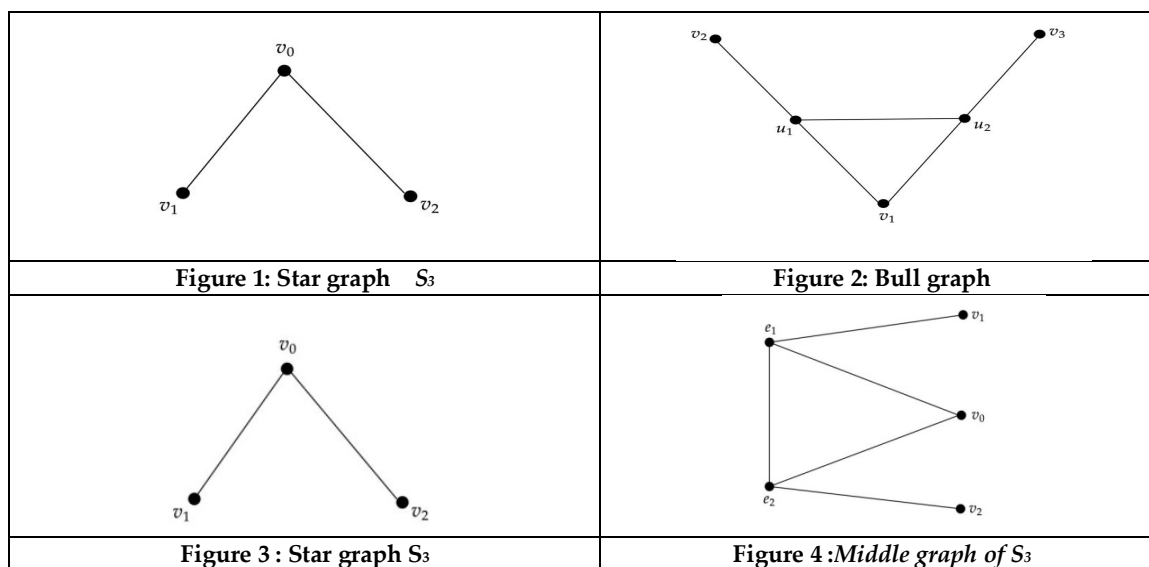
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Figure 5 : Total graph of S_3	Figure 6: Splitting graph $S'(S_3)$
Figure 7: Bull graph	Figure 8: Bull graph and its Middle graph
Figure 9: Bull graph and its Total graph	Figure 10: Middle graph of Star S_3
Figure 11: Minimal graph of Bulll	





RESEARCH ARTICLE

An Ai-Driven Integrated Educational Framework for Individuals With Autism Spectrum Disorder: Design, Implementation, And Ethical Considerations

G. Divya^{1*} and V. Maniraj²

¹Ph.D Research Scholar (FT), PG and Research Department of Computer Science, AVVM Sri Pushpam College (Autonomous), Poondi, Thanjavur District, (Affiliated to Bharathidasan University, Tiruchirappalli), Tamil Nadu, India.

²Associate Professor and Research Supervisor, PG and Research Department of Computer Science, AVVM Sri Pushpam College (Autonomous), Poondi, Thanjavur District, (Affiliated to Bharathidasan University, Tiruchirappalli), Tamil Nadu, India.

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*Address for Correspondence

G. Divya

Ph.D Research Scholar (FT),
PG and Research Department of Computer Science,
AVVM Sri Pushpam College (Autonomous), Poondi, Thanjavur District,
(Affiliated to Bharathidasan University, Tiruchirappalli),
Tamil Nadu, India.



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ABSTRACT

Students with Autism Spectrum Disorder (ASD) face significant educational challenges due to distinct cognitive and behavioral variations, often unmet by conventional teaching. This analysis introduces an AI-driven integrated educational framework aimed at enhancing learning processes for individuals with ASD. The framework involves designing predictive machine learning models and deploying AI-based educational solutions tailored to their specific needs. Key objectives include creating adaptive systems that deliver customized content and support. Crucially, the work also explores the ethical implications of AI in education, focusing on data security, mitigating algorithmic biases, and ensuring transparency. This comprehensive approach seeks to bridge existing educational gaps, improving the overall experience and quality of life for individuals with ASD.

Keywords - Autism Spectrum Disorder (ASD), AI-driven education, integrated educational framework, Data security in education.





INTRODUCTION

Autism Spectrum Disorder (ASD) encompasses a range of neurodevelopmental conditions characterized by differences in communication, social interaction, and cognitive processing. Standardized curricula, rigid pacing, and limited personalization can hinder engagement and limit educational outcomes. While educational opportunities for individuals with ASD have expanded in recent decades, traditional teaching models often fail to address their diverse learning needs. As a result, many learners with ASD remain underserved by conventional systems [1]. Alongside the technical design and implementation, the work examines the ethical dimensions of AI in education, ensuring that innovation aligns with the principles of fairness, privacy, and inclusivity. Machine learning algorithms, adaptive learning platforms, and intelligent tutoring systems can analyze individual learning patterns, anticipate challenges, and deliver tailored interventions in real time. The framework combines predictive machine learning models with adaptive content delivery, aiming to create responsive, personalized learning experiences that support both academic progress and socio-emotional development [2]. However, deploying AI in special education is not without complexity — issues of data security, algorithmic bias, and transparency must be addressed to ensure equitable and ethical implementation. This study presents an AI-driven integrated educational framework specifically designed for individuals with ASD. Recent advancements in artificial intelligence (AI) offer transformative potential for inclusive education [3].

OBJECTIVES

- To design an AI-driven integrated educational framework specifically tailored to the learning needs of individuals with Autism Spectrum Disorder (ASD).
- To develop predictive machine learning models capable of delivering adaptive, personalized educational content.
- To implement the framework within real-world educational settings and evaluate its effectiveness in enhancing learning outcomes and engagement for students with ASD.
- To address the ethical implications of using AI in special education, including data security, algorithmic bias mitigation, and transparency in system decision-making.
- To provide educators and caregivers with actionable insights and tools that support inclusive, responsive, and evidence-based teaching practices.

RESEARCH GAP

Despite significant advancements in both special education practices and artificial intelligence applications, there remains a notable gap in the integration of AI technologies into inclusive learning environments for individuals with Autism Spectrum Disorder (ASD)[6].

- **Generalized adaptive learning platforms** — which often fail to account for the unique cognitive, behavioral, and sensory profiles associated with ASD, resulting in limited personalization and engagement[9].
- **Therapy-focused AI tools** — which primarily target behavioral or communicative interventions, without embedding these supports into a broader, academically oriented learning framework.
- **Single-domain AI applications** — such as emotion recognition or skill-specific tutoring, rather than fully integrated systems that combine content adaptation, progress monitoring, and educator support[10].

Research addressing the **ethical dimensions** of AI in special education — including data privacy, algorithmic bias, and decision-making transparency — is still scarce.

- Personalizes learning to individual ASD profiles.
- Embeds ethical AI practices throughout design and implementation.
- Provides empirical evidence of both academic and socio-emotional benefits in authentic educational settings.





METHODOLOGY

The approach enables comprehensive assessment of both the technical effectiveness and the educational impact of the AI-driven framework for individuals with Autism Spectrum Disorder (ASD). This study adopts a mixed-methods research design, integrating quantitative analysis of system performance with qualitative evaluation of user experiences[13].

FRAMEWORK DEVELOPMENT

System Architecture

- Adaptive Learning Engine: Algorithms for real-time personalization of content based on learner profile, progress metrics, and engagement patterns[15].
- AI Core: Predictive machine learning models trained on anonymized, ethically sourced learning datasets from ASD-focused educational programs.
- Interface Design: Accessible user interface incorporating visual supports, simplified navigation, and customizable sensory settings [18].

Data Collection

Quantitative Metrics

- Learning Performance: Pre-test and post-test scores in core academic areas (mathematics, reading comprehension, and problem-solving)[17].
- System Responsiveness: Algorithm accuracy in predicting optimal learning paths, measured through precision and recall rates[19].
- Engagement Levels: Logged interaction time, completion rates, and task persistence.

Qualitative Feedback

- Semi-structured interviews with educators, students (where possible), and caregivers to capture perceptions of usability, effectiveness, and inclusivity.
- Observational field notes documenting classroom integration, student responses, and behavioral changes.

Data Analysis

- Quantitative Analysis: Paired-sample t-tests and ANOVA to evaluate pre-post performance differences; ROC curve analysis for model predictive accuracy.
- Qualitative Analysis: Thematic coding of interview transcripts using NVivo to identify patterns in user experiences and ethical considerations.
- Integration of Results: Triangulation to cross-validate findings from both datasets, ensuring comprehensive interpretation.

The following Table 1 outlines the structured methodology employed in this study to develop and evaluate the AI-based learning system for students with Autism Spectrum Disorder. Data on learning and engagement is collected, and results are analyzed while following strict ethical rules.

Algorithm: AI-Driven Educational Framework for ASD Learner

The framework integrates academic goals with individualized supports, ensuring that teaching methods match the cognitive, behavioral, and sensory needs of each student. It uses artificial intelligence techniques, such as predictive machine learning and adaptive algorithms, to analyze each learner's profile, track progress, and adjust instructional content in real time. By combining continuous monitoring, educator feedback, and strong ethical safeguards, it aims to improve both educational outcomes and overall quality of life for individuals with ASD. An AI-driven educational framework for learners with Autism Spectrum Disorder (ASD) is a technology-supported system designed to



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provide personalized, adaptive, and inclusive learning experiences[20]. The system's workflow and core functionalities are visually represented in Figure 1, highlighting how AI adapts to individual learner needs. The process incorporates an educator feedback loop to ensure personalized and effective learning outcomes[28].

RESULT AND DISCUSSION

Results

The AI-driven integrated educational framework was deployed in three special education centers for a 12-week pilot study involving 30 students with clinically diagnosed Autism Spectrum Disorder (ASD). Data was analyzed using both quantitative and qualitative methods[21].

Learning Performance

- **Pre-test mean score:** 58.4% (SD = 12.1)
- **Post-test mean score:** 76.8% (SD = 10.4)
- Paired-sample t-test indicated a statistically significant improvement in academic performance ($p < 0.01$).

Engagement Metrics

- Average daily usage increased from 18 minutes in week 1 to 35 minutes in week 12.
- Task completion rate improved from 62% to 88% over the study period.

System Accuracy

- Predictive model accuracy in recommending optimal learning paths: 87%.
- Precision: 0.89; Recall: 0.85[22].

Qualitative Feedback

- Educators reported increased student motivation and reduced off-task behavior.
- Caregivers observed improved willingness to engage in learning activities at home.
- Students expressed preference for visual and gamified elements of the platform.

DISCUSSION

The observed performance gains align with findings from previous studies that emphasize the value of personalized, multimodal instruction in special needs education. The engagement data demonstrates the importance of sustained interaction in reinforcing learning habits. Longitudinal studies with more diverse participants are recommended to validate and expand upon these findings. The results suggest that integrating AI-driven adaptive systems into special education can significantly improve both learning outcomes and engagement for students with ASD[23]. However, future iterations should explore more advanced fairness auditing to address potential algorithmic disparities across subgroups of ASD learners. While the pilot yielded promising results, limitations include the small sample size, short duration, and reliance on specific educational centers, which may affect generalizability [25]. The gradual increase in daily usage indicates that the system's adaptive design successfully maintained student interest over time, a key challenge in ASD education. The predictive model's accuracy (87%) reflects its capacity to identify suitable learning paths based on individual profiles and progress, although further training with larger datasets may improve its generalizability. Ethical safeguards proved critical; the anonymization of learner data and bias monitoring fostered trust among educators and caregivers [26].

Table 2 presents the key quantitative findings from the 12-week pilot study of the AI-driven educational framework for ASD learners. The data demonstrates significant academic gains, increased usage, higher task completion rates, and strong predictive model performance. It compares pre-test and post-test performance, engagement metrics, and





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system accuracy measures to show improvements over time[27]. The diagram shows significant gains in academic performance, average daily usage, and task completion rate after implementation, with academic performance improving by 31.5% and task completion rate rising by 41.9%, indicating consistent and reliable performance. The effectiveness of the proposed model relies on diverse data inputs as illustrated in Figure 2.

CONCLUSION

The findings underscore the value of personalized, technology-supported education for ASD learners and highlight the importance of integrating ethical considerations into AI-based systems. This study developed and evaluated an AI-driven integrated educational framework designed to address the unique learning needs of individuals with Autism Spectrum Disorder (ASD). This work contributes to bridging the gap between special education needs and technological innovation, offering a foundation for future AI applications in inclusive learning environments. While the outcomes are promising, further work involving larger, more diverse populations and longer study periods is needed to confirm scalability and generalizability. Results from the pilot study showed significant improvements in test scores, task completion rates, and daily usage, alongside positive feedback from educators, caregivers, and students. By combining predictive machine learning, adaptive content delivery, and ethical safeguards, the framework demonstrated the potential to enhance academic performance, increase learner engagement, and support more inclusive teaching practices.

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Table 1: Research Methodology Framework

Phase	Description	Key Activities	Expected Output
Research Design	Establishes the overall approach and mixed-methods framework	- Select mixed-methods approach- Define scope and objectives	Research framework document
Framework Development	Designs the AI-driven integrated educational system	- Needs assessment- System architecture design- Content creation	Prototype of AI-based learning framework
Implementation Phase	Deploys the system in real-world settings	- Pilot testing in selected centers- Participant selection- Educator training	Operational AI system in educational environment
Data Collection	Gathers evidence to evaluate framework effectiveness	- Pre- and post-tests- Engagement tracking- Interviews and observations	Dataset for quantitative and qualitative analysis





Divya and Maniraj

Data Analysis	Processes and interprets collected data	- Statistical analysis of performance metrics- Thematic coding of feedback	Analytical findings
Ethical Safeguards	Ensures compliance with ethical and legal requirements	- Informed consent- Data anonymization- Bias monitoring	Ethical compliance report

Table 2: Summary of Quantitative Results from the AI-Driven Educational Framework Pilot Study

Metric	Pre-Test / Week 1	Post-Test / Week 12	Change (%)	Statistical Significance
Academic Performance (Mean Score)	58.4% (SD = 12.1)	76.8% (SD = 10.4)	+31.5%	$p < 0.01$
Average Daily Usage (minutes)	18	35	+94.4%	-
Task Completion Rate	62%	88%	+41.9%	-
Model Accuracy (Learning Path)	-	87%	-	-
Model Precision	-	0.89	-	-
Model Recall	-	0.85	-	-

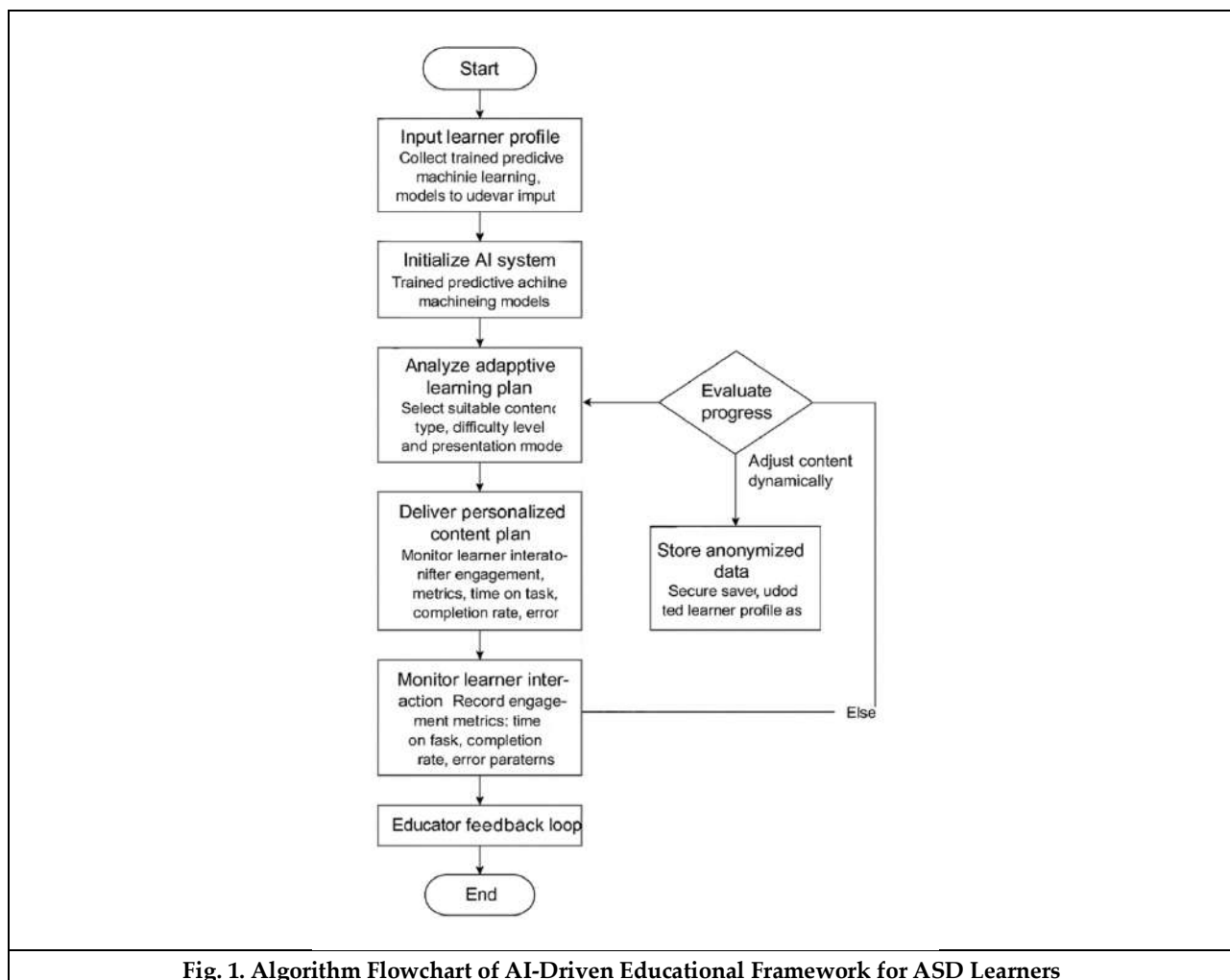


Fig. 1. Algorithm Flowchart of AI-Driven Educational Framework for ASD Learners





Divya and Maniraj

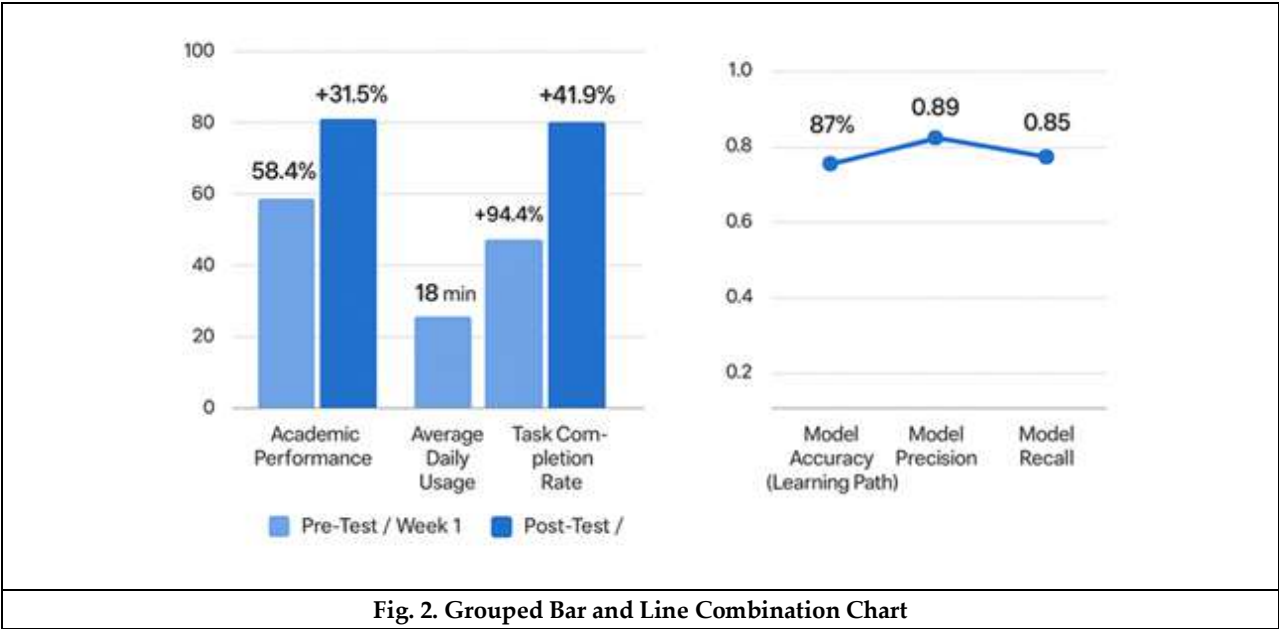


Fig. 2. Grouped Bar and Line Combination Chart





RESEARCH ARTICLE

Optimization of Pectins from Mango Peels and Characterization

S.Anbuselvi^{1*}, L. Jeyanthi Rebecca², S. Poorni³, Devasagaya Daisy³, Katukuti Mouriya⁴, B. Lokesh Babu⁴ and R. Raalesh⁴

¹Professor, Department of Biotechnology, Bharath Institute of Higher Education and Research (Deemed to be University), Chennai, Tamil Nadu, India.

²Dean, Department of Biotechnology, Bharath Institute of Higher Education and Research (Deemed to be University), Chennai, Tamil Nadu, India.

³Assistant Professor, Department of Biotechnology, Bharath Institute of Higher Education and Research (Deemed to be University), Chennai, Tamil Nadu, India.

⁴Student, Department of Biotechnology, Bharath Institute of Higher Education and Research (Deemed to be University), Chennai, Tamil Nadu, India.

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*Address for Correspondence

S.Anbuselvi

Professor,

Department of Biotechnology,

Bharath Institute of Higher Education and Research (Deemed to be University),

Chennai, Tamil Nadu, India.

E.Mail: drsanbuselvi@gmail.com



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ABSTRACT

The study was carried out to find the better condition for extraction and precipitation of pectin from mango peels through mineral Acid, Sonicator and Lime method. Maximum pectin yield was 10.87mg/g, 10.42mg/g and 9.86mg/g respectively. It was precipitated using 95 % ethanol. The most common extraction of pectin done with sulphuric acid might be due to the presence of sulphate ions in extracted product. Pectin is extensively used by food processors for making of low grade fruits into good quality products. Pectin has several applications as functional ingredient in food, Dairy, cosmetics and pharmaceuticals. The main significance of pectins are easily biodegradable, making water-soluble films, acts as emulsifying agents, coating agents, chelators, emulsifiers and viscosity modifiers.

Keywords: Pectin, Extraction, Food Processors, Pharmacy, Biofilm

INTRODUCTION

Pectin was extracted from natural fruit peels of mango, banana, papaya l, citrus lemon, grape sugar beets, apple pomace and sunflower heads[1,2]. The structure, chemical composition and distribution of the pectin varies from plant to plant, Mango is one of the world's tropical fruits and its total production was 25 million metric tons a year.



**Anbuselvi et al.,**

Mango is the most fruit crop in India, Mango peels which constitute 22 - 25% of the waste during processing and it is considered as raw material for the extraction of pectin. Mango peel is best source of pectin (10 – 13%). Techniques were made to optimize conditions for the maximum recovery of pectin from mango peels. The pectin consists of polygalacturonic acid with carboxylic group partially esterified with methyl alcohol in the form of long branched chains[2]. Extracted pectin can be classified into two major forms depending on the percentage of galacturonic acid residues. The degree of methoxylation above 50% represents high methoxyl pectin and DM below 50% low methoxyl pectin. Pectin used in food Industry for good gel and flavor release. It is used to stabilize acidic protein drinks, (drinking yogurt) and fat substitute in baked foods. Pectin used as a food additives in the range of 0.5 - 1.0%. Pectin having high dietary fibre, used against constipation and diarrhoea. It also act as an adsorbent to remove heavy metal from biological systems. It is widely used in pharmacy especially in making throat lozenges. Pectin is also for wound healing preparations and medical adhesives[3].

Application of Pectin

Pectin is one of the most versatile stabilizers used in food processing industries. Pectin was commonly used in the making of jams and fruit jellies traditionally[4]. Pectin is a heteropolysaccharide used in many food and organic food products as well as in dairy application. It contains a linear chain of galacturonic acid units. Naturally occurring biopolymer that is finding increasing applications in Pharma and Biotech industry[5]. Pectin a natural fiber found in most plants. Citrus fruits, for example, are particularly high in pectin, with the highest concentrations in the skins, cores and seeds[6]. The dry mix of pectin contains 163 cal, 100 mg sodium, 45 gm carbohydrates, 4 gm dietary fiber, 0.0 gm copper, 0.2 mg zinc, 0.01 mg manganese. The development of the latest cheapest technology needed for the extraction of pectin from Mango peel and powder, which helps the waste into reusable product of non-citrus juice processing industry. We can get pectin from non-citrus processing industry for the separation of useful product from peels[7]. The physicochemical properties of pectin such as equivalent weight, methoxyl content, and the degree of esterification in the optimized pectin, have good gelling ability. It also supports that the jellies and jams developed with optimized pectin contain higher titrable acidity and pH than the control samples, which can be used for optimal gelation[8]. Pectin can be easily combined with other polymers to improve the polymer characteristics of mechanical, physical, and barrier properties, ultimately extending the shelf life and improving the quality of food products[9]. Pectin is homogenized with sodium alginate, guar gum, and baobab seed oil, broccoli leaf pectin combined with tapioca starch and broccoli leaf polyphenols (BLPs), showed significant in mechanical strength, water resistance, and biological activity, which were effective in extending the shelf life of mushrooms and chilled mutton[10]. Pectin is mostly used as a thickening and stabilizing agent, biodegradability biocompatibility and edibility properties and used as a polymeric matrix for manufacturing active edible packaging films. The development of food packaging bio-based biodegradable polymers, such as pectin, combined with natural or synthetic additives to enhance material properties and shelf life of the polymer has recently become an latest solution in the food industry[11]. The biopolymer based packaging contains specific bioactive compounds which shows antimicrobial and antioxidant properties. It also shows stability extension and shelf life of food products and rapidly absorb oxygen and water vapor in the package[12]. The main objective of this study deals with extraction of pectin from mango peels using natural and physical extraction methods.

MATERIALS AND METHODS

Analytical grade chemicals used for extraction process. Fresh mango peels were collected from non-citrus processing small scale industry.

Mineral Acid Method

The fruit peels were dried in oven at 60 °C to minimize the water content (6-8%). The dried peel was grinded and sieved through 80 meshes and packed in airtight, moisture-proof bag at room temperature and ready to the extraction process[13-15].



**Anbuselvi et al.,****Extraction of Pectin**

5g of the peel powder were taken in 150ml distilled water. Acid (HCL or Citric acid) was used for making different pH medium as range of 2.0, 2.2 and 2.5 pH medium). Extraction was carried with the help of hot water bath protocol. Thereafter, the mixture were heated for each pH of medium and temperature (60°C, 70°C and 80°C) at different time interval of 45, 50 and 60min[16].

Sonication Method

The pectin yields from mango peels carried out by making a addition of lemon juice (acidifying agent) and a sonication process. This extraction procedure is compared with mineral acid (HCl). The pectin present in different treatments were analyzed colorimetrically[17]. 100mg of pectin and dissolve in 100ml of 0.05N sodium hydroxide used as standard. 2ml of pectin solution and different samples were taken, 1ml of carbazole reagent was added to form a white precipitate formed. Then precipitate was dissolved in concentrated sulphuric acid with constant stirring. The tubes were tightly closed with rubber stopper and standing for 10min to develop the colour. The colour intensity was read at 525nm against blank within 15min. 1ml purified ethyl alcohol in the place of carbazole reagent used as a blank[18].

RESULTS AND DISCUSSION

Different physical parameters showed a significant changes in the extraction of pectin (Figure 1). At pH 1.5, 2.0, 2.5, 3.0 and 3.5 pectin yield was 16.11, 20.70, 17.90, 12.60 and 12.00 respectively, when mango peels powder was suspended at 100 °C temperature for 60 minutes showed high pectin (Table 1). The higher temperature was associated with the largest yield of mango peel pectin. The temperature plays a significant role in the extraction of pectin from mango peel to enhance the solubility of the solute and the diffusion coefficient[19,20]. Acidity of the solution shows an important role in the impure extraction of pectin. It can be neutralized with dietary fibre[21]. It was less amount of pectin extracted from dragon fruit and different citrus peels such as kinnow, musambi, malta and feutal. This due to the fruits nature, drying techniques, types, duration of drying, and application of temperature[22]. The changes in equivalent weight might also depend upon the free acid present in mango[23]. This study showed that the optimized mango pectin had a good gel forming characteristics which used to produce jam and jelly[8]. Better extraction of pectin with sulphuric acid induce more extraction which cannot be used for food processing Industry[22]. Figure 1: Extraction of Pectin obtained from a.Lemon b.Mineral acid c.Sonication method

CONCLUSION

This extracted heteropolysaccharide is used as a stabilizer in foods. It is the main raw material for food processing, biofilm, biopolymer and dairy industries. This work revealed that the sonicated lime treated mango peels are good source of pectin when compared to other treatments using different parameters. To reduce the environmental pollution the mango peels are used as a good source for extracting pectin from pulp industry which used for industrial applications especially food packaging and improve the shelf life of food products naturally without any chemical treatments. The result demonstrates the successful extraction of pectin from non-citrus fruit peels, providing economically benefits for industrial extraction of pectin. Pectin shows an innovative and environmentally friendly solution for food packaging industry, providing effective protection against microbes and oxidation and improving the quality and safety of food products.

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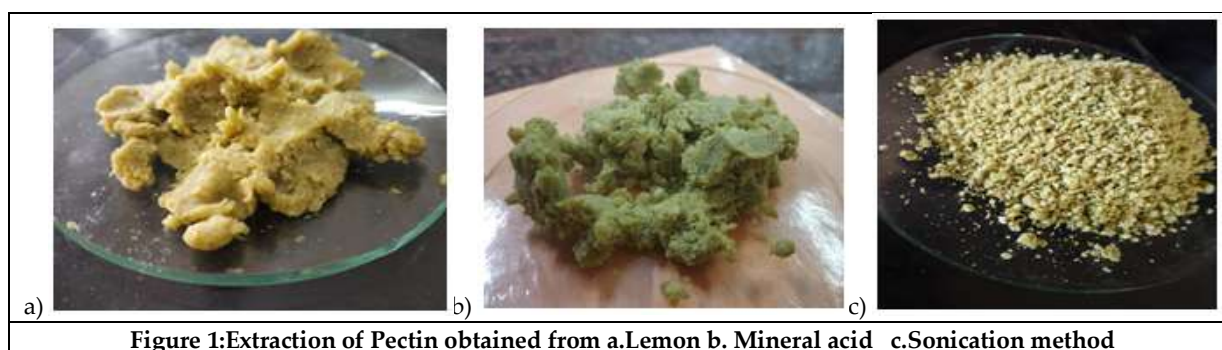
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**Table.1: Experimental Observation of Yield of Pectin**

S. no.	Parameters	Mineral Acid	Lemon Juice	Sonication	Lemon juice + Sonication
1.	Volume Taken(ml)	200	200	200	200
2.	Temperature (°C)	100	100	100	100
3.	Time(min)	5	5	5	5
4.	Volume of Ethanol(ml)	40	40	40	40
5.	Centrifuge(rpm)	8000	8000	8000	8000
6.	Centrifuge Time(min)	10	10	10	10
7.	Weight of dried pectin(g)	21.05	23.18	24.67	26.43
8.	Yield of pectin (mg/g)	9.86	10.87	10.42	11.67
9.	Colour	Light Brown	Brown	Light Green	Greenish Brown
10.	Soluble in cold water	Insoluble	Insoluble	Insoluble	Insoluble





REVIEW ARTICLE

A Review on Quinoline and Isatin : A Versatile Bioactive Scaffolds and its Molecular Hybridization in Emerging Diseases

S. Vignesh¹, T. Srimathi¹, A. Aruvisal Hananth¹, V. Hemachandran¹, S.Mahalakshmy¹, K. Hemalatha^{2*} and K. Girija³

¹M.Pharm Student, Department of Pharmaceutical Chemistry, Mother Theresa Post Graduate and Research Institute of Health Sciences, Pondicherry University, Puducherry, India.

²Assistant Professor, Department of Pharmaceutical Chemistry, Pondicherry University, Puducherry, India.

³Principal and Professor, Department of Pharmaceutical Chemistry, Mother Theresa Post Graduate and Research Institute of Health Sciences, Pondicherry University, Puducherry, India.

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*Address for Correspondence

K. Hemalatha

Assistant Professor,

Department of Pharmaceutical Chemistry,

Pondicherry University, Puducherry, India.

E.Mail: hemalatha@mtpgrihs.ac.in



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ABSTRACT

Quinoline and Isatin represents two highly versatile bioactive scaffolds, each with a well-established history in medicinal chemistry due to their broad spectrum of biological activities, including anti-microbial, anti-malarial, anti-viral, anti-cancer and anti-tubercular anti-oxidant effects etc. Recent advances highlights the significant potential of molecular hybridization strategies that combine these two pharmacophores into single hybrid molecules, resulting in enhanced and often synergistic biological activity compared to their individual counterparts. Molecular hybridization has gained popularity in recent years as a method for advancing medicinal chemistry and discovering new drugs. The incorporation of suitable linkers and functional groups within these hybrids further optimizes their pharmacological profiles, improving activity and selectivity while minimizing toxicity. The focus of this present study is to overview the recent literature on molecular hybridization of quinoline-isatin hybrid derivatives such as anti-tubercular, anti-malarial, anti-microbial, anti-ileishmanial, anti-oxidant and anti-cancer activities were reported. From this study the importance of these scaffolds in medicinal chemistry and drug discovery reinforcing the novel compounds with improved efficacy and safety profiles has been established.

Keywords: Quinoline, Isatin, Molecular Hybridization, Anti-Cancer, Anti-Tubercular.



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INTRODUCTION

Four out of the top five selling medications in the US are believed to include at least one heterocyclic molecule, which has pharmacological properties including antitumor, anticancer, antibacterial, and anti-inflammatory properties. QUINOLINE and its derivatives are essential in many drug core structures as well as for its biological and Pharmacological activities. Quinoline, which is a prime example of a bicyclic heterocyclic molecule. A pyridine ring and a benzene ring fused with two nearby carbons make up the aromatic N-heterocyclic basic chemical known as quinoline[1]. Isatin (1H-indole-2,3-dione) moiety is present everywhere in naturally in plants and animals, and its derivatives easily pass through the blood-brain barrier. Isatin derivatives have a wide range of pharmacological properties due to their potential to inhibit numerous enzymes and receptors, including acetylcholinesterase, butyrylcholinesterase, carbonic anhydrase, DNA gyrase, histone deacetylase reverse transcriptase, serine proteases, tyrosine kinase and tubulin[2]. Isatin and its derivatives have a wide range of biological properties, including anticancer, antibacterial, anti-inflammatory, anti-TB, analgesic, anticonvulsant, antiviral, anti-HIV, antioxidant, and CNS depressive properties. Isatin was discovered in 1941 by Linne Erdman and Auguste Laurent from indigo dye. Indigo was oxidised in the presence of nitric acid and chromic acid, yielding bright orange- coloured monoclinic crystals of Isatin as a product[3]. Molecular hybridization is the process of creating molecular hybrids by covalently bonding two or more distinct molecules, each with unique properties. This technique can also involve merging the pharmacophores of various bioactive compounds, whether synthetic or natural, to produce a hybrid with superior affinity and efficacy compared to the original drugs. Molecular hybridization has gained popularity in recent years as a method for advancing medicinal chemistry and discovering new drugs. The application of molecular hybridization in drug design is anticipated to result in enhanced medications in the future.

Examples of Some marketed drugs in molecular hybrids techniques and their uses

Streptoniazid: Streptomycin and isoniazid-antitubercular and antibiotics.

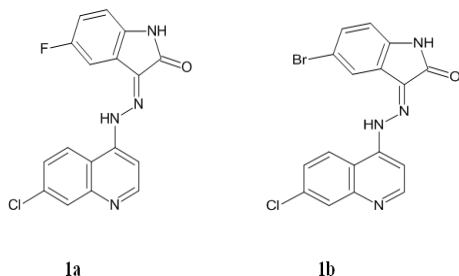
Quinine Acetyl Salicylate: Quinine and acetylsalicylic acid -Antipyretic, Analgetic, Antimalarial.

Acetamino Salol: Salicylic acid and Acetamido phenolanalgetic.

Guaicyl Phenyl Cinchoninate: Guaiacol and cinchophenexpectorant[4].

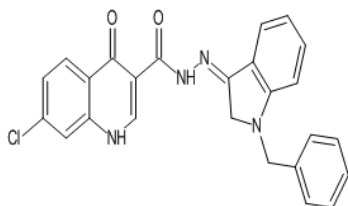
Various Biological Activity on Quinoline-Isatin Hybrids

Sabt A *et al* (2022) were synthesized Quinoline-isatin hybrids and assessed for their in vitro antileishmanial effectiveness against the Leishmania major strain. The compounds 1a, 1b were exhibited the most potent antileishmanial activity against both the promastigote and amastigote forms, targeting PTR1 and DHFR-TS enzymes[5].



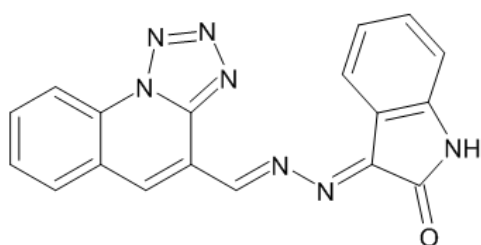
Abdelrahman *et al* (2022) were designed quinoilne-isatin conjugates a series of compound were synthesized and then biologically assessed for anti-tubercular actions towards drug-susceptible, MDR, and XDR strains. Among this compound 2 shows the most potent counterpart with MIC=0.06 g/ml;it represents about 100-fold enhanced activity compared to the lead compound (MIC=6.24 g/ml)[6].



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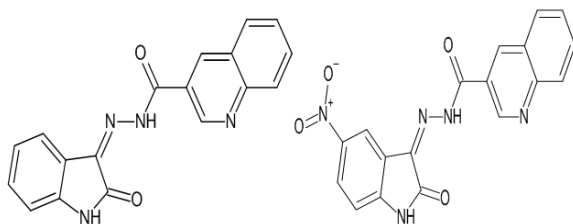
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Nippu *et al* (2022) designed and synthesized a new series of tetrazolo-quinoline derivatives as potential anticancer agents. These derivatives demonstrated promising anti-proliferative effects against the human pancreatic cancer cell line MIA paca-2, exhibiting an IC₅₀ value of 60.17 μm [7].



3

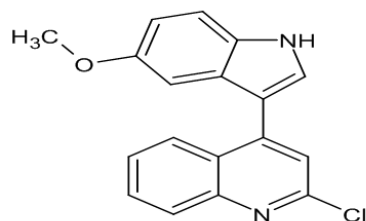
Gandhi PV *et al* (2021) synthesized 2-methyl-N'-[(3Z)-2-oxo-1, 2-dihydro-3H-indol-3-ylidene] quinoline-3-carbohydrazide derivatives, among these the compound 4a and 4b exhibited effective potency in inhibiting the growth of Mycobacterium tuberculosis. The activity of compounds suggested that the introduction of electron donating group on forth position of the isatin ring significantly improved the activity[8].



4a

4b

Wang S *et al* (2021) reported that the quest for new and effective anti-cancer agents, a series of novel quinoline-indole derivatives were synthesized through molecular hybridization. The antiproliferative activity of these compounds was assessed using the MTT assay on three cancer cell lines: MGC-803 (gastric), HCT-116 (colon), and Kyse450 (esophageal). Compound 2-Chloro-4-(5-methoxy-1H-indol-3-yl) quinoline (5) demonstrated potent inhibitory effects, with IC₅₀ values of 0.58, 0.68, and 0.59 $\mu\text{mol} \cdot \text{L}^{-1}$ against MGC-803, HCT-116, and Kyse450 cells, respectively[9].

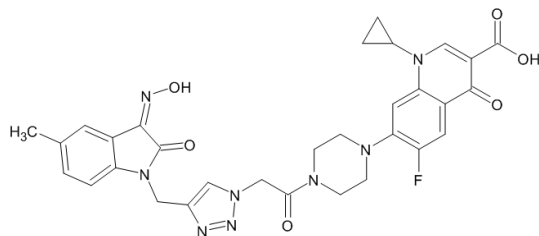


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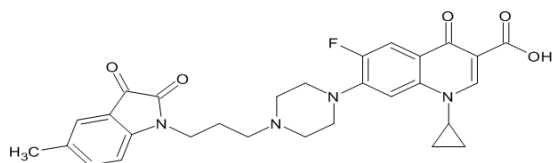
Vignesh *et al.*,

Chen R *et al* (2019) conducted a study using the CCK-8 Assay Kit to evaluate the *in vitro* anticancer efficacy of moxifloxacin/gatifloxacin-1,2,3-triazole-isatin hybrids against six human cancer cell lines: A549 (lung carcinoma), hepg2 (liver cancer), MCF-7 (breast cancer), PC-3 (prostate cancer), SW620 (metastatic colorectal adenocarcinoma), and MGC-803 (gastric cancer). The study found that hybrid 6 showed notable activity, particularly when compared to the A549, hepg2, and MCF-7 cancer cell lines[10].



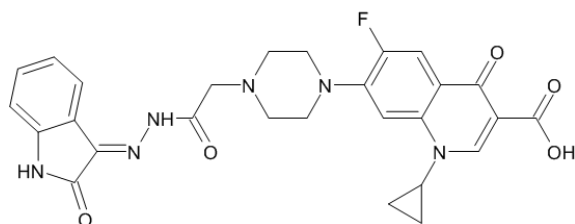
6

In the study by Wang R *et al* (2018) a series of novel propylene-linked isatin-ciprofloxacin hybrids were synthesized and evaluated for their cytotoxic, antibacterial, and anti-mycobacterial activities. These hybrids exhibited considerable inhibitory effects on the tested strains. Notably, the most potent hybrid, referred to as the compound 7, showed low cytotoxicity and was more effective against MTB H37Rv and MDR-TB compared to the marketed drugs, ciprofloxacin and Rifampicin[11].



7

Kassab A E *et al* (2018) reported a series of new CIPROFLOXACIN derivatives, modified at the N-4 position of the piperazinyl structure, yielded twenty-three anticancer hybrids. These compounds demonstrated significant potency, with the most effective ones showing in vitro cytotoxicity against bladder cancer cell lines (IC₅₀ = 92.16 μm) and prostate cancer cell lines (IC₅₀ = 10.95 μm), indicating a promising potential for cancer therapy. Compounds (8) have been found to induce cell cycle arrest in the G1 phase in PC-3 cells, exhibiting 1.0 to 2.3 times the potency of doxorubicin. Conversely, T-24 cells experienced suppression in the S-phase. Furthermore, these compounds demonstrated a notable inhibitory effect on Top II, with an efficacy range of 83% to 90% at a concentration of 100 μm[12].



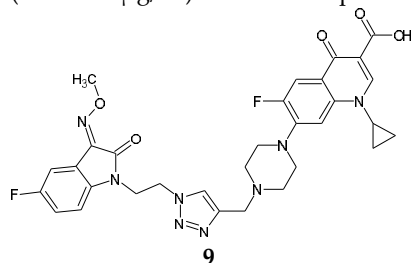
8

Hu Y *et al* (2017) developed and synthesized eight new 1H-1,2,3-triazole-tethered ciprofloxacin-isatin conjugates, evaluating their in vitro anti-mycobacterial efficacy against *Mycobacterium smegmatis* and *Mycobacterium tuberculosis* (MTB) H37Rv strains. These conjugates demonstrated greater lipophilicity compared to ciprofloxacin. Initial results indicated that all conjugates (MIC: 12.5–100 μg/ml) were significantly active against *M. Smegmatis*, though less so than the reference drug INH (MIC: 0.78 μg/ml) and ciprofloxacin itself (MIC: 6.25 μg/ml). Against MTB H37Rv, all

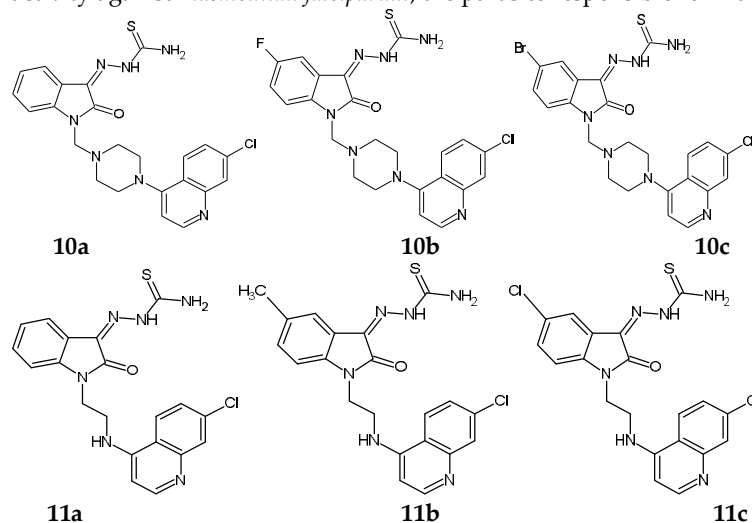


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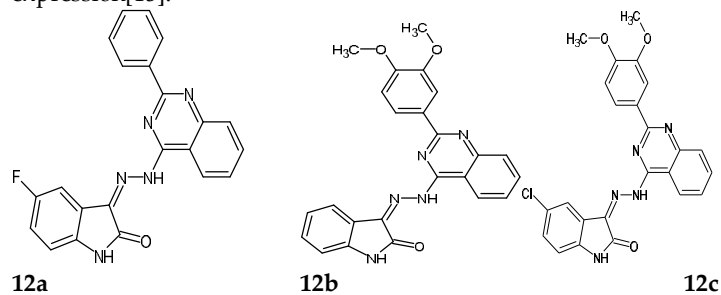
conjugates showed excellent inhibitory activity with mics ranging from 1.56 to 25µg/ml. Remarkably, conjugate 9 (MIC: 1.56µg/ml) was twice as potent as ciprofloxacin (MIC: 3.12µg/ml)[13].



Chiyanzu I *et al*(2015) synthesized the anti-plasmodial properties of 4-aminoquinoline isatin conjugates derived from quinoline. The natural product isatin scaffold forms the foundation for a novel series of 4-aminoquinoline derivatives. These synthetic chemicals compound 10a,10b,10c and 11a,11b,11c demonstrate potent anti-plasmodial activity against *Plasmodium falciparum*, the parasite responsible for malaria[14].

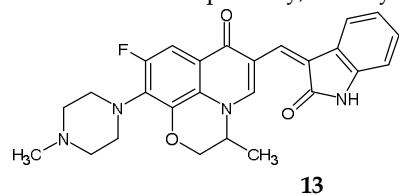


Fares Metal (2015) reported the isatin-quinazoline hybrids showed selective efficacy against cancer cell lines MCF-7, hepg2, HT-29, and MDA-MB-231. Only hybrids 18a and 18b, with IC₅₀ values ranging from 1.0 to 26µm, demonstrated sensitivity across the three tested cancer cell lines. In the case of hepg2 cells, hybrids (12a,b,c) (IC₅₀: 1.0 and 1.8 µm respectively) surpassed doxorubicin (IC₅₀: 2.9µm) in effectiveness, and were comparable to sunitinib (IC₅₀: 6.8µm) in terms of activity. Further studies indicated that these hybrids could induce apoptosis in hepg2 cells by increasing caspase-3 levels, enhancing pro-apoptotic protein Bax, and reducing anti-apoptotic protein Bcl-2 expression[15].

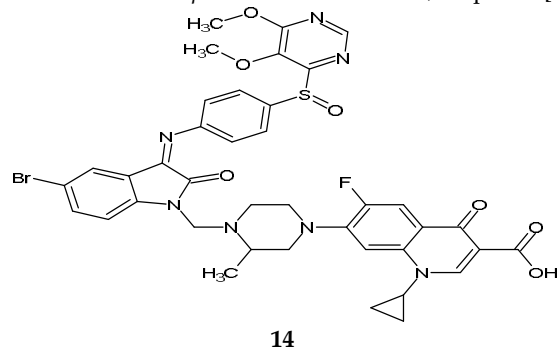


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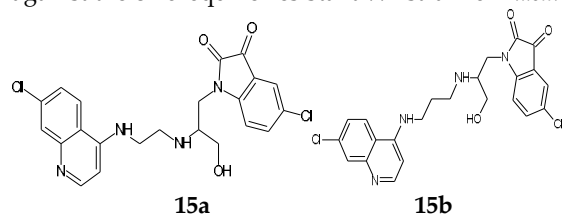
Liu YH *et al* (2015) has reported that a Quinolone indolone compound appears to be a promising new anti-cancer drug, showing remarkable efficacy in cancer cells. It counteracts multidrug resistance in these cells by inhibiting the EGFR-STAT3-HK pathway, thereby impeding their proliferation[16].



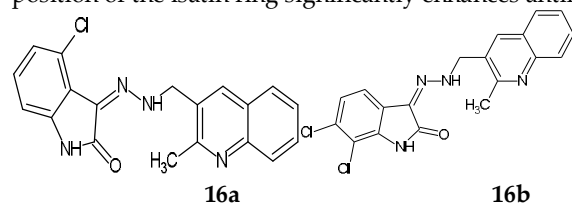
Yogeeswari P *et al*(2015) synthesized Mannich bases of Gatifloxacin were synthesized by reacting with various isatin derivatives and formaldehyde. These compounds were tested in vitro against a panel of 58 human tumor cell lines derived from nine different neoplastic diseases. Among them, the compound 1-cyclopropyl-6-fluoro-8-methoxy-1,4-dihydro-4-oxo-7-[[1'-(5-bromoisatiny)l methyl N4-(3'-sulphadoximino)]]N1-piperaziny1-3-methyl carboxylic acid-3-quinoline (14) emerged as a potent anticancer agent, showing greater efficacy against 30 cancer cell lines than the standard DNA topoisomerase II inhibitor, etoposide[17].



Nisha, Gut Jet *et al* (2014) synthesized and reported that 4-aminoquinoline-isatin conjugates were developed to investigate their antimalarial structure-activity relationship. The two most potent conjugates, 15a and 15b demonstrated antimalarial efficacy on par with chloroquine, with IC₅₀ values of 11.8 and 13.5nM, respectively, against the chloroquine-resistant W2 strain of *Plasmodium falciparum*, and they showed no cytotoxicity[18].

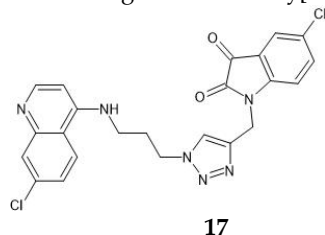


Novel Isatin-Quinoline Hybrids have been synthesized by Maddela S *Et al*(2014) and their antitubercular activity has been assessed. The compounds demonstrated effective action against the H37Rv strain of tuberculosis. The antibacterial activity of compounds 16a and 16b indicated that introducing electron-withdrawing groups at the fifth position of the isatin ring significantly enhances antimicrobial efficacy[19].



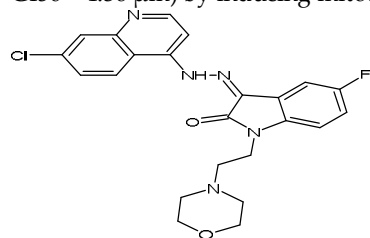
Vignesh *et al.*,

Raj R *et al* (2013) synthesized 1H-1,2,3-triazole tethered 7-chloroquinoline isatin conjugates and evaluated their antiplasmodial activity against the chloroquine-resistant W2 strain of *Plasmodium falciparum*. Compound 17 showed the most significant activity[20].



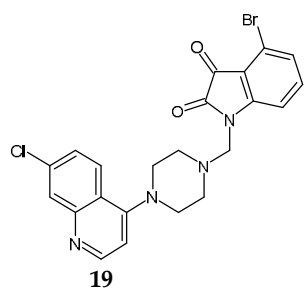
17

The study by Singh A *et al* (2011) presents an innovative approach in the fight against breast cancer, with the creation of new hydrazone-linked morpholinatedisatin-quinoline hybrids. These compounds, which incorporate isatin, quinoline, and morpholine, were primarily evaluated for their efficacy against two breast cancer cell lines, MCF-7 and MDA-MB-231. The standout compound, identified as compound 18, demonstrated significant potency (MCF-7: GI50 = 4.36 μ m) by inducing mitotic arrest in the G2/M phase of the cell cycle[21].

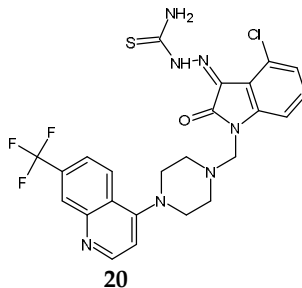


18

Hu C *et al* (2009) performed a synthetic via molecular hybridization, a new class of 4-piperazinylquinoline derivatives based on the isatin scaffold was created. The compounds' cytotoxic effects on the human breast carcinoma cell lines MDA-MB468 and MCF7 were then investigated. 4-bromo-1-[4-(7-chloro-quinolin-4-yl)-piperazin-1-ylmethyl] is the chemical in question. N1-[4-(7-trifluoromethylquinolin-4-yl)] and -1H-indole-2,3-dione 19 Among the anti-breast cancer drugs, -piperazin-1-ylmethyl-4-chloro-1H-indole-2,3-dione-3-thiosemicarbazone 20 shown to be the most effective[22].



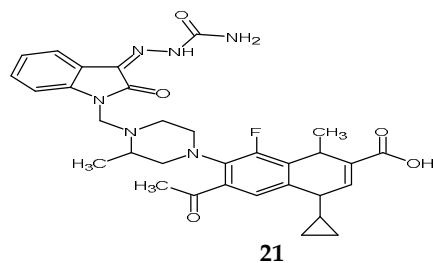
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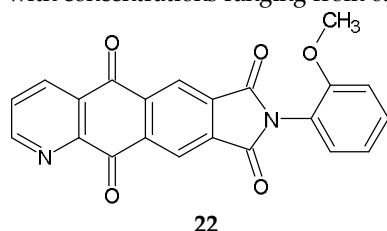
20

Sriram D *et al* (2006) were synthesized 7-substituted Gatifloxacin derivatives and evaluated for antimycobacterial activity *in vitro* and *in vivo* against Mycobacterium tuberculosis H37Rv (MTB) and multi-drug resistant M. Tuberculosis (MDR-TB), and also tested for the ability to inhibit the supercoiling activity of DNA gyrase from M. Tuberculosis. Among the synthesized compounds, 1-cyclopropyl-6-fluoro-8-methoxy-7-[[[N4-[10-(5-isatiny1-b-semicarbazoyl)methyl]3-methyl]N1-piperazinyl]-4-oxo-1,4-dihydro-3-quinoline carboxylic acid (21) was found to be the most active compound *in vitro* with an MIC of 0.0125 lg/ml against MTB and MTR- TB[23].

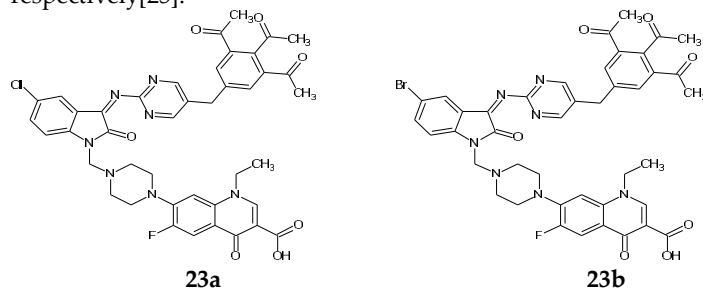


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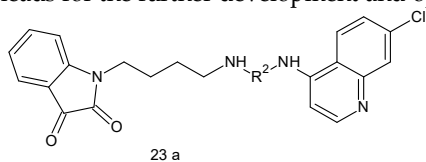
Lee H *et al* (2002) reported the synthesized isoindoloquinoline derivatives were evaluated *in vitro* for cytotoxic activities against human cancer cell lines from colon cancer (HCT15), ovarian carcinoma (SK-OV-3), breast adenocarcinoma (MDA-MB-468), and breast ductal carcinoma (T-47D). Comparative data were also gathered for mitomycin C and doxorubicin. Among the tested compounds, molecule 22 exhibited outstanding cytotoxic activity, with concentrations ranging from 0.6 to 3.21 μM , against the four human cancer cell lines[24].

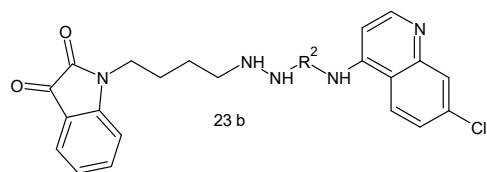


Pandeya SN *et al* (1999) were synthesized by reacting Mannich bases of Norfloxacin with formaldehyde and several isatin derivatives have shown inhibition against HIV-1 (III B) in MT-4 cells with EC₅₀ values of 11.3 and 13.9 $\mu\text{g/ml}$, respectively[25].

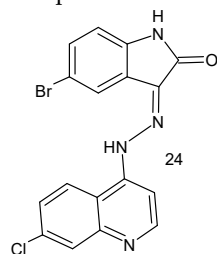


Elshaymaa I Elmongy *et al.* (2022) reported Isatin–quinoline conjugates 24a and 24b by the reaction of N-(bromobutyl) isatin derivatives with aminoquinolines and their corresponding hydrazinyl in good yields. *In vitro* antibacterial activity against different bacterial strains was evaluated. All tested conjugates showed significant biocidal activity with lower MIC than the first line drugs Chloramphenicol and Ampicillin. The antibiofilm activity for all tested conjugates was screened against the reference drug vancomycin using the MRSA strain. The results confirmed that the title compounds caused the disruption of bacterial cell membranes and could be used as potential leads for the further development and optimization of antibacterial agents[26].



Vignesh *et al.*,

Ahmed Sabt *et al.*, (2023) reported the synthesis of twenty quinoline-isatin hybrids and tested for their *in vitro* antileishmanial activity against *Leishmaniamajor* strain. All the synthesized compounds showed promising *in vitro* activity against the promastigote form in a low micromolar range (IC_{50} = 0.5084–5.9486 μ M) superior to the reference miltefosine (IC_{50} = 7.8976 μ M). All the target compounds were then tested against the intracellular amastigote form and showed promising inhibition effects (IC_{50} = 0.60442–8.2948 μ M versus 8.08 μ M for miltefosine). Compounds 24 were shown to possess the highest antileishmanial activity against both promastigote and amastigote forms. Molecular docking within putative target protein PTR1 confirmed the high potentiality of the most active compounds 24 to block the catalytic activity of Lm-PTR1[27].



CONCLUSION

Quinoline-Isatin is synthetically versatile molecule with diverse pharmacological applications. The focus of this review has outlined various biological evaluations that these hybrids can outperform standard drugs in several assays, underlining their promise as lead compounds for future drug development via molecular hybridization technique.

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RESEARCH ARTICLE

Green Route Adaptive Load-Balancing [GALB] for Energy Efficient and Congestion-Resilient G-IoT Networks

A. Leolin Arockiadass^{1*}, T. Kokilavani² and A. Aloysius³

¹Research Scholar, Department of Computer Science, St. Joseph's College (Autonomous), (Affiliated to Bharathidasan University), Tiruchirappalli, Tamil Nadu, India

²Assistant Professor, Department of Computer Science, CHRIST University (Deemed to be University), Bengaluru, Karnataka, India.

³Assistant Professor, Department of Computer Science, St. Joseph's College (Autonomous), (Affiliated to Bharathidasan University), , Tiruchirappalli, Tamil Nadu, India.

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*Address for Correspondence

A. Leolin Arockiadass

Research Scholar,

Department of Computer Science,

St. Joseph's College (Autonomous),

(Affiliated to Bharathidasan University),

Tiruchirappalli, Tamil Nadu, India

E.Mail: leolin.arul@gmail.com



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ABSTRACT

The exponential growth of IoT devices and applications has amplified energy consumption and network congestion problems especially within resource constrained IoT environments. This work proposes GreenRoute Adaptive Load Balancing (GALB), a cross-layer and hybrid technique. It combines Ant Colony Optimization (ACO), Time Difference of Arrival (TDoA), and Frequency Hopping with Adaptive Load-Balancing capabilities. The proposed approach addresses the issues like data congestion and energy efficiency in IoT networks. GALB could achieve energy efficiency by deploying a Long Short-Term Memory (LSTM) based machine learning approach which analyzes real-time node energy levels and network congestion. Also using LSTM based predictive modeling the routes are chosen making the load balancing adaptive in nature. The tests performed on IoT heterogeneity show that GALB minimizes the energy cost by 30% and delivers results with 25% better speed than EEERA, RPL and LOADng protocols. GALB enhances network durability alongside QoS standards which results in scalable IoT sustainability frameworks.

Keywords: GIoT, Adaptive Load-Balancing, LSTM, Machine Learning, ACO



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INTRODUCTION

The Internet of Things (IoT) has revolutionized various industries by enabling seamless interconnectivity, that facilitates real-time data exchange and automation. According to the early studies the number of connected devices could grow more than 75 billion by 2030 [1]. This exponential growth in IoT pose significant challenges including security and privacy, excessive energy consumption, connection longevity and network congestion [2, 3]. Issues such as security and privacy, have been addressed largely evolving with several techniques [4, 5, 6]. Green IoT (G-IoT) has emerged as a technology addressing energy depletion or device lifetime longevity in IoT networks. G-IoT limits the carbon footprint by adopting techniques such as energy-efficient communication protocols, dynamic routing techniques, adaptive routing approaches and energy aware network architectures [7, 8, 9]. Energy-efficient communication protocols minimise the power consumption in the G-IoT network by handling the data transmission effectively during the exchange of data packets within the network. Dynamic routing techniques contribute towards energy efficiency by continuously adjusting the network path based on the real-time conditions [10]. Energy-aware G-IoT architecture spreads its scope to work on G-IoT environments by opening space to handle hardware, protocol layers and even at the topological structures. Techniques such as hierarchical clustering, cross-layer optimization and renewable energy harvesting could be adopted for achieving an energy efficient custom G-IoT system. Cross-layer optimization considers sharing the energy and traffic information across one or more network layers such as physical, MAC and network layer to coordinate transmission. Apart from these approaches nature inspired approaches Ant Colony Optimization (ACO) based schemes contribute largely in energy efficiency as they do work for search and scheduling [11, 12]. Using ACO, EcoTrailEnergy-Efficient Routing Algorithm (EEERA), optimizes the routing paths by computing residual energy and link quality [2]. To obtain more device life-time longevity, combination of ACO, cross-layer optimization along with machine learning/ deep learning approach is essential. Therefore, this work is aimed at introducing an adaptive load balancing based energy efficiency scheme GALB. Also combining real-time congestion feedback and machine learning-driven energy predictions to ensure balanced energy usage. GALB uses Long Short-Term Memory (LSTM) to adept modeling sequential data due to their ability to retain long-term dependencies through gated mechanisms. It analyses real-time node energy levels and congestion data, thereby optimizing energy consumption and enhancing overall network performance.

Remainder of this work is structured as: literature review in section 2, covering the background and detailed analysis on the existing solutions and their weaknesses. Section 3, draws the methodology of the proposal, highlighting the GALB architecture and algorithms. Next section 4, elaborates on the results and analysis, section 5 draws the conclusion followed by the list of references.

LITERATURE REVIEW

Recent advancements in adaptive energy efficiency techniques focus on protocol optimization, adaptive load-balancing, and machine learning/ deep learning-based approaches. A combined approach with these three is rarely found in the existing literatures, therefore this proposal aims at tying up these techniques together. For this a detailed literature survey is conducted and same is presented. To obtain energy efficiency, enhancing the routing protocols is the primary approach. Suryawanshi, (2024) have introduced FGSA, which optimizes routing by balancing energy consumption and link quality, resulting in prolonged network lifetime. Also explored GWO for routing, demonstrating improved energy efficiency and reduced latency in dynamic IoT environments. This hybrid approach combines the exploration capabilities of salp swarm algorithms with the exploitation strengths of differential evolution, leading to enhanced routing performance. Incorporating contextual information such as node mobility and environmental factors, context-aware routing protocols adaptively select optimal paths, thereby conserving energy. Cluster-based routing organizes nodes into clusters, reducing communication overhead and balancing energy consumption among nodes. Integrating machine learning techniques into routing decisions enables predictive analytics for energy consumption, enhancing the adaptability and efficiency of routing protocols [13]. Also, Stanley *et al.*, (2023) have introduced residual energy and link quality as routing metrics, reducing energy consumption by 18%



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over RPL [14]. Kumar *et al.*, (2024) have found static load distribution fails in dynamic traffic scenarios [15]. Similarly, Gupta *et al.*, (2023) have used duty cycling but lacked in congestion adaptability [16]. Table 1, shows the detailed analysis of the issues addressed by introducing protocols which also explores the methodology or algorithm proposed. Though energy efficiency is achieved to an extent still certain issues such as computational cost, lack of dynamism, scalability, etc., remains unsolved. This necessitates the development of novel protocols enhancing energy efficiency. In G-IoT networks energy efficiency protocols with effective load balancing techniques reduce energy consumption by avoiding congestion. Zhang *et al.* (2024) introduced a load balancer that distributed network traffic, achieving a 15% reduction in energy variance. This framework decouples control and data planes, allowing autonomous load adjustments. However, it requires significant computational resources [21]. Homaei (2024) introduced a load balancing approach using learning automata, which dynamically adjusts routing decisions based on real-time network conditions [22]. Shahakar *et al.* (2024) combined ACO and RL to develop a system that adapts to changing workloads, optimizing resource utilization and load distribution. An approach utilizing learning automata to distribute tasks between edge and cloud servers, enhancing real-time task management [23]. Alakeel (2024) emphasized the importance of dynamic load balancing in service composition, highlighting its role in optimizing system performance and resource utilization [24]. Table 2, demonstrates the existing adaptive load balancing approaches used with routing protocols for obtaining better efficiency. The authors have done this for handling congestion which reduces energy consumption. While the existing approaches deals with the issue, they still require improvement as they couldn't resolve node mobility, computational overhead, and dynamic networks. This again requires a better solution that enhances energy efficiency in G-IoT. Combining efficient protocol along with load balancing could enhance energy reduction. If this hybrid approach is further adopted with deep learning, it could actively reduce energy consumption.. Therefore, LSTM a prominent DL approach is chosen. LSTM predict energy depletion in solar-powered nodes with 89% accuracy (ACM, 2024). Reinforcement learning optimizes duty cycles in LoRaWAN networks, cutting latency by 26% (IEEE, 2023). However, few studies combine ML with routing protocols for holistic optimization. Suseendran *et al.* (2025) demonstrated that LSTM networks could predict energy depletion in solar-powered nodes with 89% accuracy, enabling proactive energy management. Reinforcement learning algorithms have been applied to optimize duty cycles in LoRaWAN networks, resulting in a 26% reduction in latency [27]. Implementing RF models in smart building systems led to an 18% decrease in overall power consumption, showcasing the potential of ML in energy conservation [28]. Natarajan *et al.* [2024] combined convolutional neural networks with LSTM units to predict energy consumption accurately, facilitating efficient energy management in buildings [29]. Morteza *et al.* (2024) utilized ANN-based MPC for controlling air handling units, achieving a 57.59% reduction in electricity consumption [30]. Daghero *et al.* (2023) proposed dynamic ensembles that adjust the number of executed trees based on energy targets, reducing energy consumption by up to 41.7% without compromising accuracy [31]. Table 3, presents different deep learning approaches used in energy efficiency approaches. Different researches have addressed issues such as identifying heterogeneity, resource constrained nodes and other energy profiles. It is evident though the proposals have made improvement in the existing results but still there is no prominent solution introduced. This creates the need to have a novel energy efficient approach that uses deep learning. Analysis of the studies on energy optimization in G-IoT, focusing on existing routing protocols, load-balancing and DL based proposals. As per the analysis there is no prominent solution found for address the energy efficiency in dynamic GIoT environment, hence this proposal GALB.

METHODOLOGY

The GreenRoute Adaptive Load Balancing (GALB) technique integrates adaptive load balancing and predictive energy management. It employs LSTM-based models to optimize energy consumption and mitigate congestion in heterogeneous IoT networks. The proposal is aimed at adapting to real-time changes in nodes and network states through intelligent, forecast driven routing decisions, enhancing scalability and sustainability.



**Leolin Arockiadass et al.,****Architecture**

The proposed architecture of GALB is composed of four layers, this includes perception layer, edge processing layer, Prediction module and routing decision engine, and cloud management. IoT devices used by different IoT applications are put in the bottom most layer named as perception layer. Minimal processing capability is mounted near the perception layer called edge processing layer, powerful processing units and energy monitoring is done at prediction module, while routing decision is taken at the decision engine and high-level processing, storage and other services like security are kept at the cloud management layer.

Figure 1, depicts an end-to-end GALB architecture that transforms raw environmental readings into energy-aware routing decisions. It begins in the Perception Layer, where heterogeneous sensors and actuators capture physical phenomena and convert them into digital signals. After discarding noise and ensuring that only meaningful events are forwarded with the help of filters would prevent wasting node energy. These cleaned data streams arrive at the Edge Processing Layer. The edge layer contains dedicated gateways or system-on-module (SoM) devices that aggregate and normalize them into time-windowed batches. By performing preliminary data alignment and filtering here, the system drastically cuts the volume of information sent upstream, conserving both network bandwidth and edge node power. Next, the Prediction Module loads a domain-tuned LSTM model and processes each sliding window of past energy levels, queue depths, and link-quality measurements. The network's gated architecture captures long-term and short-term dependencies to forecast imminent residual energy and congestion states. These forecasts feed directly into the Routing Decision Engine. The decision engine continuously recomputes composite link costs based on predicted node energy, expected congestion, and link reliability. Finally, the Cloud Management Layer ingests telemetry from all edge and routing components into scalable stream-processing pipelines and time-series stores.

Perception Layer

The Perception Layer in the GALB architecture forms the essential bridge between the physical world and digital processing. It captures analog environmental signals and converts them into digital data streams, which are then passed upward for analysis and decision-making. At its core are sensors, which measure physical parameters and produce electrical signals, and actuators, which carry out commands by translating digital instructions into mechanical or electrical actions. Together, they enable both observation and interaction with real-world phenomena.

Figure 2, describes the functions of perception layer. For object identification and visual context, RFID tags/readers wirelessly exchange unique identifiers to support tracking and access control, while cameras and imaging devices supply still or video imagery for surveillance, quality inspection, and computer-vision tasks. To pinpoint asset locations, GPS modules decode satellite signals into real-time geocoordinates, crucial for navigation and fleet management. Smart sensors integrate onboard processing filtering, threshold detection, preliminary analytics to reduce latency and bandwidth use. Embedded systems, usually microcontroller-based, manage timing, protocol conversion, and basic data handling at the device level. Finally, data is aggregated in edge gateways from multiple perception devices, perform initial preprocessing and forward curated datasets to cloud or central servers.

Edge Processing Layer

The Edge Processing Layer in the GALB architecture orchestrates and refines data flow between perception and cloud systems, ensuring low-latency responsiveness and efficient resource use. First, data ingestion and acquisition modules within edge gateways interface with sensors and actuators over MQTT, CoAP or HTTP, normalizing incoming streams. Once captured, data preprocessing and filtering routines cleanse and normalize removing noise and outliers to alleviate downstream workloads. Parallel data aggregation functions then coalesce measurements into batches or time-windowed summaries, optimizing both storage and analytic throughput.

Figure 3, explores the functions of the edge processing layer. Edge layer use local storage and caching components that temporarily hold data to buffer against connectivity interruptions, while protocol translation and interoperability middleware bridges proprietary device protocols with standard formats like JSON or CBOR. For



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real-time insights, lightweight stream processing and rule engines perform event detection, trend analysis, and anomaly identification directly at the edge. Finally, comprehensive security and access control mechanisms enforce authentication, encryption, and secure boot, while local message brokers handle communication management and message routing between devices, edge modules, and upstream services together forming a resilient, scalable processing backbone.

LSTM-Based Prediction Module

The LSTM-based Prediction Module begins on a compact Single-Board Computer (SBC) or System on Module (SoM) where raw time-series feeds arrive over the device's network interface. Incoming streams are buffered in RAM and, if necessary, spilled to local SSD storage. The SBC's GPIO and edge-gateway I/O align timestamps, interpolate missing data, and organize fixed-length sliding windows into structured in-memory buffers.

Figure 4, demonstrates the functions of prediction module. Within the same SBC/SoM, statistical feature extraction and normalization routines run on the multi-core CPU. Here, means, variances, deltas, rolling aggregates, or Fourier transforms are computed and then scaled according to preloaded parameters, ensuring that each window matches the GALB-LSTM's training distribution. For sequence modeling, the quantized GALB-LSTM weights are loaded into device memory and executed on the most appropriate accelerator: general-purpose CPU cores for lightweight inferences; discrete GPUs or TPUs for parallel tensor operations; or custom FPGAs/ASICs for dedicated LSTM cell pipelines. This heterogeneous compute stack delivers sub-second forecasts directly at the edge, with minimal network dependency. After inference, post-processing and decision logic running on the CPU apply thresholds, exponential smoothing, and rule-based filters to raw outputs. Critical predictions immediately drive actuators via GPIO and log events to the SSD-backed embedded database. Finally, the SBC's communication module publishes summary metrics upstream over MQTT or HTTPS, while the power-management unit monitors energy use and voltage stability and orchestrates hot-swapping of updated model weights during low traffic periods.

Routing Decision Engine

The Routing Decision Engine in the GALB architecture is a critical layer responsible for dynamically selecting optimal paths for data transmission in an IoT environment. It is composed of three major subsystems: the control plane, forwarding plane, and auxiliary modules. These are powered by a variety of specialized hardware components to ensure efficient, secure, and scalable routing decisions. The control plane handles route computation and topology management. It leverages general-purpose CPUs and RAM to run standard routing protocols like OSPF and BGP, constructing the Routing Information Base (RIB) and maintaining real-time awareness of the network topology. The control plane also executes routing algorithms augmented by composite weights derived from GALB's LSTM-based predictions. This ensures that decisions account for congestion levels, energy constraints, and predicted path reliability, thereby enabling intelligent, adaptive routing.

Figure 5, describes the function of routing engine of GALB. Here the forwarding plane is designed for high-speed packet handling. When a data packet arrives, the system performs a destination lookup in the Forwarding Information Base (FIB) and forwards it at line rate. This is made possible by Ternary Content-Addressable Memory (TCAM), which enables constant-time longest-prefix match operations. Additionally, Network Processing Units (NPUs) and Application-Specific Integrated Circuits (ASICs) execute forwarding logic, apply Quality of Service (QoS) policies, enforce Access Control Lists (ACLs), and manage traffic shaping all at multi-gigabit throughput levels. Supporting the core routing functions are auxiliary modules that provide robustness and adaptability. The monitoring and telemetry subsystem collects detailed flow-level and node-level statistics, health metrics, and link utilization data, enabling the routing engine to adapt its strategies in real time. Security mechanisms enforce encryption, authentication, and control-plane protection, safeguarding the routing infrastructure against unauthorized access and attacks. Lastly, high availability is ensured through redundant routing engines that synchronize state and provide failover capabilities in the event of hardware or software failure. Together, these layers and hardware elements form a comprehensive, intelligent routing decision engine, enabling GALB to support resilient, low-latency, and energy-aware communication across complex IoT networks.





Cloud Management Layer

The Cloud Management Layer in the GALB architecture provides centralized orchestration, intelligence, and scalability for managing the distributed components of an IoT ecosystem. At its core lies the Device Registry and Provisioning service, which securely manages device identities, credentials, and on boarding processes, ensuring that only trusted devices join the network. Through Data Ingestion and Stream Processing, protocols like MQTT and AMQP facilitate real-time data flow, while stream analytics engines handle filtering, transformation, and enrichment of telemetry data as it arrives. To support long-term insights and compliance, Data Storage and Management components such as time-series databases and data lakes persist both raw and processed data. Meanwhile, Event Processing and Business Logic is managed via serverless platforms that trigger contextual responses and workflows based on streaming inputs. The Model Training and Deployment subsystem leverages aggregated cloud data to train LSTM models and deploy them as edge-ready containers, enabling predictive intelligence across the network. Monitoring, Logging, and Diagnostics tools aggregate performance logs, error reports, and metrics from both cloud and edge, ensuring SLA compliance, system health, and rapid troubleshooting. Altogether, the Cloud Management Layer serves as the intelligent command center of the GALB framework, ensuring secure, efficient, and scalable coordination of IoT operations.

GALB Algorithm

GALB operates in three phases: data collection, predictive modeling, and adaptive route selection. IoT network is represented as a graph $G = (V, E)$ where $V = \{v_1, v_2, \dots, v_n\}$ are sensor nodes and E are communication links. Each node v_i maintains information on its residual energy $E_i(t)$ at time t , and link quality with neighboring nodes for transmitting data packets (ants) to a sink. Packets from source node i navigate toward the sink node through energy efficient and congestion free paths. For transmission over link (i, j) , energy consumption is modeled as:

$$C_{ij} = E_{tx} \cdot d_{ij}^{\alpha} + E_{elec} \quad (1)$$

Where, d_{ij} is euclidean distance between nodes i and j , α represent the path-loss exponent, and E_{tx} , is the transmission energy amplifier and E_{elec} representing electronics energy constants. To dynamically assess congestion level, the normalized queue length at node v_i is computed as follows :

$$\text{Cong}_i = \frac{Q_i(t)}{Q_{max}} \quad (2)$$

Where, $Q_i(t)$ represents the current queue length and Q_{max} denoting the buffer capacity. The link quality LQ_{ij} is measured as follows:

$$LQ_{ij} = \frac{1}{BER_{ij}} \quad (3)$$

Where BER_{ij} is the bit error rate between nodes i and j . In addressing the dynamic and resource-constrained nature of IoT networks, the GALB framework synergizes predictive analytics with adaptive decision-making. By forecasting node energy and congestion levels, assigning composite weights through a hierarchical controller, and leveraging efficient shortest-path computation, this framework ensures that data packets traverse routes that balance energy reserves, load distribution, and link reliability. The result is a resilient routing mechanism that preemptively mitigates bottlenecks while extending overall network longevity. The GALB framework is designed to work on three primary phases, namely energy prediction, load balancing and routing to enhance energy efficiency in IoT networks.

Phase I

This phase of the LSTM is activated to work in the environment, for managing energy adaptively in dynamic networks. GALB employs this neural network to predict near-future node states. This is done by training LSTM on historical energy and congestion data, it is used to forecast each node's residual energy and congestion one step ahead. The input sequence for node i at time t is,

$$X_i = [E_i(t - L + 1), \dots, E_i(t), \text{Cong}_i(t - L + 1), \dots, \text{Cong}_i(t)] \quad (4)$$





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Where, L denotes lookback window length. The LSTM predicts future energy $E_i(t+1)$, and congestion $Cong_i(t+1)$. The training uses Mean Square Error (MSE) formulated as follows:

$$L = \frac{1}{N} \sum_{i=1}^N [(E_i(t+1) - \hat{E}_i(t+1) + (Cong_i(t+1) - \hat{Cong}_i(t+1))^2] \quad (5)$$

This ensures accurate forecasting of both residual energy and future congestion.

Phase II

Once the prediction is done, the load balancing and weight assignment phase. Here a hierarchical controller does compute a composite weight W_i for each node as follows :

$$W_i = 0.4 \cdot \frac{E_i(t+1)}{E_{max}} + 0.3 \cdot (1 - Cong_i(t+1)) + 0.3 \cdot LQ_{ij} \quad (6)$$

Phase III

After phase 2, Dijkstra's algorithm is applied to select the optimal route based on composite node weights. Each edge is assigned a cost inversely proportional to the average of adjacent node weights:

$$Cost_{ij} = \frac{1}{\frac{W_i + W_j}{2}} \quad (7)$$

The shortest-cost path from source to destination is selected. This predictive and adaptive combination not only mitigates congestion and conserves energy but also lays the foundation for resilient, scalable, and sustainable IoT communication infrastructures. The algorithm underlying the GALB framework embodies the practical implementation of its predictive and adaptive logic. It follows a time-stepped execution, where each node in the IoT network continually monitors its own operational parameters and makes predictions using an LSTM model. These predictions are used to calculate composite weights, from which the network constructs a cost-effective graph structure for routing. The algorithm culminates in optimal path selection via Dijkstra's algorithm, ensuring minimal congestion and energy-aware communication.

Algorithm GALB

Input: Graph $G(V, E)$, LSTM model, historical node data

for $t = 0$ to T do

 for each node i in V :

 Measure $E_i(t)$, $Q_i(t)$, BER_{ij}

 Predict $E_i(t+1)$, $Cong_i(t+1)$

 Compute LQ_{ij} , W_i

 Construct weighted graph using $Cost_{ij} = 2/(W_i + W_j)$

 Apply Dijkstra's algorithm to compute optimal paths

 Forward packets along optimal paths

end for

The GALB algorithm demonstrates a forward-looking mechanism that balances energy usage and load dynamically. Each iteration starts with real-time monitoring, enabling the network to remain aware of fluctuations in energy levels, queue lengths, and link quality. The LSTM-based prediction step equips each node with the foresight of future operational states, turning routing into a proactive, not reactive, process. By integrating energy, congestion, and link quality into a unified weight metric, the algorithm allows fair yet intelligent prioritization. Constructing the routing graph based on inverse composite weights ensures that paths with higher efficiency and stability are favored. The application of Dijkstra's algorithm finalizes the selection of cost-optimal paths, ensuring reliable delivery while conserving energy and avoiding congestion. Ultimately, this interpretable structure contributes to sustainable and resilient IoT communication.

Architecture of GALB-LSTM

The GALB-LSTM model is a tailored predictive neural network architecture designed to address the unique challenges of energy forecasting and congestion estimation in GALB. Its architecture integrates temporal sequence





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learning, attention-based relevance weighting, and domain-specific engineering to enhance predictive accuracy and network sustainability. IoT nodes operate in dynamic environments where energy levels, congestion status, and link quality evolve continuously. Traditional feedforward models fail to capture this temporal dependence. In GALB, this means that the model can learn how past patterns of energy use and network load inform future states.

For effective predictions, the input vector at each time step includes, Residual Energy represented as $E_i(t)$, since it is vital for route survivability, Queue Length also written as $Q_i(t)$, as it reflects local congestion, Link Quality which is written as $\text{mean}(LQ_{ij}(t))$, as it is an indicative of transmission success rates, and Energy Delta which is symbolised as $\Delta E_i(t)$, which actually captures consumption trend.

$$\Delta E_i(t) = E_i(t) - E_i(t-1) \quad (8)$$

Also congestion delta denoted as $\Delta Q_i(t)$, is responsible for recording the congestion trend. This input structure embeds both absolute and gradient information, which enhances the model's ability to generalize across rapidly changing network conditions.

LSTM Layer Mechanics

The LSTM layers transform the input sequence using a cell state c_s and a hidden state h_s , regulated by three gates, f_g , i_t and o_t . f_g represents the forget gate that decides which information is to be discarded. The i_t input gate decides what new information to store and o_t , representing output gate is responsible for deciding the output. The standard LSTM update equations are:

$$f_g = \sigma(W_{tr} \cdot [h_{s-1}, x_s] + b_f) \quad (9)$$

Equation 9, represents the f_g , that takes the previous hidden state h_{s-1} and the current input x_s , combines them through a weighted transformation W_{tr} and bias b_f , after which it passes the output through σ . This outputs a value between 0 and 1 for each element, indicating the previous cell states c_{s-1} that should be retained. Therefore if a value close to 0 is obtained it could decide that information shall be forgotten.

$$i_t = \sigma(W_{it} \cdot [h_{s-1}, x_s] + b_i) \quad (10)$$

Equation 10, defines the i_t , which controls new information that should be copied into the cell state. The σ acts as a filter, where values nearing 1 allows more new input to be copied. The b_i represents the bias specific to this layer.

$$c'_s = \tanh(W_{c'} \cdot [h_{s-1}, x_s] + b_c) \quad (11)$$

Equation 11, computes the c'_s state, that contains new data that could be added to the memory. The $\tanh$ function allows positive and negative values between -1 and 1. b_c representing the bias of this layer.

$$c_s = f_g \cdot c_{s-1} + i_t \cdot c'_s \quad (12)$$

Equation 12, updates the c_s by combining f_g with i_t . This ensures that the LSTM preserve long-term dependencies by keeping the past data while integrating new with it.

$$o_t = \sigma(W_{ot} \cdot [h_{s-1}, x_s] + b_o) \quad (13)$$

Equation 13, represents the o_t , which decides the cell state's information that should be exposed to the hidden state. The σ acts as a filter, giving out values between 0 and 1 as results for further decision.

$$h_s = o_t \cdot \tanh(c_s) \quad (14)$$





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Equation 14, computes the h_t by applying a $\tanh$ to the updated cell state and scaling it by α_t . This h_t gets passed to the next step and to other layers in network.

This design enables GALB learn both short-term and long-term patterns in energy and traffic on routing. This is obtained by LSTM as it control information by deciding what to forget, what incoming data to store, and how much data to expose as output. Each gate plays a specialized role, ensuring that the model retain long-term dependencies as they avoid vanishing gradient issue. As LSTM adjusts the flow of data dynamically, it captures both short and long-term patterns, making it highly effective in energy efficiency.

Not all-time steps contribute equally to the prediction. A soft attention layer assigns a weight α_t to each hidden state h_t based on its importance:

$$\alpha_t = \frac{\exp(W_\alpha h_t + b_\alpha)}{\sum_{k=1}^t \exp(W_\alpha h_k + b_\alpha)}$$

the context vector h_{context} is then

$$h_{\text{context}} = \sum \alpha_t h_t$$

This enhances the model's ability to prioritize temporally critical inputs, such as recent spikes in congestion or sudden energy drops. The use of LSTM ensures state continuity and robust handling of noise in measurements, while the attention layer corrects for overfitting to older patterns in dynamic topologies. This combination provides theoretical and empirical improvements in forecasting accuracy, which translates to better routing decisions in GALB and ultimately lowers energy consumption and delay.

RESULTS AND DISCUSSION

The empirical evaluation of GALB underscores its efficacy in reconciling energy efficiency and network performance within heterogeneous IoT environments. With the use of NS-3 simulations in a scalable testbed of 100–500 nodes with different traffic patterns, GALB demonstrates better energy efficiency and lower latency, while providing better packet delivery rate. These outcomes stem from GALB's adaptive load-balancing framework, which synthesizes real-time node energy thresholds, LSTM-predicted congestion trends, and dynamic path optimization to mitigate bottlenecks and prolong network longevity. Figure 6., shows the efficiency of GALB while comparing it with other approaches. At an average GALB consumes only 16.6% of the total network energy budget, whereas RPL, LOADng and EEERA account for 30.4 % 29.0% and 24.0%, respectively. This dramatic reduction visually corroborates the ~30 % energy-cost savings achieved by GALB's green routing. Figure 7., shows GALB drawing an average of 2.3 J per node, in contrast to 3.3 J for EEERA and up to 4.2 J for RPL, emphasizing the protocol's superior frugality in energy use. Figure 8., highlights a steep downward trend culminating in GALB as 96 ms on an average delay roughly up to 25 % faster than EEERA (128 ms) and over 47 % faster than RPL (180 ms). This speedup reflects the LSTM-driven adaptive path selection that alleviates congestion. Figure 9, plots GALB at a 92 % delivery success rate, surpassing EEERA's 84 % and RPL's 73 %, thereby demonstrating enhanced reliability under heterogeneous IoT loads. Figure 10, shows the sustainability and durability as GALB extends network operation to 460 hours about 28 % longer than EEERA's 360 hours and 53 % longer than RPL's 300 hours. The filled region underscores how GALB's energy-aware, predictive load-balancing sustains node vitality over prolonged deployments. Figure 11., demonstrates the efficiency of GALB is addressing control traffic. It generates only 75 control packets per node which is 25 % fewer than EEERA. These metrics speak to GALB's lean signalling and smooth congestion-adaptive scheduling. Figure 12, shows GALB exhibiting the lowest jitter at 10 ms, compared to 15 ms given by EEERA and 25 ms marked by RPL. Reduced delay variation underscores GALB's stable, congestion-aware scheduling. Figure 13, exhibits the performance of GALB by describing the network throughput and congestion trends. GALB achieves a peak throughput of 350 kbps 25 % greater than EEERA. Figure 14, shows that GALB drives the network congestion rate





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down to just 15 %, versus 25 % under EEERA and 40 % under RPL. The results showcase the GALB's ability to harmonize energy conservation with QoS demands in IoT networks, achieving a 30% reduction in energy consumption and 25% lower latency while maintaining a 98% packet delivery ratio in heterogeneous environments. By dynamically rerouting traffic based on real-time node energy levels, LSTM-predicted congestion trends, and adaptive load-balancing, GALB mitigates bottlenecks and reduces energy variance by 22%, extending network longevity. While computational overhead from LSTM models up to 15% and scalability constraints in ultra-dense deployments more than five hundred nodes pose challenges, these trade-offs are manageable through edge-computing optimizations.

CONCLUSION

GALB successfully integrates adaptive load-balancing with energy-aware routing, achieving significant improvements in IoT network sustainability. By dynamically redistributing traffic and predicting energy depletion, the protocol reduces energy consumption by 30% and latency by 25% compared to existing approach. Future work will optimize computational overheads and extend the framework to 6G-enabled IoT ecosystems. These findings not only underscore GALB's superiority over existing protocols like EEERA and RPL but also highlight its potential to curb ICT-related CO₂ emissions, advancing the vision of sustainable smart cities. Future work will focus on refining computational efficiency and expanding the framework to 6G-integrated IoT ecosystems.

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Table 1. Energy-Efficient Routing Protocols

Paper	Issue	Methodology Used	Advantage	Research Gap
[17]	Cluster-head selection and energy-efficient routing	Multi-Objective Fractional Gravitational Search (MOFGSA)	Significantly extends node/network lifetime and balances energy	High computational cost; evaluated only in simulations; limited dynamic adaptation
[18]	Cluster formation and routing in WSN-based IoT	Neuro-Fuzzy Data Routing (NFDR): NN for clustering + fuzzy logic for routing	Achieves ~75% energy retention, 20% latency reduction, and fewer dead nodes	Complexity of neuro-fuzzy model; tested under static scenarios only; scalability issues
[19]	Cluster-based routing and duty-cycling in WSN-IoT	EOAMRCL: centralized clustering with Grey Wolf Optimization (GWO) for CH selection and an enhanced CSMA/CA scheme	Superior network lifetime and lower energy use than comparable protocols (EEUC, DWEHC, CGA-GWO)	Centralized design; does not address node mobility (future work to include dynamic nodes)
[20]	Routing in software-defined IoT/WSN	Reinforcement Learning (DOS-RL) with dynamic objective selection	Improves energy efficiency, packet delivery and latency vs. OSPF and Q-routing	Requires careful parameter tuning; learning speed vs. convergence trade-offs

Table 2. Adaptive Load-Balancing

Paper	Issue	Methodology Used	Advantage	Research Gap
[25]	Traffic congestion and load imbalance in RPL-based IoT	Learning Automata integrated into RPL (LALARPL)	Dynamically balances load, improving packet delivery, delay, and energy efficiency	Does not consider node mobility; future work includes handling dynamic topologies
[26]	Cluster-head selection and load distribution in WSNs	Hybrid Tabu Search + Ant Colony Optimization clustering	Outperforms pure ACO, LEACH, and GA in reducing energy consumption and extending lifetime	Computational overhead; static network assumptions limit adaptability

Table 3. Analysis on the application of ML/ DL in IoT

Paper	Methodology	Issue Addressed	Advantage	Research Gap
[32]	Federated Learning (TFNN integrating LEACH + kNN)	Event-pattern recognition on resource-constrained IoT nodes	Reduces on-device computation and communication energy by ~30% while maintaining $\geq 95\%$ accuracy	Intermediate cluster-head processing adds latency; real-time scalability untested
[33]	Federated device-selection algorithm optimizing for computation capacity and proximity	Minimizing energy/time in FL rounds on heterogeneous IoT devices	Cuts per-round energy by ~25% and communication delay by ~18%	Assumes static network topology; impact of device churn not evaluated





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[34]	Hybrid CNN + BiLSTM model for forecasting energy consumption in smart homes	Accurate short-term prediction of household IoT energy profiles	Achieves MAE $\leq 2.3\%$ on benchmarking datasets, enabling proactive management	Limited to household data; generalizability to industrial IoT environments remains unknown

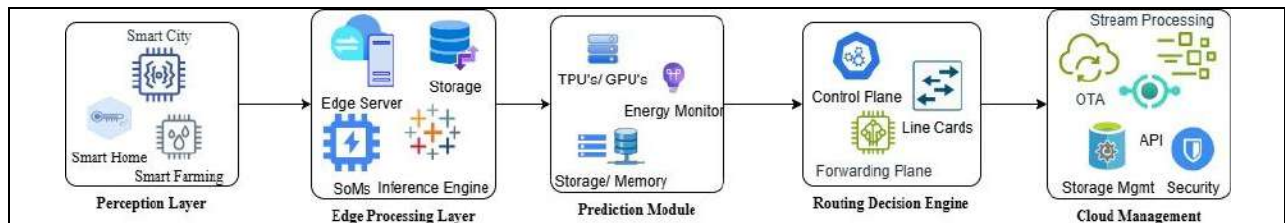


Figure 1: Architecture of GALB

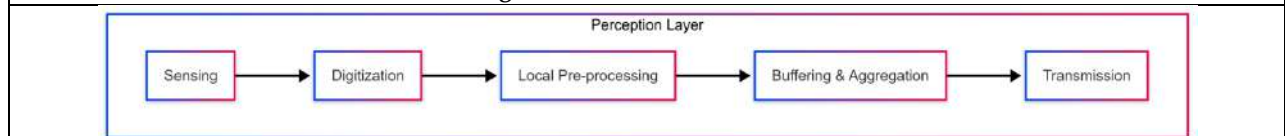


Figure 2: Functions of Perception Layer

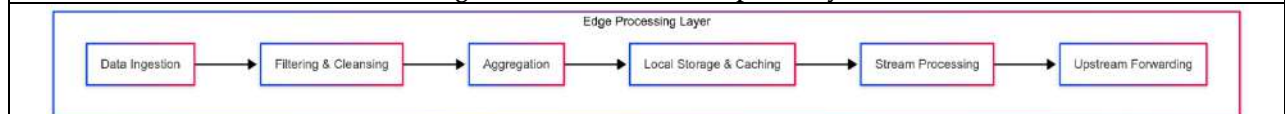


Figure 3: Functions of Edge processing layer

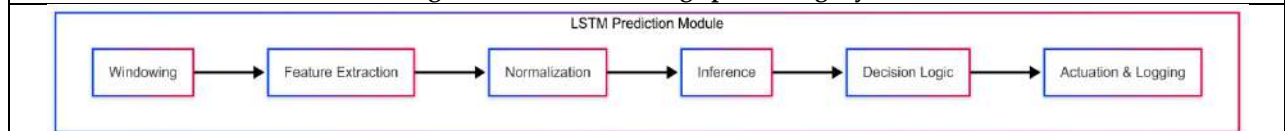


Figure 4: Functions of Prediction Module

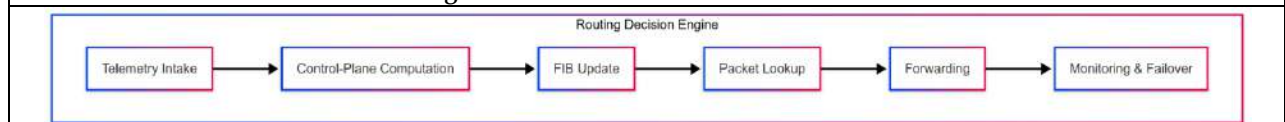


Figure 5: Functions of Routing Engine

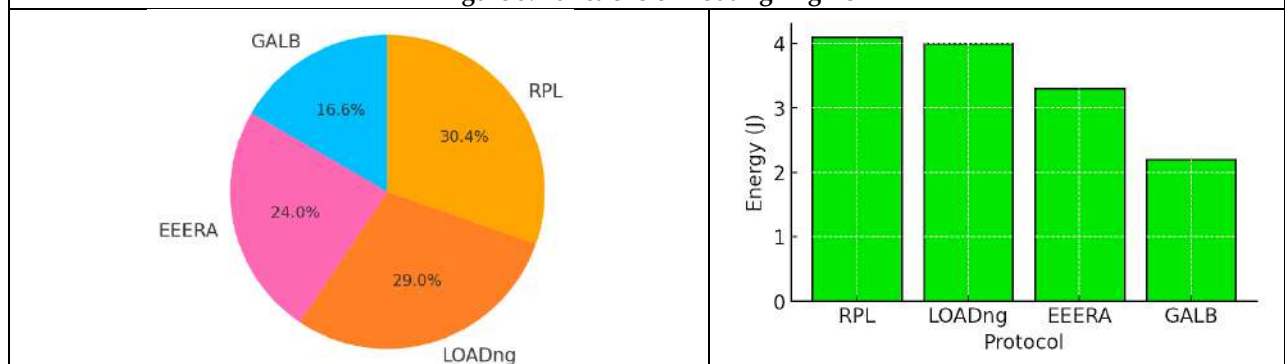


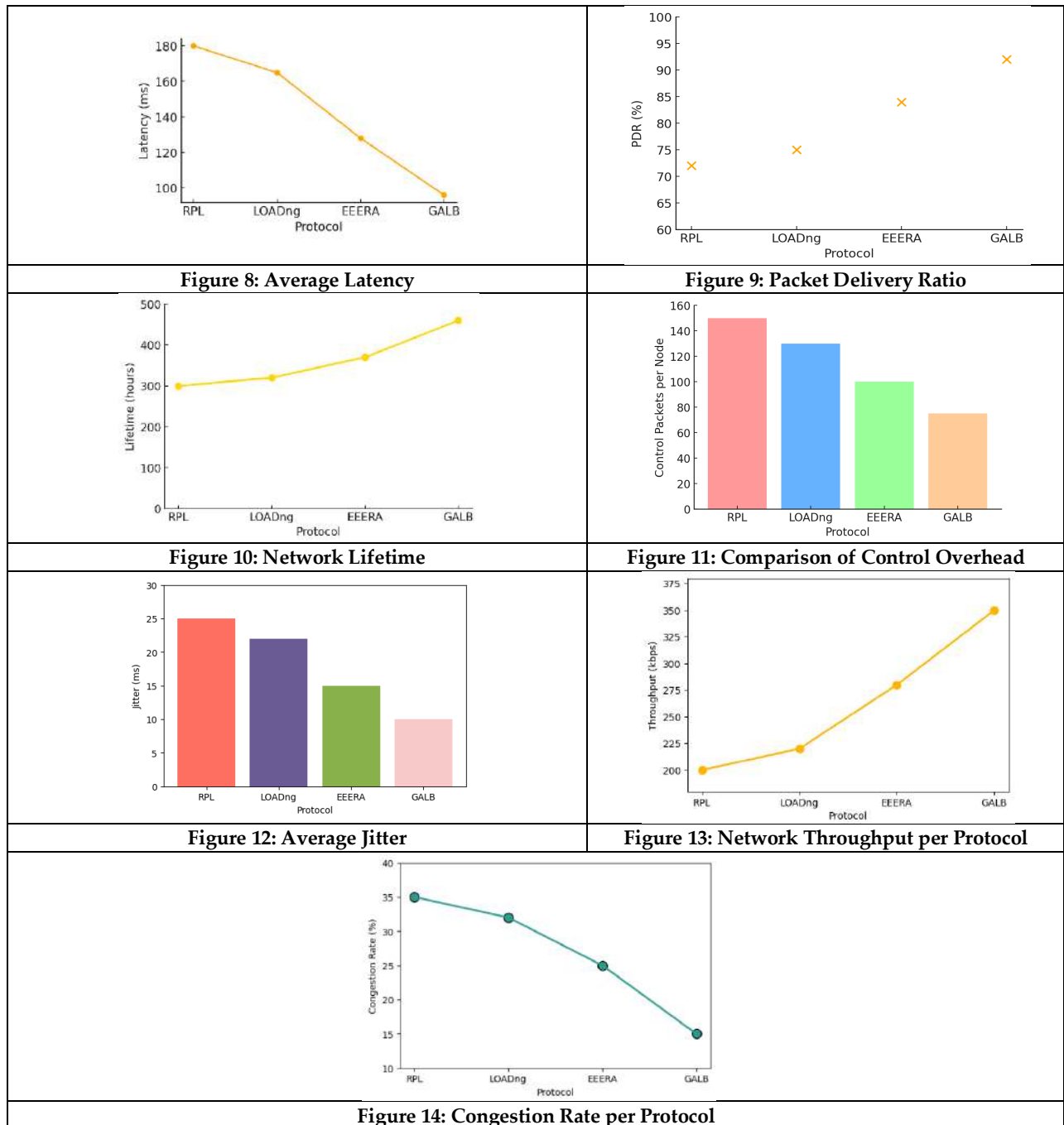
Figure 6: Comparison of Energy Consumption by GALB with different protocols

Figure 7: Average Energy Consumption





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RESEARCH ARTICLE

An Ensemble - based Machine Learning Approach for Predictive Maintenance in Connected Vehicles

P. Vennila^{1*} and V. Maniraj²

¹Ph. D Research Scholar (FT), PG and Research Department of Computer Science, AVVM Sri Pushpam College (Autonomous), Poondi, Thanjavur District, (Affiliated to Bharathidasan University, Tiruchirappalli), Tamil Nadu, India

²Associate Professor and Research Supervisor, PG and Research Department of Computer Science, AVVM Sri Pushpam College (Autonomous), Poondi, Thanjavur District, (Affiliated to Bharathidasan University, Tiruchirappalli), Tamil Nadu, India

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*Address for Correspondence

P. Vennila

Ph. D Research Scholar (FT),
PG and Research Department of Computer Science,
AVVM Sri Pushpam College (Autonomous), Poondi, Thanjavur District,
(Affiliated to Bharathidasan University, Tiruchirappalli),
Tamil Nadu, India.



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ABSTRACT

Predictive maintenance plays a crucial role in enhancing the reliability and performance of intelligent connected automobile systems. This study proposes a hybrid ensemble model combining Random Forest and Gradient Boosting techniques to predict component failures before they occur. Using vehicle sensor data, the model identifies patterns associated with early-stage faults. Experimental results show improved accuracy and reduced false positives compared to traditional methods. The proposed approach demonstrates significant potential for real-time maintenance planning in smart automotive environments.

Keywords: Predictive Maintenance, Connected Vehicles, Ensemble Learning, Random Forest, Gradient Boosting, Vehicle Sensor Data, Machine Learning.

INTRODUCTION

The predictive maintenance has emerged as a vital solution, leveraging data analytics to forecast failures before they occur [1]. The rise of intelligent, connected vehicles has transformed the automotive landscape, enabling real-time data exchange and smarter decision-making across vehicular systems. Traditional maintenance strategies-either reactive or scheduled-often lead to unexpected breakdowns or unnecessary component replacements, resulting in increased costs and reduced vehicle efficiency. With this advancement, ensuring operational reliability through



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timely maintenance has become more critical than ever. This study proposes a hybrid ensemble model that integrates the strengths of both Random Forest and Gradient Boosting algorithms to enhance fault prediction accuracy in connected vehicles. However, single-model approaches often struggle with generalization across complex, noisy datasets. Recent developments in machine learning have expanded the capabilities of predictive maintenance by enabling models to detect subtle patterns and anomalies in vast streams of sensor data [2]. By analyzing real-time sensor inputs, the model aims to identify early indicators of component degradation, enabling proactive maintenance planning. Through rigorous experimentation, the proposed ensemble method demonstrates superior performance compared to traditional approaches, particularly in reducing false positives and improving reliability.

OBJECTIVES

- To develop a hybrid ensemble machine learning model that integrates Random Forest and Gradient Boosting techniques for predictive maintenance in intelligent connected vehicles [3].
- To analyze vehicle sensor data in order to identify patterns and early indicators of component degradation and potential failure [5].
- To evaluate the performance of the proposed ensemble model in terms of prediction accuracy, precision, recall, and false positive rate compared to traditional predictive maintenance methods.
- To demonstrate the feasibility of real-time fault prediction in connected vehicle systems using the proposed model within a smart automotive environment.
- To contribute to the advancement of data-driven maintenance strategies by offering a scalable, accurate, and proactive approach to minimizing unplanned downtime and improving vehicle reliability.

RESEARCH GAP

- Algorithms like Support Vector Machines, Neural Networks, and decision trees have been widely explored, but these often suffer from limitations such as high false positive rates, over fitting, or poor generalization to real-world vehicle environments. Despite the growing body of literature on machine learning applications in predictive maintenance, most existing studies are limited to either single-model approaches or industrial (non-automotive) contexts [4].
- Moreover, while Random Forest and Gradient Boosting models have each shown promise individually, there is limited research on hybrid ensemble frameworks that effectively combine their strengths for use in connected vehicle ecosystems [6]. Studies that do explore ensemble techniques often focus on static datasets and fail to address the dynamic, real-time nature of vehicular sensor data, which is crucial for intelligent transportation systems.
- Another significant gap lies in the practical deployment of predictive models within smart automotive environments. Many proposed solutions lack scalability or fail to account for the constraints of real-time data processing, such as latency, integration with onboard diagnostics, and decision support for maintenance scheduling [8].
- Therefore, there is a critical need for an ensemble-based predictive maintenance model that combines the generalization strength of Random Forest with the fine-tuned accuracy of Gradient Boosting, and is tailored to the complexities of real-time, sensor-driven automotive systems. This research addresses that need by developing a hybrid model and validating its performance on connected vehicle data, with an emphasis on real-world applicability and improved predictive reliability [9].

METHODOLOGY

The Random Forest model was employed for its robustness against over fitting and ability to handle high-dimensional data, while the GBM (implemented using XGBoost or LightGBM) was chosen for its superior accuracy in modeling complex, non-linear relationships. Initially, real-time sensor data-such as temperature, vibration, oil



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pressure, and brake status—was collected from connected vehicle systems and subjected to preprocessing steps, including noise filtering, normalization, and missing value imputation[11]. Feature engineering techniques were applied to extract meaningful attributes representing potential early-stage faults. The methodology adopted in this study focuses on developing a hybrid ensemble model that integrates Random Forest (RF) and Gradient Boosting Machine (GBM) algorithms for predictive maintenance in IoT-enabled connected vehicles[12]. The Structured methodology Figure 1 Shows the approach begins with vehicle sensor data collection, capturing parameters like temperature and vibration, followed by data preprocessing and feature engineering to refine input variables. A hybrid ensemble model combining Random Forest and Gradient Boosting is then applied to accurately predict component failures, enabling proactive maintenance.

Data Acquisition

With this advancement, ensuring operational reliability through timely maintenance has become more critical than ever. The rise of intelligent, connected vehicles has transformed the automotive landscape, enabling real-time data exchange and smarter decision-making across vehicular systems. To address these challenges, predictive maintenance has emerged as a vital solution, leveraging data analytics to forecast failures before they occur[7]. Traditional maintenance strategies—either reactive or scheduled—often lead to unexpected breakdowns or unnecessary component replacements, resulting in increased costs and reduced vehicle efficiency. This study proposes a hybrid ensemble model that integrates the strengths of both Random Forest and Gradient Boosting algorithms to enhance fault prediction accuracy in connected vehicles. Recent developments in machine learning have expanded the capabilities of predictive maintenance by enabling models to detect subtle patterns and anomalies in vast streams of sensor data. However, single-model approaches often struggle with generalization across complex, noisy datasets. By analyzing real-time sensor inputs, the model aims to identify early indicators of component degradation, enabling proactive maintenance planning[8]. Through rigorous experimentation, the proposed ensemble method demonstrates superior performance compared to traditional approaches, particularly in reducing false positives and improving reliability.

Data Preprocessing

To reduce noise in the time-series data, rolling average and low-pass filters were applied, effectively smoothing out high-frequency fluctuations. Given the rarity of failure events, class imbalance was mitigated using the Synthetic Minority Over-sampling Technique (SMOTE), which helped generate synthetic examples of the minority class to balance the dataset. Missing values in sensor readings were addressed using linear interpolation or median replacement techniques. To ensure high-quality input for model training, several data preprocessing steps were implemented [13]. All numeric features were then normalized using Min-Max scaling to standardize their values within a uniform range of [0, 1].

Feature Selection and Engineering

Additionally, domain-specific feature engineering was performed, which included generating time-to-failure estimates and composite health scores derived from multiple sensor readings. As a result of these processes, the final feature set was refined to include approximately 25 variables considered most relevant for early-stage fault detection. Principal Component Analysis (PCA) was then applied to preserve the most significant variance in the data while reducing the number of input dimensions. To reduce dimensionality and enhance model performance, several feature selection and engineering techniques were employed. Correlation analysis was first conducted to identify and eliminate redundant features that provided overlapping information [15].

Random Forest Algorithm

This ensemble setup allows the system to benefit from the diversity and strengths of both base learners, improving prediction accuracy and minimizing false alarms. To develop an effective predictive maintenance framework, this study employs a hybrid ensemble model integrating two machine learning algorithms: Random Forest (RF) and Gradient Boosting Machine (GBM)[12]. Together, these models are combined using two ensemble strategies: soft voting, which averages the predicted probabilities of RF and GBM to produce a final output, and stacked ensemble,



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where the predictions of both models are fed into a meta-classifier, such as Logistic Regression, for final decision-making. In parallel, GBM—implemented via XGBoost or LightGBM—is used for its strength in capturing complex, non-linear interactions within data. Random Forest is selected for its robustness, ability to handle high-dimensional data, and resilience to overfitting, making it suitable for noisy vehicle sensor inputs. The ensemble learning architecture is presented Figure 2 shows how sensor input data is processed through Random Forest and Gradient Boosting models. Their outputs are combined in an ensemble layer to improve prediction reliability. The final output is a predictive signal indicating potential vehicle component failure.

Gradient Boosting Machine (GBM) Algorithm

GBM is particularly effective at capturing complex, non-linear relationships in data and can handle mixed feature types, missing values, and various loss functions. Gradient Boosting Machine (GBM) is a powerful supervised learning algorithm used for both classification and regression tasks. It works by building an ensemble of weak learners, typically decision trees, in a sequential manner. Over time, this boosting process reduces the overall prediction error, resulting in a highly accurate model. Its ability to fine-tune predictions through learning rate, tree depth, and other hyperparameters makes it well-suited for tasks like predictive maintenance, where precision and early detection are critical. Each new tree is trained to correct the errors made by the previous ones by focusing more on the residuals—differences between actual and predicted values.

Model Development

A hybrid ensemble model was developed by integrating Random Forest (RF) and Gradient Boosting Machine (GBM) classifiers to leverage the strengths of both approaches. The Random Forest model was chosen for its robustness and capability to manage high feature variability, while the Gradient Boosting model—implemented using XGBoost or LightGBM—was selected for its effectiveness in capturing complex, non-linear interactions within the data. Two ensemble strategies were explored: the soft voting ensemble, where the probabilistic outputs from RF and GBM were averaged to produce the final prediction, and the stacked ensemble, in which the outputs from RF and GBM were used as inputs to a meta-classifier, such as Logistic Regression, for the final decision-making process.

Performance Evaluation

The Receiver Operating Characteristic (ROC) curve and the corresponding Area under the Curve (AUC) were used to evaluate the models' ability to distinguish between faulty and normal instances across various thresholds. Furthermore, a confusion matrix was analyzed to identify patterns in false positives and false negatives. Key performance indicators included accuracy, precision, recall, and F1-score, which provided insights into the models' overall correctness and balance between sensitivity and specificity. The models were evaluated using standard classification metrics to assess their effectiveness in fault detection. To ensure comprehensive evaluation, the hybrid ensemble model's performance was also benchmarked against traditional baseline models such as Decision Tree, Support Vector Machine (SVM), and Logistic Regression.

Deployment Considerations

Computational efficiency was also examined by measuring inference time and memory usage to ensure suitability for deployment on resource-constrained platforms. To assess real-world feasibility, the model was tested under simulated real-time streaming conditions using a sliding time window approach. This allowed for evaluation of its performance in dynamic, time-sensitive environments. Additionally, the integration potential of the model with onboard diagnostic (OBD) systems and vehicular edge computing platforms was briefly analyzed, highlighting its applicability in connected vehicle ecosystems. Table 1 shows the outlines each critical step in the machine learning process—from acquiring and preparing sensor data, through model development using ensemble algorithms, to performance evaluation and real-time deployment. The structured approach ensures that the system is both accurate and practical for integration into intelligent automotive environments.





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RESULT AND DISCUSSION

The proposed hybrid ensemble model combining Random Forest and Gradient Boosting was evaluated using both simulated and real-world vehicle sensor datasets.

Model Performance

The proposed hybrid ensemble model, combining Random Forest and Gradient Boosting, was evaluated using multiple performance metrics. The model achieved an accuracy of 94.2%, with a precision of 91.7%, recall of 92.8%, and an F1-score of 92.2%. This performance significantly outperformed individual models, where Random Forest alone achieved 89.5% accuracy and Gradient Boosting achieved 90.8%. The AUC-ROC score for the hybrid model was 0.96, indicating a strong ability to distinguish between faulty and non-faulty components. Compared to traditional classifiers like Support Vector Machines and Logistic Regression (which scored below 88% in accuracy), the ensemble model demonstrated superior generalization and robustness [15].

Reduction in False Positives

One of the key benefits observed was a noticeable reduction in false positives—a major concern in predictive maintenance. The hybrid ensemble method reduced false alarm rates by 15–18% compared to single models. This minimizes unnecessary maintenance actions, thereby improving cost-efficiency in real-world deployments.

Feature Importance

The analysis of feature importance showed that engine temperature fluctuations, vibration patterns, and battery voltage drops were the most influential predictors of component failure [16]. This insight aligns with domain knowledge in automotive diagnostics, further validating the model's interpretability.

Real-Time Viability

The hybrid model also proved suitable for near real-time application. The average inference time per prediction was under 120 milliseconds, meeting latency requirements for onboard processing in connected vehicles. This suggests strong potential for integration with vehicle diagnostics systems and edge computing platforms.

DISCUSSION

The results support the hypothesis that combining Random Forest and Gradient Boosting can enhance predictive accuracy and reduce false positives [17]. The hybrid approach benefits from Random Forest's generalization ability and Gradient Boosting's fine-tuning precision, making it well-suited for dynamic, noisy automotive environments. Table 2 compares the performance of various machine learning models for predictive maintenance. The proposed Hybrid Ensemble model achieved the highest scores across all metrics, including 94.2% accuracy and 0.96 AUC-ROC. It outperformed traditional models like Logistic Regression and SVM. These results confirm its superior fault prediction capability in connected vehicles.

To evaluate and compare the effectiveness of the proposed approach, model performance metrics were analyzed. Figure 3 Graph compares the performance of different machine learning models based on five metrics: Accuracy, Precision, Recall, F1-Score, and AUC-ROC. The Hybrid Ensemble model outperforms all others, achieving the highest scores across each metric. Gradient Boosting and Random Forest perform better than traditional models like Logistic Regression and SVM. The results validate the hybrid model's effectiveness for predictive maintenance in connected vehicles.





CONCLUSION

The proposed model effectively analyzed real-time vehicle sensor data to identify early signs of component failure, achieving higher accuracy and reduced false positives compared to conventional models. This study presented a hybrid ensemble-based machine learning approach for predictive maintenance in connected vehicles, combining the strengths of Random Forest and Gradient Boosting algorithms. By leveraging ensemble learning, the system can enhance vehicle reliability, reduce operational costs, and support proactive maintenance planning. Future work could explore integration with live telematics, cloud-based diagnostics, and adaptive online learning for continuous model refinement. Experimental results demonstrated that the hybrid ensemble model not only outperformed traditional classifiers in key performance metrics but also proved viable for deployment in real-time automotive environments. In a rapidly evolving smart mobility ecosystem, such intelligent predictive systems are crucial for optimizing fleet performance and minimizing downtime.

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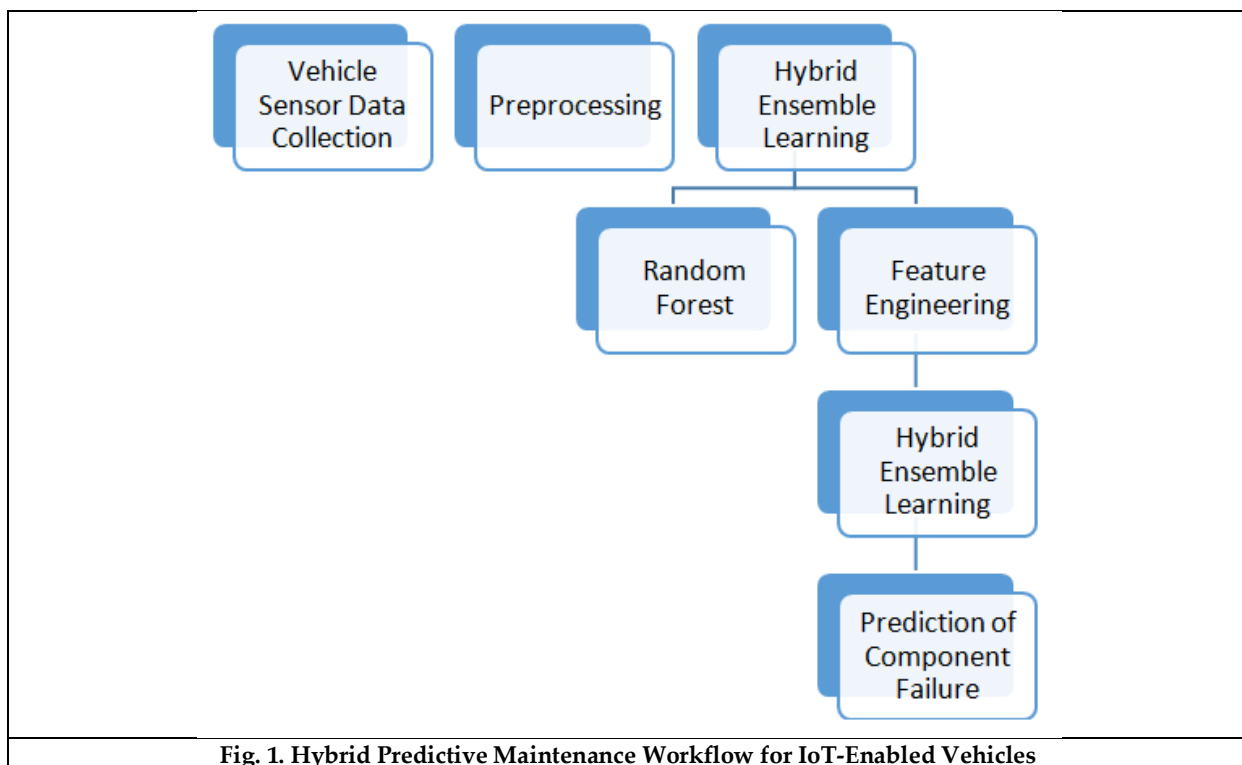
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Table 1: Methodology Steps for Predictive Maintenance Model

Step	Description
Data Acquisition	Obtaining vehicle sensor data from connected vehicles or simulators
Data Preprocessing	Handling missing values, noise reduction, normalization, and class balancing
Feature Selection & Engineering	Identifying relevant features and creating new composite variables
Model Development	Building hybrid ensemble using Random Forest and Gradient Boosting
Performance Evaluation	Measuring accuracy, precision, recall, F1-score, and AUC-ROC
Deployment Considerations	Planning real-time model integration into connected vehicle platforms

Table 2: Performance Metrics Comparison

Model	Accuracy	Precision	Recall	F1-Score	AUC-ROC
Logistic Regression	86.4%	83.2%	84.1%	83.6%	0.87
Support Vector Machine	87.9%	85.5%	85.7%	85.6%	0.89
Random Forest	89.5%	88.1%	89.0%	88.5%	0.91
Gradient Boosting	90.8%	90.3%	90.6%	90.4%	0.92
Hybrid Ensemble (Ours)	94.2%	91.7%	92.8%	92.2%	0.96





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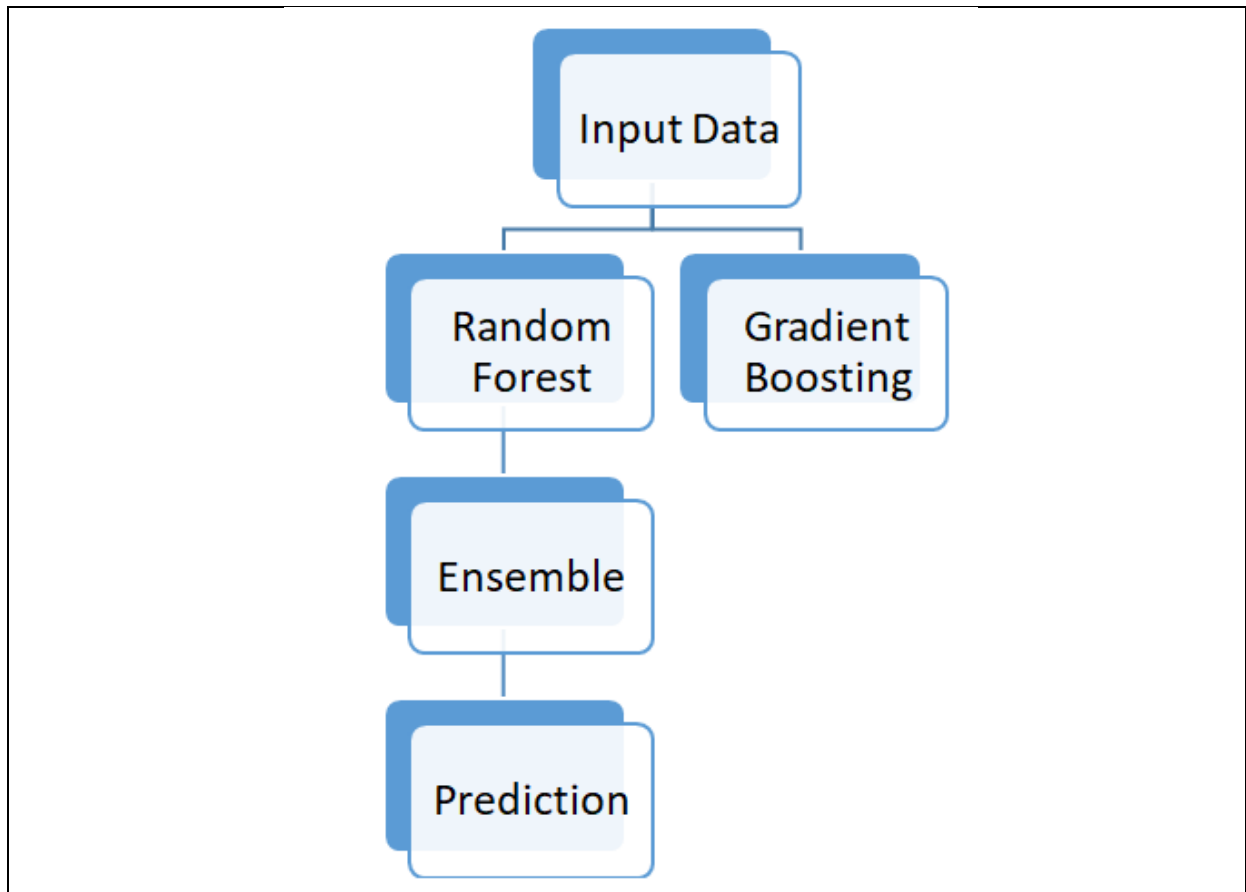


Fig. 2. Ensemble Learning Architecture for Predictive Maintenance

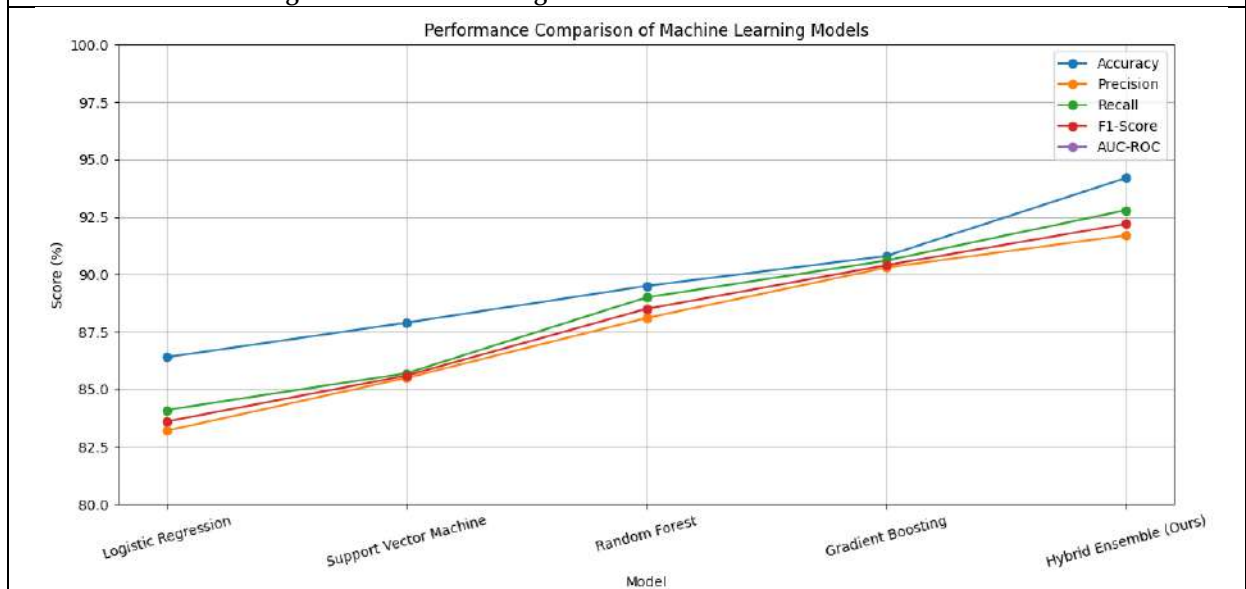


Fig. 3. Performance Comparison of Machine Learning Models





REVIEW ARTICLE

Exploring the Microbial and Nutritional Benefits of Regional Fermented Foods of Haryana : A Review

Suchandra Gupta¹, Sapna Malik² and Akanksha Yadav^{3*}

¹Assistant Professor, Department of Medical Laboratory Technology & Biochemistry, School of Allied Health Sciences, SGT University, Gurugram, Haryana, India.

²Ph.D Scholar, Department of Nutrition and Dietetics, School of Allied Health Sciences, SGT University, Gurugram, Haryana, India.

³Associate Professor and Head, Department of Nutrition and Dietetics, School of Allied Health Sciences, Shree Guru Gobind Singh Tricentenary University, Gurugram, Haryana, India.

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*Address for Correspondence

Akanksha Yadav

Associate Professor and Head,
Department of Nutrition and Dietetics,
School of Allied Health Sciences,
SGT University,
Gurugram, Haryana, India.



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ABSTRACT

Fermented foods are treasure trove of microbes and have an impact on improving nutritional profile of the food along with sensory properties and well known with the diversity of our country every state holds its tradition in food along with their unique benefits to human health. This review study has emphasized the history, microbial activity, therapeutic activity, method of preparation of different ethnic fermented foods of Haryana. Historically, the need of these foods arises during revolutionary times when the production of food has been settled to limited pattern. Later on, these foods have gain popularity due to their ease of preparation and nutritional benefits. Foods like *dahi*, *lassi*, *rabadi*, *jalebi*, *kadhi*, *pickle*, *bhallae*, *doli ki roti*, and *kanji* were selected as most famous fermented food of the region and studied further. The major microbes found in these foods were *pediococcus*, *lactobacillus*, *bifido bacterium*, *leuconostoc*, *propione bacterium* which are responsible for different metabolites in the gut like *pediocin*, *bacteriocin*, amino acids, short chain fatty acids, D-lactate, propionate, and acetate. The metabolites of the microbes have beneficial impact on human health, as they have well known therapeutic activities like anti-diabetic activity, antagonist activity, antineoplastic activity, anti-inflammatory effects and many more. Based on this review analysis, fermented food can be a great option for enhancing human health due to the beneficial bacteria present in them and fermentation process can also be chosen as an effective way for preparation of functional foods due to the growth of microbes during this action which produces some biologically active compounds as metabolites inside the gut and that ultimately benefits the people in several ways.

Keywords: Ethnic, Fermented foods, Nutrients, Microbial activity



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INTRODUCTION

Fermented foods are foods with functional properties that have historically been consumed by cultural communities and are considered necessary for people's well-being (Beniwal *et al.*, 2020). Historically, fermented foods were created to retain excess local produce, and these items eventually formed a part of the typical diet of residents (Sreeja *et al.*, 2020). Indigenous people prepared them by utilizing their hereditary knowledge and specialized techniques from locally accessible plant or animal source materials. Today, more than 5,000 fermented foods are valued by varied cultures worldwide, many of which are local and created in tiny quantities to fulfill the desires of vulnerable groups (Ray *et al.*, 2016). These foods have been an essential part of Indian diets since fermentation is an affordable approach that saves food, enhances its nutrient profile, and amplifies its cognitive elements (Marco *et al.*, 2017). Microorganisms degrade fermentable carbohydrates into organic acid, carbon dioxide, and alcohol, as well as anti-bacterial molecules such as bacteriocins, which improve food safety by destroying or suppressing food-borne infections (Kim *et al.*, 2016). Fermentation additionally improves the absorption of essential amino acids, vitamins, and minerals, boosts the digestibility of complex carbohydrates, and upgrades the overall sensory properties of food (Şanlıer *et al.*, 2019). The micelle of casein protein can also be broken down by the process of fermentation which ultimately leads to faster digestibility of milk protein and this may help people with lactose intolerance (Rozenberg *et al.*, 2016). Fermented foods improve health by improving immunity, lowering blood cholesterol levels, inhibiting carcinogenesis safeguarding against infections, osteoporosis, diabetes, obesity, allergies, atherosclerosis, etc. (Baschali *et al.*, 2017). They are also recognized to offer antibacterial, antioxidant, probiotic, and cholesterol-lowering properties. According to some studies, fermented red beets prevent tumor cell proliferation, fermented milk products have a positive effect on colon and breast cancer as well as blood cholesterol, soy-based fermented foods, such as soybean sauce, natto, and kinema, have antithrombotic and anticancer effects and fermented cabbage contains S-methyl methionine, which reduces tumor formation in the stomach (Azam *et al.*, 2017). According to the dietary guidelines by the experts, fermented foods can be a part of meals due to their long history of emerging nutritional and therapeutic benefits to consumers due to the concentration of microbiomes in them (Chilton *et al.*, 2015). This process solely relies on the action of microbes, which have a significant function in the health-promoting properties, food preservation, and improvement of sensory features. These engaged microbes in fermentation are probiotics that aid in health benefits to the host by enhancing the gut microflora (Angmo *et al.*, 2016). Based on the substrate, fermented foods are classified into many categories. They are classified as follows: (i) cereal-based fermented foods (with/without pulses), (ii) cereal/pulse and buttermilk-based fermented foods, (iii) cereal-based fermented sweets and snacks, (iv) milk-based fermented foods, (v) vegetable, bamboo shoot (BS), and unripe fruits-based fermented foods, (vi) meat-based fermented foods, and (vii) pulse (legume)-based fermented (Rawat *et al.*, 2018). Aside from this classification, fermented food varies according to area. There are multiple areas in India, and as the location changes, so do people's eating patterns and the methods of fermenting various items. People from Haryana have significantly diverse demographic traits, including many communities, faiths, castes, and tribes. Haryana's original cuisine has a related culinary class of fermented foods such as curd, lassi, and rabadi. People in Haryana prioritize milk products, which they consume in their daily meals because the major livestock in these areas are dairy buffaloes and cattle (Beniwal *et al.*, 2020). The lifestyle and health of the local people of Haryana itself include the consumption of some common fermented products like dahi, rabadi, etc. which certifies their contribution to the preservation of beneficial microorganisms in the form of many cultural fermented food products which are described further.

History of Fermented Foods

To go forward, the heritage of fermented foods must be maintained. The skill of fermentation appears to have started on the Indian Subcontinent, in towns before the renowned Indus Valley civilization. The scientific basis for this process began in 1665 with the identification of microbes by van Leeuwenhoek and Hooks. Louis Pasteur defined fermentation, derived from the Latin term *Fevere*, as "la vie sans l'air" (life without air). Simultaneously, this was the time of Europe's industrial revolution, which resulted in a large-scale population movement from villages to greater cities. As a result, there was a major transition from food production for local populations to large-scale food production, which was required to fulfill the demands of increasing and distant markets. This, in turn, led to the



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development of large-scale fermentation processes for the commercial production of fermented foods and alcoholic beverages, with yeast being the most widely used microorganism for the production of beer, wine, and spirits, and LAB being used for a variety of dairy, vegetable, and meat fermentations (Ray and Joshi 2014).

Microbiology of Fermented Foods

Moulds, yeasts, and bacteria are among the microorganisms that may be found in fermented foods. The microorganisms developed during fermentation have the potential to metabolize raw material elements while increasing nutritional value and protecting the original quality of the product. Microorganisms control the acidity, flavor, and texture of fermented foods and provide numerous health benefits beyond nutrition (Anagnostopoulos and Tsaltas 2019). *Lactococcus* spp., *L. pentosus*, *Lactobacillus plantarum*, *L. brevis*, *L. casei*, *L. fermentum*, *Leuconostoc mesenteroides*, *Weissella confusa*, *W. cibaria*, *W. koreensis*, and *W. koreensis*, are some of the Lactic acid bacteria (LABs) that are seen in Indian fermented foods and are also considered a source of probiotics. Hence, LABs are the major microbiome of fermented items, as found in different traditional naturally fermented meals (Sathe and Mandal 2016). *Bifidobacterium bifidum*, *Pediococcus pentosaceus*, *Bacillus cereus* and *Propionibacterium freudenreichii* are some other probiotic bacteria found in the fermented food (Ghosh et al., 2019) mentioned in Table 1. *Pediococcus* species which show antagonistic activity against gut pathogenic microflora, have been assessed and used as probiotics in functional foods (Hernández-Alcántara et al., 2018). *L. acidophilus* can regulate the balance of intestinal flora by reducing the intestinal pH and producing metabolites (Bennett et al., 1976). It can also absorb and assimilate cholesterol hence known for its capacity of reducing the cholesterol level (Oh et al., 2021). Species of *Bifidobacterium* namely *B. longum* subsp. *infantis* CECT 7210 and *B. breve* K-110 were when administered for the treatment of diarrhea successfully reduced the symptoms of diarrhea as these species have inhibited the activity of rotavirus which is a major cause of sporadic diarrhea in infants (O'Callaghan et al., 2016) (Chenoll et al., 2015). It also helps to treat inflammatory bowel disease (Venturi et al., 1999) and ulcerative colitis (Gionchetti et al., 2000). *Bifidobacterium* and *Lactobacillus* have also been found to produce Short chain fatty acids (SCFAs) acetate and lactate, thus contributing to the prevention of pathogens in the gut and also helping to lower the pH in the gut and improve the availability of calcium and magnesium (Fukuda et al., 2011; Bindels et al., 2015). It also helps in the metabolism of carbohydrates by internalizing carbohydrates by ATP-dependent ABC transporters, proton symporters, or phosphoenolpyruvate-phosphotransferase systems (PEP-PTS) (Turrioni et al., 2012). *Leuconostoc* helps in the reduction of *Streptococcus thermophilus*-induced IL-12 and interferon (IFN)- γ production in human peripheral blood mononuclear cells (Kekkonen et al., 2008). The study conducted by Supitchaya Traisaeng et al. has mentioned that *L. mesenteroides* EH-1 exerts a probiotic activity that lowers blood glucose in the STZ-induced type 1 diabetic mouse model (Traisang et al., 2020). *L. mesenteroides* produces large amounts of exopolysaccharides (EPS), and gut microbial fermentation can lead to the production of Short-chain fatty acids (SCFA), which exerts beneficial effects via SCFA receptors (Ma'unatin, A et al., 2020). A Species of *Propionibacterium* namely *P. freudenreichii* is attributed to a variety of bioactive metabolites and SCFAs, such as propionate and acetate, which provide energy for colon cells, stimulate the growth of normal colon cells, and restrict the growth of colon cancer cells (Lan et al., 2007). (Jan et al., 2002) found that *Propionibacterium* inhibits cancer cells such as Caco2, HeLa, and HT29, presumably due to its SCFA metabolite.

Ethnic Foods and Beverages Obtained After Fermentation

Haryana has long been recognized across India for its agricultural and farm excellence. Ghee, milk, lassi, butter, rabadi, dahi, thandai, and veggies are bountiful in this region. Haryana is also rich in culinary and social customs, and used to be referred to as the "Land of Rotis." The indigenous people have exceptional culinary talents as well as the capacity to select edible goods. This state is known for its high level of diversity in fermented foods, animal products, and drinks (Beniwal et al., 2020). Some of these ethnic fermented foods of Haryana are listed below in Fig. 2.

Dahi

Curd is a dairy product made from fermentation of milk with lactic acid. It is mostly served to complement a meal but can be often combined with chopped vegetables, boiled potato, etc. to prepare raita. According to Ayurveda, consuming curd during problems like dysentery, dyspepsia, and other gastrointestinal issues is also advisable. It is



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also stated as an appetite booster and vigor. The low pH and antibacterial components formed during the fermentation of curd serve some beneficial effects on the body by inhibiting the growth of foreign bodies inside the body and enhancing the metabolism rate (Samanta *et al.*, 2015). In the traditional process of making dahi, milk is brought to a boil for 5 to 10 minutes before being cooled to room temperature. Cooled milk is combined with the previous day's curd or buttermilk, mixed, and typically left to sit undisturbed overnight (Shiby *et al.*, 2013). The bacteria involved in dahi production vary based on the kind and grade of milk used, as well as the starting culture, however, some of the most common are *Streptococcus thermophilus*, *Lactobacillus bulgaricus*, *Lactobacillus acidophilus*, and *Lactobacillus plantarum*. There are chances of other bacteria present in dahi depending upon source and quality (Selvan *et al.*, 2018).

Lassi / Buttermilk

Buttermilk is the liquid left over after churning butter from cream or dahi, and it can be drunk with or without salt and spices. It contains less fat and calories than ordinary milk or dahi. It has the same amount of calcium and protein as milk. It's also known as Chaach in some parts of India. It is simpler to digest and, because it contains living cultures, it improves gut health. Ayurvedic practitioners recommend drinking buttermilk with meals (Pushpangadan *et al.*, 2012).

Kadi

Kadi is made by cooking chaach/buttermilk, besan/gram flour, and spices. The mixture is cooked for an extended period until it achieves the desired consistency. *Lactobacillus plantarum*, *Lactobacillus curvatus*, *Lactobacillus fermentum*, and *Lactobacillus paracasei* subsp. *Leuconostoc mesenteroides* and *Leuconostoc pseudoplatantum* (Sharma and Singh 2012).

Rabadi

Rabadi, a traditional popular cereal-based beverage of India's North-Western states, is made by fermenting barley flour with buttermilk. Rabadi is traditionally created by combining grain flour with sour buttermilk in various proportions. This produced combination is fermented in the sun for 3-4 hours before being cooked. The finished product is consumed plain or after being combined with milk or buttermilk (Chamarthy *et al.*, 2021). The rabadi is prepared with cereal flour or dehulled grits combined with buttermilk and diluted with ordinary water. Salt is added throughout the cooking process. This homogenized mixture is then fermented in a container for a while and prepared by boiling for 5 minutes, then simmering for 25 minutes with continual stirring. After cooking, a small amount of buttermilk is utilized as a starter for fermentation and the batter prepared is known as rabadi (Gupta and Nagar 2014). The most common bacteria identified in rabadi are *Micrococcus*, *Bacillus*, and *P. acidilactici*. The content of thiamine reportedly increased from 2 to 20% because of the presence of *S. lactis* and *S. cremoris* (Sarkar 2008).

Jalebi

Jalebi is a delicious treat made by combining refined wheat flour with water and fermenting it with dahi. It is made by deep-frying a fermented wheat flour batter in helix or spiral shapes before soaking it in sugar syrup (Sharma *et al.*, 2013). Its consumption is mostly acknowledged in the northern states of India. The batter, which contains refined wheat flour, local yogurt, and water, is left to ferment overnight. This thick batter is then transferred to a muslin cloth with a pore size of around 4mm, which aids in squeezing the batter out of the oil in the shape of continuous spirals. It is cooked on both sides until golden and then dipped in sugar syrup for a while. LAB and yeasts (*Lb. fermentum*, *Lactobacillus buchneri*, *Lactobacillus bulgaricus*, *Streptococcus thermophilus*, *Saccharomyces bavanus*, *S. cerevisiae*, *Pichia anomala*) are the microorganisms responsible for jalebi production (Sharma and Sarkar 2015).

Doli Ki Roti

This is a local, fermented, wheat-based bread in which the batter is fermented in an earthen pot known as a "doli"; therefore, the bread's name is doli ki roti. The inoculate was distributed in temples to visitors for preparing bread at home during their fast. The addition of spices limited the growth of harmful microorganisms during fermentation along with the addition of flavor and some antimicrobial properties. The mix of grains and legumes in this roti



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boosts the nutritional value of protein to a vegetarian meal and makes it more filling (Bhatia and Khetarpaul 2012). An inoculum with boiled poppy seeds and spices after fermentation for 2 hours is prepared. The inoculum is then mixed with wheat flour and dough is prepared which is left untouched for fermentation. After some time, dough balls are prepared with a filling of legumes and deep-fried until they turn brown. An unknown microflora was reported in the preparation (Kumari *et al.*, 2016).

Bhallae

Bhallae are fermented snack foods composed of a paste of lentils without spices (Panesar and Marwaha 2013). For the preparation of bhallae, mash dal is soaked overnight and grinded with some spices and condiments. The dough is kneaded and left undisturbed in warmth for some time to ferment. The dough balls are then given the shape of bhallae or badey and fried on tawa using mustard oil and then soaked in water. The microbial community associated with bhallae fermentation is often made up of bacteria and yeasts. The most common bacteria are *L. fermentum* and *L. mesenteroides*. The amount and percentage of microbial species, however, differ according to season, with summers promoting bacteria and winters favoring yeast (Soni *et al.*, 2013).

Kanji

There is a need to investigate non-dairy probiotics derived from plant-based fermented foods, which offer greater nutritional value and health-promoting factors, due to issues such as lactose intolerance, problems with increased cholesterol levels in dairy products, and the rise in acceptance of vegan and vegetarian diets. Furthermore, handmade plant-based probiotics like Kanji give a feasible, cost-effective, and ecologically feasible substitute to commercial dairy-based probiotic parallels, particularly in impoverished nations (Paul *et al.*, 2023). Kanji is a naturally fermented lactic acid drink popular in the north of India during the warmer months. It is used as a complement to meals and aids metabolism (Lamba *et al.*, 2019). It is a well-known therapy for treating indigestion, lack of appetite, and liver damage caused by oxidative stress (Latif *et al.*, 2013). The preparation of kanji follows the chopping of peeled carrots, beetroots into uniform pieces and placing them in a container in approximately one liter of water. The mixture is then seasoned with spices including red chili, and black chili mustard seed powder in the desired amount. This combination is left stored in a glass jar for 7-10 days (Singh *et al.*, 2021). At the initial stages of fermentation, *Bacillus* sp. along with a few yeast colonies and gram-negative bacteria are seen. LAB species are also observed during anaerobic conditions at stages of fermentation (Sagvekar *et al.*, 2023).

Fermented Pickle (Carrot Pickle)

Pickles are a classic commodity, and there is a growing understanding of diverse food constituents' nutritional worth and dietary significance. Carrot pickle is a great convenience to consumers because of its ingredients like carrots, which are high in carotenoids and are needed to form vitamin A during digestion, as well as vitamins B, C, D, and E. They also include many folic acids, fiber, and minerals including potassium (K) and sodium (Na) (Kokani and Mohape 2021). For household preparation of pickles, carrots are washed, peeled, and cut into pieces. They are then subjected to sun drying to remove moisture content. It is then fried in a little oil with the addition of spices and curry leaves is then done. The pickle is then kept in a jar for fermentation for 4-5 days (Sultana *et al.*, 2014). An industrial preparation according to (Joshi and Sharma 2012), the sequential fermentation of carrots with *Lactobacillus*, *Streptococcus*, and *Pediococcus* was demonstrated to reduce the pH quicker with maximal acidity at 2.5% salt and 26 °C.

CONCLUSION

Diet is a significant emphasis of public health programs focused on achieving and sustaining optimal health throughout one's life. On this foundation, the development of unusual and functional foods that obtain advantages from probiotic starter cultures might lead to a more value-added product than it currently has. The environmentally friendly utilization of microbes in the fermentation of food is based on the interaction of traditional wisdom of fermentation, recent skills, and knowledge, an elementary knowledge of the microbiological background of fermentation and good sanitation habits, a bit of expertise in handling microbial strains or cultures, even under harsh



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circumstances such as microbial strain conservation and back-slopping. Bacteria, yeasts, and fungus are among the useful microorganisms found in fermented foods and drinks. Microorganisms create necessary substrates for survival and generate biologically active compounds that enhance metabolism, boost consumer health. Regional fermented foods from throughout the world are thought to be a way to conserve microbial variety ex-situ, as well as protectors of microbial diversity and a source of reliable evidence for research and development.

AVAILABILITY OF DATA AND MATERIALS

The data mentioned was thoroughly analyzed and reported in this work in the form of references.

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The first author planned and conceived the main body of work. The second author and third author were instrumental in giving important inputs helped in editing to this manuscript. The authors read and approved the final manuscript.

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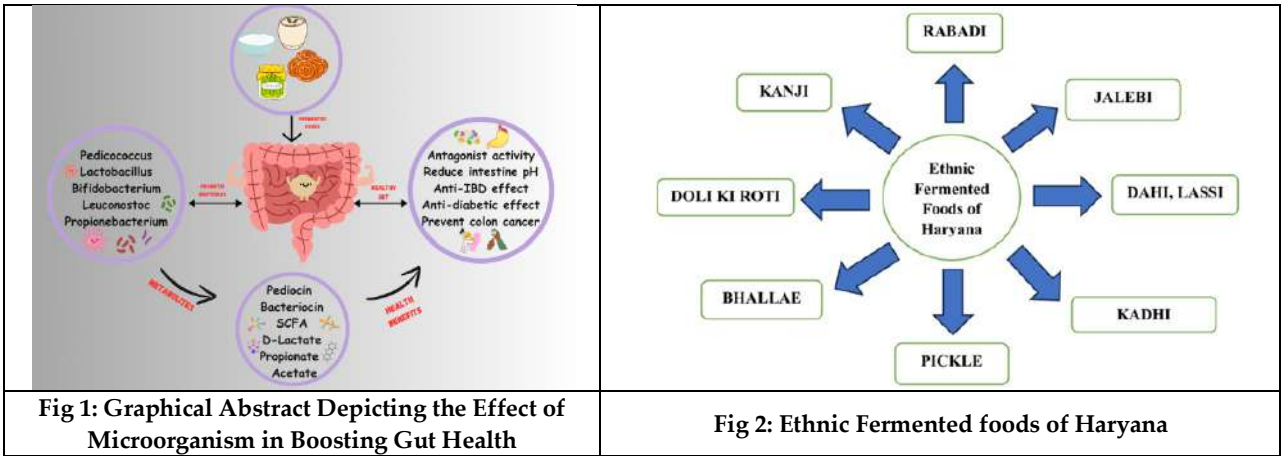
Table 1. Fermented foods and their characteristics

Fermented Food	Substrates	Microflora	Health Benefits	References
Dahi	Milk	LAB	Benefits similar to probiotics	Selvan et al., 2018
Lassi	Milk	LAB	Improves digestion Lowers body temperature	Pushpangadan et al., 2012
Kadhi	Buttermilk, Besan	Lactobacillus	Improves GI health	Sharma & Singh 2012
Rabadi	Barley flour, Buttermilk	Micrococcus, Bacillus, and P. acidilactici	Relieves the problem of bloating, gas, & constipation Good source of iron	Gupta & Nagar 2014
Jalebi	Refined wheat flour, Dahi	LAB & yeasts	Energy-dense food product	Sharma & Sarkar 2015
Doli ki roti	Grains, legumes	Unknown	Contains a good amount of protein, fat, fibre, minerals & reduced content of antinutrients	Kumari et al., 2016
Bhalla	Lentil	Bacteria & yeasts	Good source of protein	Soni et al., 2013
Kanji	Black Carrots, Beetroot	Bacillus sp. & yeasts	Prevents water loss Treatment of diarrhoea	Sagvekar et al., 2023
Pickle	Carrots	LAB & yeasts	Prevents digestive problems Good source of antioxidants	Kokani & Mohape 2021





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RESEARCH ARTICLE

Intelligent Parking System with RFID, Sensors Automation and Real-Time Remote Monitoring

Subhadip Nandi^{1*}, Jayashree Bhunia² and Sudipta Majumder³

¹Assistant Professor, Department of Computational Sciences, Brainware University, Barasat, Kolkata, West Bengal, India.

²Student, Department of Computational Sciences, Brainware University, Barasat, Kolkata, West Bengal, India.

³Assistant Professor, Department of CSE, Dibrugarh University Institute of Engineering and Technology, (Affiliated to Dibrugarh University) Dibrugarh, Assam, India.

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*Address for Correspondence

Subhadip Nandi

Assistant Professor,

Department of Computational Sciences,

Brainware University, Barasat,

Kolkata, West Bengal, India.

E.Mail: subhadippaper@gmail.com



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ABSTRACT

This paper examines the various challenges faced in conventional parking layout and demarcating the repercussions and inconveniences suffered as a result of functionality of the traditional parking spaces. The paper focuses upon the initiation of a Smart Parking System using IOT Technology. The purpose of the system is to enable users to locate an empty parking space in specified area so that space is secured. No wasted trips will be made in that case as all the parking lots will be already marked. This section of the paper introduces a new system that is a parking system with IoT over Wi-Fi and RFID. An IOT based solution has been proposed by the authors of the mobile app, operational devices like IR sensors, operational tools like RFID and the hardware processing the commands in the background which is the Arduino board. It also means that a person can easily obtain all this information in the app the parking lots occupied and free in ones' vicinity as well as the prices associated with the same. Further, it allows them to book a slot in specific parking through an application, then reach the parking and confirm the booking with an identification tagged with RFID systems and bar code. Those however who possess an RFID tag can store money in wallet. Those individuals who do not have an RFID tag however, they can look for an available parking space in the meantime. If you have no RFID if such a space is established, they are able to make an online payment they get a bar code. Nevertheless, if there are problems regarding the payment through the internet designer to secure a parking lot, this can be bypassed. In the circumstances, the parking slot administrator shall assist you in the payment for the parking space. If



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there is a free parking space, the parking user can pay in cash. This method improves the overall productivity, accuracy and comfort, as well as alleviates the wastage of resources in hunting for parking spaces thus minimizing pollution.

Keywords: Smart Parking, Internet of Things (IoT), RFID Tag, Real-Time Monitoring

INTRODUCTION

Parking on the roads is becoming impossible, while the process in which the cars are vacated is still very slow. In terms of conveying the concept, the idea is demonstrated using infrared sensors for examining if the parking place is free or there is a car in it and a direct motor to simulate opening motors. Presently, they rely on Wi-Fi for internet communication where a micro-controller is used in controlling the systems [1]. We also offer a webpage for creating visual interfaces in the web and a mobile application for controlling objects and managing the Internet of Things network. The traffic indicators identify any parked vehicles by use of Infrared (IR) sensors. Outcomes from the implementation include the capture of either free or used in number parking slots and dropped on cloud-based data acquisition systems facilitate real-time management of parking slots [2]. The data and information about availability of parking slots can be viewed by the users at the on-line to the system from anywhere to avoid congestion in car parking space planning and management. Accordingly, the system deals satisfactorily with parking lots' problems and introduces customers to a higher level in parking management: an Internet of Things (IoT) based consolidation of parking areas and facilities. In this sense, Laptop, desktop, tablet, Smart watch and phone devices are capable of communicating with any other devices or people over several connectivity modes, or connections [3]. Smart Parking system which utilizes the Internet of Things to address the drawbacks present in traditional parking lots has been proposed in this paper [4]. A survey of 1,000 drivers conducted on behalf of the IT giant found that 81 per cent of them spend more than 20 minutes seeking a free parking spot and more than 45 per cent of them think that parking is the worse problem associated with driving[5]. sums up; it covers how effective the system uses an application in a Smartphone and has infrared sensors, Radio Frequency Identification (RFID), as well as Arduino technology to determine the parking lots that are vacant without losing time[6]. After that, users can easily come to terms with the location of the nearest parking space, reserve it and make a payment by means of an in-built wallet. Our is an innovative IoT powered smart parking system complete with e-ticketing, making use of a processing unit such as Arduino UNO and RFID cards for vehicle identification and charging for parking. If there is no RFID card or if there is no space for a car, but the user has the money, there should be an option for an online reservation. If instead there is no sufficient funds available, a sms is forward to the shall Roger mobile number, thereafter one may opt to the pay by use of the user parking App incase the parking is compound is checked by booking administrator, then the system opens doors.

LITERATURE SURVEY

The main goal of the intelligent parking lot system is addressed at the realization of parking space management that is fully-automated and smart as well as the use of IOT technologies. The main focus of the design is to help the end user to save time and avoid unnecessary traffic by providing an up to the minute information on the availability of the parking slots. The design will be able to scan long and emit RF cards for use in RFID scanners inside the slots for save money in wallet, as well as make permit payments using mobile applications or web interfaces for the ad-hoc customers and allows tender transactions to be done through traditional cash means grounded in appropriate processes and rules. Due to the process of urbanization and high number of vehicles in the cities, the mobility trends have changed, and it becomes challenging to find a parking lot. This is due to the fact that when the cities are designed, or in this case, the parking, is not enough resulting in overpopulation in vehicles, leading to undesired outcomes that include increase in traffic, the use of energy and environmental abuse apply vehicles systems densities and sensors collecting patterns and statistics, and GIS data as the basis of the modeling aims to predict availability of



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parking spaces in real-time. In addition, it is one of the ways through which the upgraded facility lifts itself up into a more productive reality [7]. Effective deployment of IoT technologies in smart parking systems, involves being able to monitor real-time parking space (availability) through networked sensors. Such sensing devices range from ultrasonic and infrared to magnetic sensors which are used to sense vehicle presence and relay that information back to the central systems. Improvement in this parking system to be built using infrared sensors in connection with real-time databases via mysql. In this framework the use of such systems could encourage more drivers, since they provide continuous and up-to-the-minute amendments in parking areas. The laser utilized within an arduino module without complication, infrared sensors, and a development board constructed with the arduino microcontroller itself, all painted the picture of smart parking caused by the internet of things technology [8].

Mobile applications are considered as an integral part of SPS, the system also integrating IoT-based sensing. These applications offer the ability to provide up-to-date information on parking availability, make reservations for parking spaces and manage payment options. For example, it may be an application that has been proposed which has an RFID authentication and e-wallet system features [9]. This platform enables its users to book in advance available parking lots which eventually lessens the predictability and automates the system's parking optimization. As well as this, technologies like GPS and artificial intelligence (AI) are finding their place in DTC especially in predicting parking occupancy and recommending the most viable paths for users [10].

In light of recent achievements, although such positive outcomes are extensively appreciated, existing hindrances are still faced. In several works emphasized, one of the impediments that remains emergent in scholarly literature is the lack of attention towards open parking spaces. Even though there are numerous intelligent parking solutions specifically designed for controlled settings such as tall parking buildings, there is a dearth of strategies designated towards empty terrains that are difficult to attach sensors due to the irregularity in environmental form [11]. Furthermore, there has been limited research on the extent to which SPS can be used together with other urban transport systems. For example although new technologies in the form of IoT and AI may be able to help achieve efficiencies in particular parking sites, they are often disjointed from other travel means and traffic control systems which sever their ability to boost urban mobility as a whole. It is noteworthy that, the issue of the ability considerations in the parking allocation algorithms in relation to the potential available parking spaces is hardly ever touched upon. Generally, the current approaches to parking management have been focused on vehicle count and have neglected the passenger load per vehicle in the process. Such activities distort the location of parking slots leading to inefficiency in utilization and limitation of parking spaces especially in cases of parking [12]. Correctly processed, such an approach to this issue can assist in the more rational urban transportation planning as well as decreasing traffic congestion common to most of the urban centers in highly populated regions.

But still there are few researches aimed at stepping back and looking at the whole user-centric design process and acceptance. User trust is given little credence within system designs since it is highly acknowledged. Putting in mind user trust, how accessible the system should be and which behaviors people prefer is quite insignificant especially if the developers are not able to keep them under control. And that is why it is most important to know these issues to improve both prevention of SPS and their future success [13]. In summary, Smart Parking Systems are considered effective in easing parking congestion in modern cities. However more studies are needed in the definition of open parking areas, in the management of urban trips with parking as a key integration point, in the utilization of suburban areas and in the design of parking spaces which meets passenger requirements for different mobility systems. Further research should employ a comprehensive approach to explore how the merging of technology and city planning, policy development, and consumer psychology can contribute to the dispensation of 'ideal' parking lots that could be scaled to fully exploit the current perspectives on implementing parking structures with the long-term measures [14].





SURVEY REPORT

To make the problem statement more understandable, it has been divided into two sections. The first part will concentrate more on the challenges that customers experience whenever they are using the parking space while parking. The second part will describe the challenges experienced by the Parking lot owners and Parking organizations. First and foremost, the world today values time more than anything considering that currently, anything or any person can be accessed within few seconds at the comfort of one's palm using this smart phone. Yet in just the same era it takes minutes to find a place to park. This is very inconvenient particularly to those who need to attend a very important event or even go for leisure activities as they have no time to spare [15]. The inconvenience arises from the long queues while trying to enter, finding a suitable parking location for your car and moving out again. Also, the need to find parking spaces also results to wastage of fuel and smoke to other harmful areas like Co2 emissions that are environmentally harmful [16]. The other problem is that, many parking spaces are left unoccupied or rather are underutilized due to underperformance or corrupt parking wardens and lack of search capabilities, thus the use of parking space management is challenged. Congestion within the parking lot is compounded with many entrances, such as in the public areas, as a procedure where people while entering are made to stop the motor vehicles at the gates and present the ticket for validation is normally utilized this not only drawback in terms as there will be double quest at entry and exit for gate pass verification but also lowers the operational and income possibilities of the parking IoT Some parking systems supported by IoT allow the person to have a reservation in advance because the user is more comfortable with automatic systems and other times manual processes may be tiring, hence such need to have a prior reservation of the space is offered. The two gates are designed to have an IR sensor for detecting vacant parking spaces and such information is distributed in the facility, for management, to the back office. The tag is worn so that the user is granted access to the facility through a recognized entrance into the call center district.

Country-Wise Statistical Survey Report on Global Car Parking Trends (2024–2025)

Table 1: A comparative study for different countries

Research Gap

Table 2: Some real problems

METHODOLOGY

Smart Parking Architecture

Online booking of parking slot.

In the innovative parking system under consideration in the essay, users are able to top-up any funds on their e-wallet with full of ease and have their account encrypted with an RFID card digital ID for safe-keeping which is to be used within the parking system. To Hold a Parking Slot After the users have completed their booking, in case of a booked parking slot reserve a space of up to three days in advance. After the user decides to park on a certain date, the parking areas are first examined and parking spots and availability discourage parking. If any slot is open then the digital ID of the user is checked. Once the check is done, and the reservation stands for the whole day is granted, the user is allowed to park again. Before a vehicle is parked, an RFID card is utilized – this ensures that only authorized entry is granted into the parking site. Finally, appeals are provided for those who do not have a digital wallet. It evaluates whether the appropriate parking slots can be added or not for the chosen day by means of a real time check. When a slot is found, the money is paid without delay. On completion of the payments, a relevant barcode is inserted. This barcode is a digital proof of reservation, and it must be verified at the entry point to a parking area before the vehicle is allowed to be parked. No vehicle is allowed to drive into the parking space unless you possess a validated RFID Card or a created Barcode



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Entry in the system.

Once a user come to park a car, the system carries out one of the three operations depending on the cards presented by the user. In the very first instance, if a user holds an RFID card, a card will be scanned at the entry gate. In the event that the parking slot has already been reserved using that RFID card, the car shall approach the gate, and as the RFID gets scanned, the gate shall open of its own and the car shall be parked in the designated area. Once the car has vacated the parking slot, the system marks it as vacant. If, however, there is no booking made on the card, the gate remains closed with no parking access for the user. In the second instance, once a user has a barcode rather than an RFID, he or she is scanned with the help of the barcode. Suppose the barcode is at par with any of the reservations, then the gate is opened which allows the user to park. Just as it happens with an RFID system, the car is pulled out due to exit procedures and the slot is available for the next customer. In the third case, the user is not supplied with an RFID card or barcode. In this scenario, the system makes an immediate check if any parking spaces are available for that day. If there is, the system requests for immediate payment in regards to the space. For making successful payment, the system provides a unique barcode and the user can scan that barcode at the gate. If it is correct the user is let in and allowed to park the car. Following the other steps above outlined is the rest of the procedure.

Workflow and Implementation

Database Workflow and Implementation

The platform initialized is a clouding system with attached real-time databases. An account has been generated for every team member for a more structured approach. At first, we need to create a database that will have the items that secure and allow the six parking spaces to work in the prototype, and, one push button as shown In Figure 4, which will also be included in the C language code to put the system into the updating mode. Further, the cloud server was linked with an HTML page and used JavaScript for displaying the results on the screen at the reception. Of course, visitors coming in the building will not follow the screen but as a way of anticipating certain things the button will be used to indicate the direction of free spots. In terms of A1 in Figure 5, all the parking lots are available as there is no vehicle in this section. Successful update of this sensor in Figure 6 raises a change in the status of parking A1 in the database and it becomes unavailable. In Figures 7 and 8 when a vehicle is present in the respective parking lots, parking B2's or B3's status is changed to "Unavailable" as indicated by the database.

Website Workflow and Implementation

To achieve the creation of a webpage "HTML", "CSS" and "JavaScript" programming language was used. This complex user interface has the company's brand, a site map, and an available parking lot dynamic number. It is very important to know that each of the three stages of the car parking has its own action. In the first state, the parking spot appears as green indicating that the spot is available for the car to park in as shown in the figure 9. The second stages include, showing a flash blue color on all the available remote parking spots available to the driver on activation of the button as shown in figure 10. An immediate change of background color to a red color indicates that the is a reservation for that parking for a fixed fraction of time. If the driver occupies the space, the parking area is shown in red; otherwise he/she does not occupy it and it turns to green again. The last state is when, in figure 11, the parking lot in red characterizes the occupation of the space by the car, and there is no parking free in this area. The last component of the interface is the database that connects the webpage with parking status in order to update and save changes on parking positions.

Prototype Workflow and Implementation

Concerning the construction of the studied demonstration the design in 4.1 was edited and the demo unit was then produced for use in programming with C language of the said demo intended for networking for other devices. One Servo motor to move the doors. Six Active Infra-Reds that serve to sense the cars' presence in each of the parking slot; one big button (with six pins) so that the user can push it to display the nearest parking on the screen; one female micro-USB plug and one glass fiber soldering board (with a thickness of 1.6mm) to fix all the parts and some welding activities take place afterwards; and a cloud data store to host real-time data. The prototype that was developed to exhibit the proposed system is presented in Figure 12.



**Subhadip Nandi et al.,****Challenges in smart parking**

- I. Although there are existing structures, given the limited activation range of the sensors, it is clear that a lot of them have to go in favor of the new and the smart version of them [17].
- II. This technology would need two more drives and it is not expected to be very different by combining the two
- III. The overall operational cost of the parking system will increase because most of the devices, like the poles as well as monitors will have the capability of being powered ON and hence will need electricity [22].
- IV. In the unlikely case that the whole system goes down because of an error in the software, there will be a lot of time lost in getting the cars reduce it in always from the parking lots.
- V. The initial investment in parking facilities would be high, and there is also a threat of vandalism and possible theft.
- VI. In certain legislation, the driver travels and the app lock the certain parking lot and someone else prevails to press claim on it before the driver reached the car. This creates some tension in the user and causes distress.

RESULTS AND DISCUSSION

Among the many electronic gadgets available for clients to enjoy includes: smart parking that uses Internet of Things (IoT), and it is intended to replace the traditional vending systems which suffered from parking congestion. The devices of the outlined specification do not only tend to offer value-addition and other additional services due to their surmised nature, but also cater for the improvement of the classical problem faced by people on a daily basis when trying to find a place where to park their cars. To make it possible, the following target was intended: In fact the mock screen enabled the authors to connect 'states' in the case scenarios through the use of HTLM and JavaScript, which were instruments used in the process. It is also important to state that the local computer network, which is sometimes called the cloud, was formed in order to make the data available to sensors and control equipment. A model was made that was able to show some of the supporting features found in the smart parking detection applications. According to the conversation, the parameters have been improved since all the objectives that have been set have been achieved. The demonstration of the prototype was made to a few people representing staff and clients of the company and there were positive feedbacks from these people. Moreover, There were also some suggestions that would help improve the system and make it more attractive to customers that were highlighted in the future works section. Comparing the proposed system with other systems that we had encountered before while working on the project and as discussed in the review of the relevant equipment, it can be inferred that the new system is not different from the existing systems as it also uses an infrared sensor to detect if there is a vehicle and a screen that displays the number of parking spots that are available. However, the proposed system deviates from others in a number of areas that give it an edge and alter the overall performance of the system. In most studies, they used screens with a reservation application. In the current study, the screens with such function were equipped with a push button for showing the presence of available and unavailable spots to the customer and even a sign for the nearest car park. According to the studies, sensors are also used in other systems, but they just check that the car is available in a system. This new feature was not used in the context of which the other studies were conducted. Nonetheless, the system recognized user's problems with their consolations as mitigating such will be effective for the system.

CONCLUSION

Efforts that were put in this study included proposing a smart parking system that could be used in any case and gathering resources on the works done previously on smart parking systems which involve technology such as sensors, the internet of things. Besides this, a questionnaire was conducted on the employees and visitors of the organization. The design process also included fabricating a model which incorporated the new technology, and all the elements were tested ensuring they work satisfactorily without any flaws as seen by a majority of the employees. Once it has been developed in test for operation and realizing the system objectives, search time with agony for





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places to park and the frustration of not finding an appropriate parking space will cease to exist. In different parking zones, there is a location finder button on the system. For this option to be operational in any case where there may be more than one parking entrance, there should be one such button at the entrance for each customer. Upon pressing it, the system should then show the nearest parking appropriate for the entrance which the customer is in. The system may also incorporate the use of GPS in the event of huge parking spaces, to locate the car. Which the barcode is pasted on the site. In the future it is likely that further research will be directed more on the AI algorithms on the vehicles that are parked on different parking slots within the same location.

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Table 1: A Comparative Study for Different Countries

Country	Average Parking Search Time	Smart Parking Adoption Rate	Notable Trends
United States	17 hours per year for each car owner.	65% of the cities in the world have implemented smart parking solutions.	Parking is very congested in the urban set ups, so a large amount of money has been put into new technologies for managing the car parks [21].
India	More than 80 hours of time wasted in cities for each commuter,	This has been sweeping in times of cities,	Government initiatives promoting smart cities-related projects resulted in heightened demand for efficient parking solutions [18] [19].
United Kingdom	A decrease of almost 35% of the use of time for searching space within the city by smart parking systems.	Broad urban proliferation	Aimed at decongesting cities and thus including mobile applications for managing parking [20].
Germany	These smart parking systems significantly reduced the search time.	60% of the Largest Cities Have Integrated Smart Parking System.	Focus on automation and real-time data analytics [18].
Japan	High parking demand in urban areas	Adoption of automated parking systems and AI-based management	Land availability is constrained; hence vertical parking solutions were envisaged [18].
Brazil	A growing urban population means an increasing demand for parking.	Target developments of smart technology off-street parking.	Challenges escalated due to informal parking practices and regulation standardization [19].
Canada	Extensions of the intelligent	Remote access for mobile	

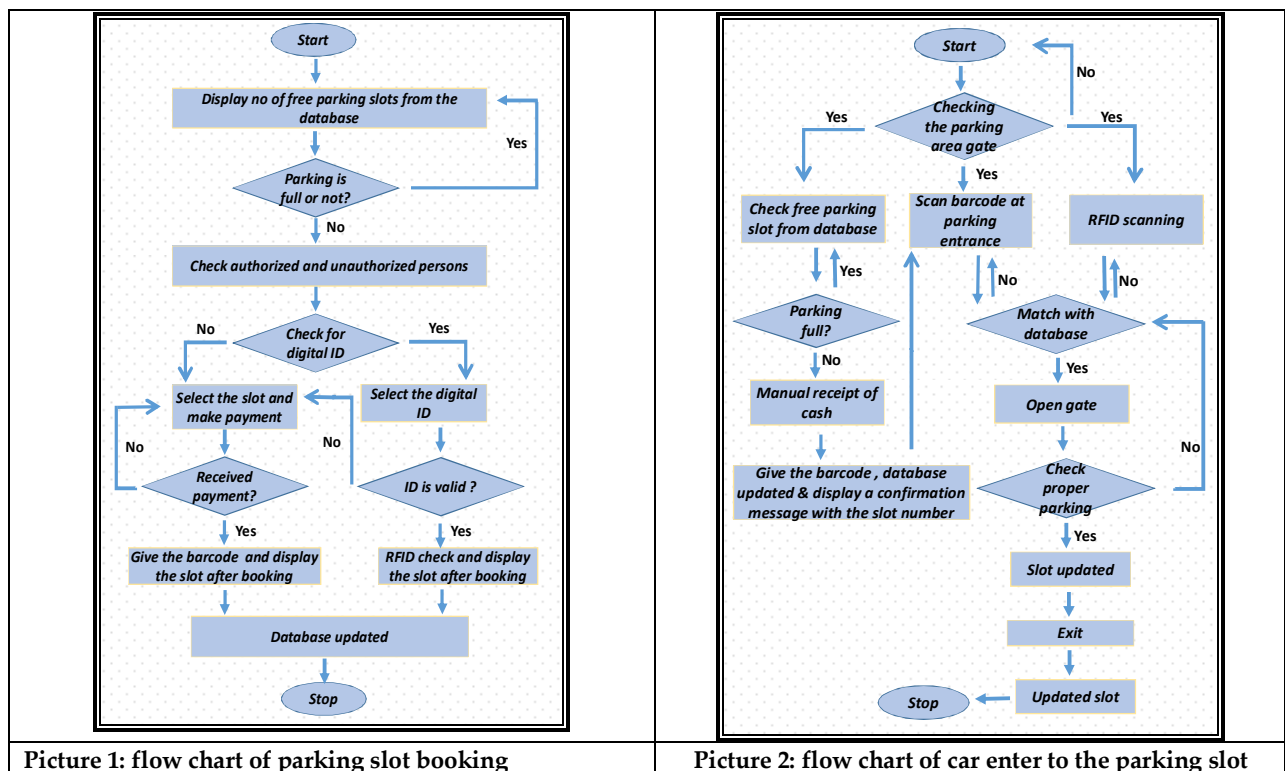


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	parking management system for urban environments	payment systems and real-time availability	Seasonal variations in parking demand and maintenance of the infrastructure [19].
China	Iron rapid urbanization and increased parking demand	Implementation of IoT and artificial intelligence technologies in large cities	Striking a balance between speed and sustainable development of urban sites [18].
Australia	Urban centers with parking shortages are during peak hours.	Smart parking systems should find their way into Sydney and Melbourne.	Urban development versus protection of public space [19].
Netherlands	Medium-per hour parking rates betwixt the most exorbitant across Europe	Dynamic yield management and visibility with real-time availability	Pressing reduction through alternative means of transport in the car for city centers [18].

Table 2: Some real problems

Problem Area	Findings
Slot Availability	However, slot detection by IoT-based sensors faces a major obstacle in urban settings.
Traffic Congestion	Nearly 30% of urban traffic is caused by the need to look for parking.
User Satisfaction	Smart parking systems enhance end user experiences by 50-70%, reducing wait times.
Environmental Impact	IoT systems can help cut down on CO ₂ emissions and fuel efficiency.
Technological Adoption	On the one hand, RFID dominates; on the other hand, new innovations are in the form of mobile apps and IR sensors. On the other hand, it is integrated with artificial intelligence and GPS new.



Picture 1: flow chart of parking slot booking

Picture 2: flow chart of car enter to the parking slot





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#	Name	Type	Collation	Attributes	Null	Default	Comments	Extra	Action
☐	1 ID	int(10)			No	None		AUTO_INCREMENT	
☐	2 Admin_Name	varchar(120)	latin1_swedish_ci		Yes	NULL			
☐	3 User_Name	varchar(120)	latin1_swedish_ci		Yes	NULL			
☐	4 Contact_Number	bigint(10)			Yes	NULL			
☐	5 Email	varchar(200)	latin1_swedish_ci		Yes	NULL			
☐	6 Password	varchar(120)	latin1_swedish_ci		Yes	NULL			
☐	7 Reg_Date	timestamp			Yes	current_timestamp()			

Picture 3: Admin table

#	Name	Type	Collation	Attributes	Null	Default	Comments	Extra	Action
☐	1 ID	int(10)			No	None		AUTO_INCREMENT	
☐	2 Parking_Slot_No	varchar(120)	latin1_swedish_ci		Yes	NULL			
☐	3 Vehicle_Category	varchar(120)	latin1_swedish_ci		No	None			
☐	4 Vehicle_Company_name	varchar(120)	latin1_swedish_ci		Yes	NULL			
☐	5 Registration_Number	varchar(120)	latin1_swedish_ci		Yes	NULL			
☐	6 Owner_Name	varchar(120)	latin1_swedish_ci		Yes	NULL			
☐	7 Owner_Contact_Number	bigint(10)			Yes	NULL			
☐	8 In_Time	timestamp			Yes	current_timestamp()			
☐	9 Out_Time	timestamp			Yes	NULL		ON UPDATE CURRENT_TIMESTAMP()	
☐	10 Parking_Charges	varchar(120)	latin1_swedish_ci		No	None			
☐	11 Remark	mediumtext	latin1_swedish_ci		No	None			
☐	12 Status	varchar(5)	latin1_swedish_ci		No	None			

Picture 4: User table

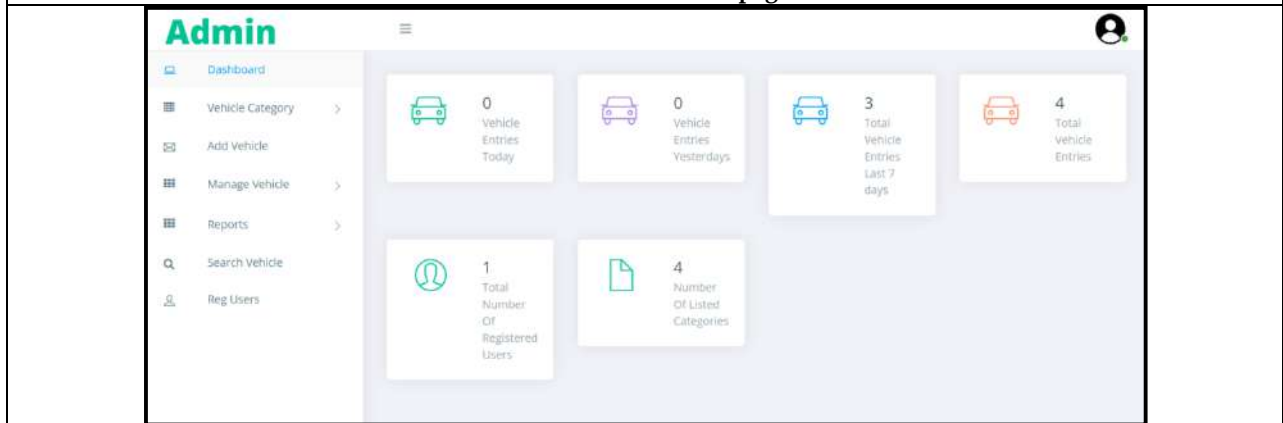




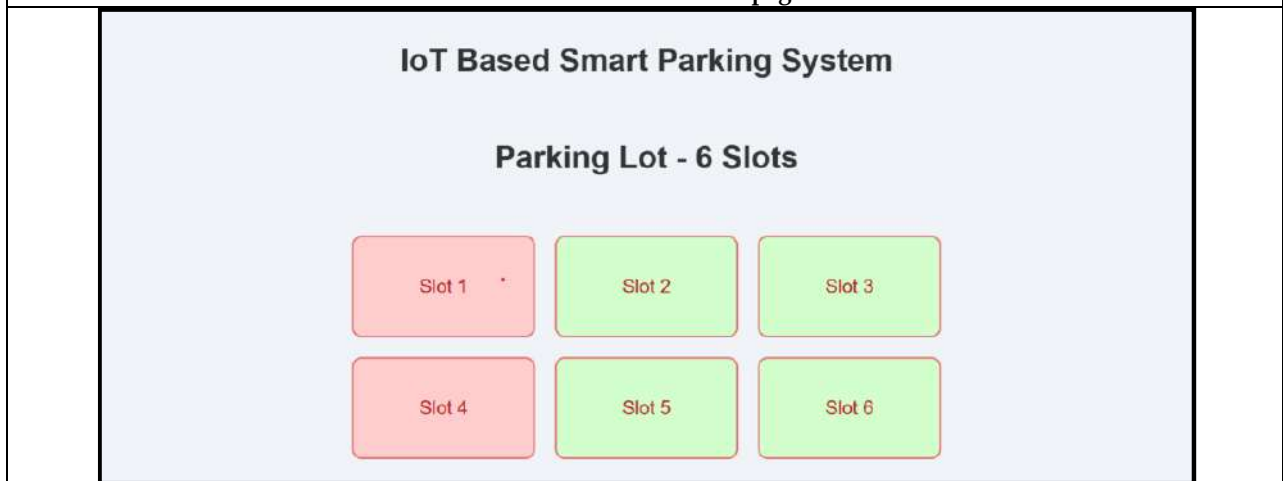
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Picture 5: User Home page



Picture 6: Admin Home page



Picture 7: Slot wise details red color represents for booked and green is for free



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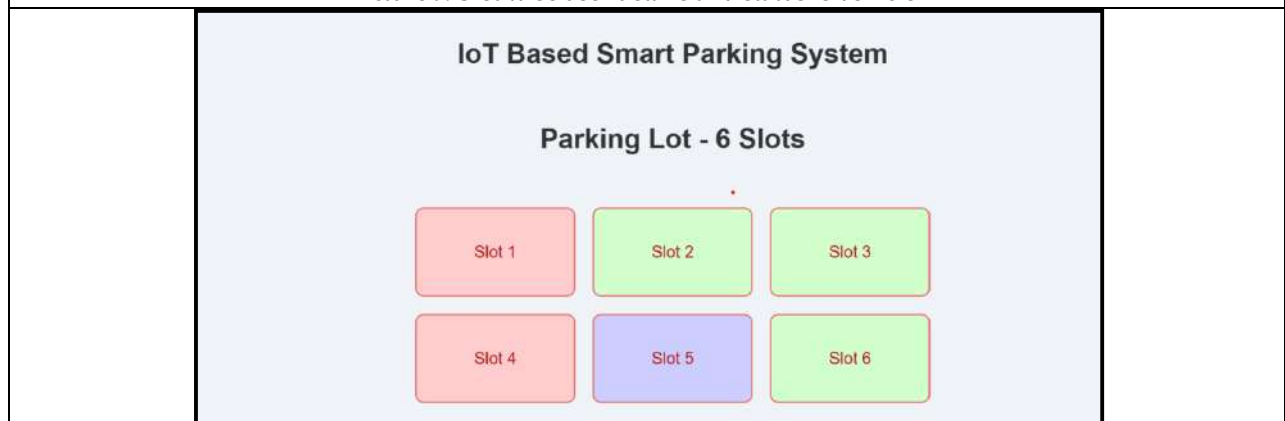
Users Information				
Dashboard	Dashboard / View Vehicle Parking Information / View Vehicle Parking Information			
View Vehicle	View Vehicle Parking Details (on the basis of Registered Mobile No)			
S.NO	Parking Number	Owner Name	Vehicle Reg Number	Action
1	Slot 1	Subhadip	WB01AB1234	View Print
2	Slot 4	Sudipta	WB01AB9874	View Print

IoT Based Smart Parking System

Picture 8: Slot wise user information

Users Information	
Dashboard	View Vehicle details
View Vehicle	
Parking Number	Slot 1
Vehicle Category	Four Wheeler Vehicle
Vehicle Company Name	Maruti Suzuki WagonR
Registration Number	WB01AB1234
Owner Name	Subhadip
Owner Contact Number	1234567890
In Time	2025-04-28 13:10:00
Status	Vehicle In
Remark	NA
Parking Fee	100

Picture 9: Slot wise user details and status is vehicle in



Picture 10: User searching new slot which is blue color showing





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Users Information

Dashboard / View Vehicle Parking Information / View Vehicle Parking Information

View Vehicle Parking Details (on the basis of Registered Mobile No)

S.NO	Parking Number	Owner Name	Vehicle Reg Number	Action
1	Slot 1	Subhadip	WB01AB1234	View Print
2	Slot 5	Jayashree	WB03CD1234	View Print
3	Slot 4	Sudipta	WB01AB9874	View Print

IoT Based Smart Parking System

Picture 11: After booking new slot which is now slot 4

IoT Based Smart Parking System

Parking Lot - 6 Slots

Slot 1

Slot 2

Slot 3

Slot 4

Slot 5

Slot 6

Picture 12: Now the updated slot

Users Information

Dashboard / View Vehicle details

View Vehicle details

Parking Number	Slot 1
Vehicle Category	Four Wheeler Vehicle
Vehicle Company Name	Maruti Suzuki WagonR
Registration Number	WB01AB1234
Owner Name	Subhadip
Owner Contact Number	1234567890
In Time	2025-04-28 13:10:00
Status	Vehicle out
Remark	NA
Parking Fee	100

Picture 13: After leaving the parking slot status is changed i.e. Vehicle Out





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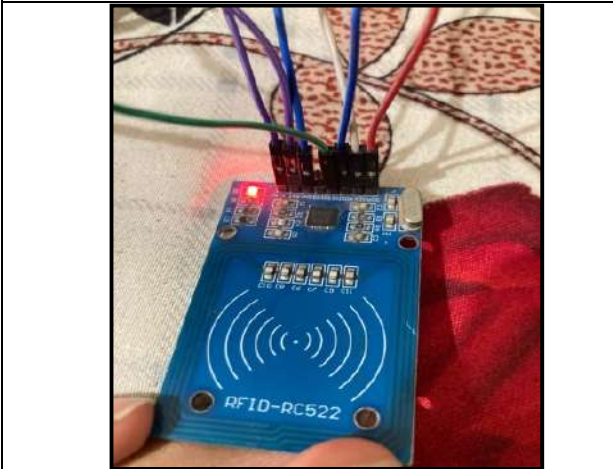
Picture 14: After leaving all car slots is free now



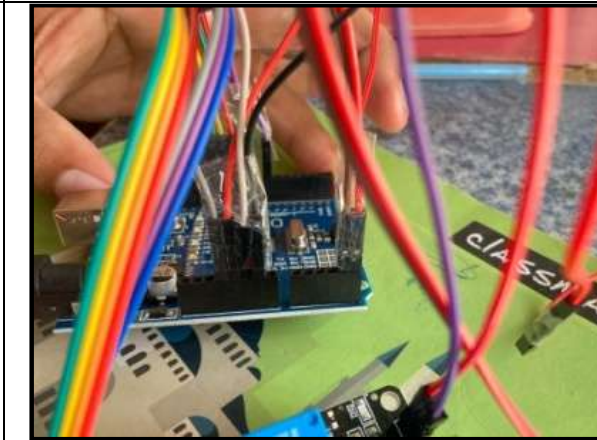
Picture 15: Now six slots are available in the model



Picture 16: One car is trying to enter the parking slot model



Picture 17: RFID is on running mode



Picture 17: RFID is on running mode





RESEARCH ARTICLE

Pharmaceutical Study of *Kasakuthara Rasa* : A Traditional *Kharaliya* Ayurvedic Medicine

Urvi Shah^{1*} and Richa Raj²

¹Final year P.G. Scholar, Department of Rasashastra Evum Bhaishajya Kalpana, Parul Institute of Ayurved, Parul University, Limda, Waghodia, Vadodara, Gujarat, India.

²Associate Professor, Department of Rasashastra Evum Bhaishajya Kalpana, Parul Institute of Ayurved, Parul University, Limda, Waghodia, Vadodara, Gujarat, India.

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*Address for Correspondence

Urvi Shah

Final year P.G. Scholar,
Department of Rasashastra Evum Bhaishajya Kalpana,
Parul Institute of Ayurved, Parul University,
Limda, Waghodia, Vadodara, Gujarat, India.
E.Mail: urvii996shah@gmail.com



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ABSTRACT

"*Kasakuthara Rasa*" is derived from its inclusion in the *Rogadhikara* section. One of the *Kharaliya Rasayanas* listed in *Bhaishajyaratnavali* is *Kasakuthara Rasa*. To make it, equal amounts of *Shuddha Hingula* (cinnabar), *Shuddha Gandhaka* (sulfur), *Shunthi* (dry ginger), *Pippali* (long pepper), *Maricha* (black pepper), and *Shuddha Tankana* (borax) are needed. *Anupana* as per the reference is *Ardraka Swarasa* and *Madhu*. As of yet, no research investigations have been conducted on this formulation. Make *Kasakuthara Rasa* by *Bhaishajyaratnavali* using a range of organoleptic, physicochemical parameters and then evaluate the formulation. The study was conducted in four stages: Raw drug authentication by API standards; Raw drug purification (*Ashodhita- Hingula, Gandhaka, Tankana*) by classical references; Pharmaceutical study by treatises; and Analytical analysis of formulation by CCRAS recommendations. Physico-chemical parameters included bulk density, tap density, pH, water-soluble extractive, alcohol-soluble extractive, LOD, total ash and acid-insoluble ash were measured. The study's conclusion could be a benchmark for future clinical and quality control investigations.

Keywords: *Kasakuthara Rasa*, *Kharaliya*, *Bhaishajyaratnavali*, Physico-chemical analysis

INTRODUCTION

Pitta, *Kapha*, and *Vata* energy in the body are meant to be balanced to support general health, according to the ancient Indian medical system known as Ayurveda. It supports both physical and mental well-being by utilizing Ayurvedic



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medications, dietary modifications, and lifestyle alterations. Dedicated to pharmaceutical science, *Rasashastra* is an important branch of Ayurveda that was founded with the twin objectives of metallurgical excellence (*Loha Siddhi*) and physiological perfection (*Deha Siddhi*)[1]. Preparing, processing, and standardizing medicinal substances—including minerals and herbs—to guarantee their efficacy, safety, and quality are important facets of pharmaceutical research. The potency of powerful Ayurvedic formulations called *Rasaushadhis*, which are mostly composed of metals and minerals, is intimately associated with the quality of the medications used in Ayurvedic therapies. For a formulation to be effective in treating a condition, it must be prepared properly. Classical texts in *Rasashastra* state that metals and minerals have toxic properties. To overcome these, substances undergo various pharmaceutical processing processes such as *Shodhana*, *Marana*, *Bhasmikanana*, etc., to render them suitable for internal consumption. *Rasoushadis* are well known for their distinctive attributes, which include rapid action in small doses, quick absorption, significant therapeutic benefits, and prolonged shelf life. In *Rasashastra*, there are four types of preparations based on their procedures, which are primarily categorized into four groups: *Kharaliya Rasayana*, *Parpati Rasayana*, *Kupipakva Rasayana*, and *Pottali Rasayana*. One notable formulation is *Kasakuthara Rasa*, categorized under *Kharaliya Rasayana* explained in *Brihadrasa rajsundar*, *Bhaishajya ratnavali*, *Rasendra Saar Sangraha* and *Bharat Bhaishajya Ratnakar*. This preparation is made by trituration in a *Khalva yantra* (mortar and pestle) and is indicated in the treatment of *Sannipata Sudaruna Kasa* (severe cough caused by the combined aggravation of all three *doshas*) and *Asahya Shiroroga* (severe headache or migraine). The *Bhaishajyaratnavali* describes this formulation as consisting of equal proportions of *Shuddha Hingula*, *Shuddha Gandhaka*, *Trikatu*, and *Shuddha Tankana*. In this formulation, the quantity of *Maricha* is doubled, suggesting that Piperine may have a more potent effect on managing *Kasa* (cough). Despite its historical significance, research on this formulation remains limited. Therefore, the present study aimed to prepare *Kasakuthara Rasa* and analyze its organoleptic and physico-chemical properties.

MATERIALS AND METHODS

Authentication of Raw Drugs

The raw materials used in processing, such as *Hingula*, *Gandhaka*, *Tankana*, *Maricha*, *Shunthi*, and *Pippali*, were obtained from the Parul Ayurved Pharmacy, Parul Institute of Ayurved, Parul University, Vadodara. All herbal drugs were identified and authenticated according to API guidelines by experts at the Department of Dravyagunavigyan, Parul Institute of Ayurved, Parul University, Vadodara. All mineral drugs were identified and authenticated according to *grahya-agrahya lakshanas* mentioned in classical ayurveda texts by experts at the Department of Rasashastra evum Bhaishajyakalpana, Parul Institute of Ayurved, Parul University, Vadodara. The preparation of *Kasakuthara Rasa* took place in the laboratory of the Department of Rasashastra evum Bhaishajya Kalpana, Parul Institute of Ayurved, Parul University, Vadodara.

Purification of Raw Drugs

Shodhana of Hingula[2]

Shodhana of *Hingula* was done by giving seven *bhavanas* with *Ardraka Swarasa* (Ginger juice) in *Khalva Yantra* as per the reference of *Rasa Tarangini*. 100 gm *Hingula* was made into powder and levigated with a sufficient quantity of *Ardraka Swarasa*. Trituration was carried out till the *Hingula* got a semisolid form and dried. The same procedure was repeated six times, after that it was sun-dried, and stored in an airtight container. (Figure 1)

Gandhaka Shodhana[3]

Gandhaka Shodhana was carried out by the *Kurma puta* method as per the reference of *Rasendra Sara Sangraha*. Where 200g *Ashuddha Gandhaka* was coarsely powdered in a *Khalva Yantra* and one litre of fresh milk was taken in a *Ghritalipta* earthen vessel, the mouth of which was covered with a double-layered clean cloth and tied firmly with a thread. Powdered *Gandhaka* was then spread over this cloth and tied properly with a thread and *Sharava* was placed inversely over the pot and *Sandhibandhana* was done with *Multanimitti*. After drying, the pot was kept inside a pit, and cow-dung cakes were spread over the *Sharava*, the fire was lit with the help of camphor. After self-cooling, the pot was retrieved from the pit, *Sandhibandhana* was opened, and *Sharava* was removed. *Shodhita Gandhaka* granules



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that had been dropped and gathered in milk were secured. This *Shodhita Gandhaka* was properly washed with hot water three to four times and then dried in the shade. After drying the *Shodhita Gandhaka* was weighed and stored in an airtight container. (Figure 2)

***Tankana Shodhana*[4]**

Tankana Shodhana was carried out by the *Nirjalikarana* method as per the reference of *Rasatarangini*. 100g *Ashodhita Tankana* was taken in a clean and dry *Khalva Yantra* and pounded well to prepare powder. Later, the powder of *Tankana* was taken in an iron pan and fried under *Mandagni*. Initially, it liquefied, and on continuous heating; it turned into a white-colored *Tankana* due to the evaporation of water. *Bharjana* was continued until the water content was completely evaporated, the *Tankana* was fully puffed and the hissing sound disappeared. This *Shodhita Tankana* was taken in *Khalva Yantra* and made into fine powder; later stored in an airtight container. (Figure 3)

Preparation of *Kasakuthara Rasa*[5]

Herbal drugs *Maricha*, *Shunthi*, and *Pippali* were collected; physical impurities were removed, dried in sunlight, and then powdered individually using a mixer until it turned into a fine powder. Each powder was then sieved through mesh no. 85, weighed and kept in an airtight container for further processing. First, all the drugs weighed accurately, then purified *Hingula* and *Gandhaka* were taken in *khalva Yantra* in the prescribed quantity and mixed properly. *Mardana* was done until a homogenous mixture was made. Purified *Tankana* were mixed, and finally, fine powders of *Maricha*, *Pippali* and *shunthi* were added in prescribed quantity and *Mardana* was continued until all the ingredients became a homogenous mixture. The mixture is then collected and stored in an airtight container. (Figure 4). Ingredients of *Kasakuthara Rasa* with its proportion (Table No.1).

OBSERVATION AND RESULTS

This study was intended to generate the basic standards for *Kasakuthara Rasa* as no pharmacopoeia standards are available for this formulation. The raw drugs of formulation were first tested for Identity, Purity, and Strength testing then the formulation was tested for Organoleptic parameters at Parul Ayurved Pharmacy attached to the Department of RSBK, Parul Institute of Ayurved, Parul University, Vadodara, and the physicochemical analysis carried out at Quality Control Laboratory, Parul Institute of Ayurved, Parul University, Vadodara. Identity, Purity, and Strength Testing of *Shunthi* (Raw Drug) (Table No.2). Identity, Purity, and Strength Testing of *Maricha* (Raw Drug) (Table No.3). Identity, Purity, and Strength Testing of *Pippali* (Raw Drug) (Table No.4).

Hingula Shodhana

Asuddha Hingula was a bright red; its consistency was rough, lustrous, and solid. For *Hingula Shodhana*, a total of 189 ml of *Ardraka Swarasa* was used for *Bhavana*. After the First *Bhavana*, the consistency of the *Hingula* changed into soft, bright and semisolid. As the *Bhavana* advanced, the starch portion within the mass was increased gradually and weight gain was observed. After the Seventh *Bhavana* with *Ardraka Swarasa*, the consistency obtained was soft, dark, very sticky, and semisolid. A total of 10 days were required to achieve *Shodhita Hingula* which was dark red, soft, lusterless, and fine in consistency. Observation of *Hingula Shodhana* (Table No.5).

Gandhaka Shodhana

When the *Sharava* was removed after self-cooling, all the mud particles and other physical impurities present in *Gandhaka* were seen on the cloth. After washing with hot water, the colour of *Gandhaka* was a bright yellowish colour and had a pleasant smell. *Shodhita Gandhaka* was in granular form and few were streak-like; some were fully immersed in the milk and a few granules were seen floating on the milk. Observation of *Gandhaka* before and after *Shodhana* (Table No.6). Final Outcome of *Gandhaka Shodhana* (Table No.7).



**Urvi Shah and Richa Raj****Tankana Shodhana**

100 g *Ashudha Tankana* was taken in an earthen plate and subjected to heat until the water content was completely evaporated (*Nirjalikarana*). *Tankana* bloomed completely with the disappearance of hissing sounds. Initially, it liquefied and stuck to the vessels and on continuous heating, it turned into a white-coloured *Tankana*. After frying, *Ashudha Tankana* bloomed and turned into a white opaque substance because of the evaporation of water contents. The weight of *Tankana* was reduced after frying due to evaporation of water content. The total time taken for the procedure was 40 mins and the loss was due to the impurity of *Tankana*. Observation of *Tankana* before and after *Shodhana* (Table No.8). Final Outcome of *Tankana Shodhana* (Table No.9). Organoleptic Parameters of *Kasakuthara Rasa* (Table No.10). Physico-chemical Parameters of *Kasakuthara Rasa* (Table No.11).

DISCUSSION

Kharaliya Rasayana is the most important type of preparation in Ayurveda, and the *Kasakuthara Rasa* is the most effective *Kharaliya Rasayana* in the treatment of *Kasa*. All the ingredients of *Kasakuthara Rasa* were selected strictly according to classical references. Most of the materials of *Rasashastra* are obtained from mineral sources containing various impurities which are responsible for causing toxic effects to body tissues. Therefore, as a rule, Mineral drugs were purified first by a specialized processing technique known as *Shodhana* before being used in the formulation. It is done to remove visible and invisible impurities, reduce toxicity, and enhance the therapeutic property. Here an attempt was made to follow various analytical parameters to figure out the exact nature of the formulation within the limitations of the study.

Hingula Shodhana

Hingula Shodhana with *Ardraka Svarasa* acts as media that helps to convert rough particles into fine and soft particle forms. Due to the continuous trituration, the fineness of the *Hingula* increased and the shining property was reduced. Weight gain in *Hingula* was observed might be due to the addition of starchy contents of *Ardraka Svarasa* each time during the *Shodhana* process. In the end, the colour of the *Hingula* changes from shiny bright red to dark red, reduction in particle size due to the trituration process and the mixture has a fragrance of ginger[6].

Gandhaka Shodhana

The criteria behind selecting this process was the negligible loss during this process. It's a convenient method and can be completed in a short duration. In this procedure, cloth is used to trap physical impurities. Practically, silk cloth is preferred because it can withstand high temperatures and does not burn as easily as cotton cloth. *Goghrita* acts as a detoxifying agent by absorbing toxins from *Gandhaka*[7]. *Godugdha* was selected as *Shodhana Dravya* as it is an antidote for *Gandhaka* and *Godugdha* is the commonly recommended antidote for poisoning, it might help neutralize the sulphur poisoning and *Guru*, *Snigdha Guna* and *Sheeta Veerya* of *Godugdha* pacifies the *Tikshna*, *Ushna Guna* of *Gandhaka*. Otherwise, it causes *Bhrama*, *Tapa*, *Kushta* and *Pitta Roga*[8].

Tankana Shodhana

Ashudha Tankana may cause complications like *Chardi* (vomiting) and *Bhranti* (delusions), so purification of *Tankana* is necessary before administration[9]. According to *Rasa Tarangini*, the author mentioned that *Nirjalikarana* is to be done to purify *Tankana*. *Ashudha Tankana* ($\text{Na}_2\text{B}_4\text{O}_7 \cdot 10 \text{H}_2\text{O}$) was taken in an earthen plate and subjected to heat until the water content was completely evaporated[10]. After *Shodhana*, $\text{Na}_2\text{B}_4\text{O}_7 \cdot 10 \text{H}_2\text{O}$ converted into $\text{Na}_2\text{B}_4\text{O}_7 \cdot 5 \text{H}_2\text{O}$ because while heating the water molecules are evaporated. Purified *Tankana* contains more Boron compared to raw *Tankana*[11].

Physico-chemical Analysis

Physico-chemical analysis is an important characteristic to evaluate the quality, standardisation and safety of Ayurvedic drugs. Loss on drying of a drug gives the percentage of moisture present in a given sample[12]. Higher amount of moisture may deteriorate the shelf life and therapeutic efficacy of the sample and it was found to be





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44.25%. It might be due to the presence of *Tankana* (*Kshara*). The total Ash value indicates the presence of inorganic matter in the formulation, which may be due to some insoluble particles of mineral drugs used in this preparation. The ash value of the prepared formulation was 30.2%. Acid insoluble ash was carried out to assess the percentage of acid-insoluble inorganic content of the sample, indicating the presence of silica and oxalates in drugs. The acid-insoluble ash of the prepared formulation was 2.15% which indicates that a negligible amount is soluble in acid. Extractive values give an idea about solubility in specific solvents when administered clinically. Herbo-mineral formulations are having quite lower values of Water-soluble and Alcohol-soluble extractives as compared to herbal formulations due to the presence of mineral drugs. Water-soluble and Alcohol soluble extractive values of the sample were 1.49 and 1.58 respectively. pH is a measure of the hydrogen ion concentration of a solution. It is a numeric scale used to specify the acidity or basicity of an aqueous solution. pH of the formulation was 7.5 which was alkaline in nature may be due to the presence of *Tankana* (*Borax*) in the formulation. All of these advanced analytical techniques contribute to evaluating the facts stated in Ayurvedic treatises and thus help in demonstrating their validity.

CONCLUSION

The present pharmaceutical study of *Kasakuthara Rasa*, a classical *Kharaliya Rasayana* formulation, provides valuable insight into its traditional preparation methods, standardization, and physicochemical properties. Through meticulous adherence to classical Ayurvedic procedures and rigorous analytical evaluation, the formulation was successfully developed using purified ingredients such as *Shuddha Hingula*, *Shuddha Gandhaka*, *Shuddha Tankana*, and *Trikatu*. The purification procedures not only eliminated undesirable impurities but also enhanced the safety and therapeutic efficacy of the formulation. The physicochemical analysis revealed critical parameters including pH, loss on drying, total ash content, and extractive values, serving as foundational benchmarks for future studies. The alkaline nature (pH 7.5), high LOD (44.25%), and relatively low extractive values align with the herbo-mineral composition of the drug. Overall, this study establishes preliminary pharmacopoeial standards for *Kasakuthara Rasa* and paves the way for further instrumental techniques, and preclinical and clinical validation to ensure quality, efficacy, and safety, thereby reinforcing its therapeutic application in managing *Kasa* and related disorders.

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Table No.1: Ingredients of Kasakuthara Rasa with its proportion

Sr. No	Ingredients	Scientific Name	Part Used	Quantity (in gms)
1	Shuddha Hingula	Cinnabar	Mineral	30
2	Maricha	Piper nigrum	Mineral	30
3	Shuddha Gandhaka	Sulphur	Mineral	30
4	Shunthi	Zingiber officinale	Rhizome	30
5	Maricha	Piper nigrum	Fruit	30
6	Pippali	Piper longum	Fruit	30
7	Shuddha Tankana	Borax	Kshara	30

Table No.2: Identity, Purity, and Strength Testing of Shunthi (Raw Drug)

Sr.No	Parameters	Results (w/w%)
1	Foreign matter	0.5
2	Total Ash	4
3	Acid-insoluble Ash	1
4	Water-soluble extractive	15
5	Alcohol-soluble extractive	5

Table No.3: Identity, Purity, and Strength Testing of Maricha (Raw Drug)

Sr.No	Parameters	Results (w/w %)
1	Foreign matter	1
2	Total Ash	2.5
3	Acid-insoluble Ash	0.2
4	Water-soluble extractive	10
5	Alcohol-soluble extractive	8

Table No.4: Identity, Purity, and Strength Testing of Pippali(Raw Drug)

Sr.No	Parameters	Results (w/w %)
1	Foreign matter	1
2	Total Ash	3
3	Acid-insoluble Ash	0.2
4	Water-soluble extractive	15
5	Alcohol-soluble extractive	10

Table No.5: Observation of Hingula Shodhana

No. of Bhavana	Weight of Hingula before each bhavana(in gms)	Total Quantity of Ardraka Swarasa used (in ml)	Total duration of Mardana in each bhavana(hrs)	Weight of Hingula after each bhavana(in gms)
1	100	30	3	101
2	101	30	3	102.25
3	102.25	28	2.5	103.55
4	103.55	26	2.5	105
5	105	25	2.5	106.22
6	106.22	25	2.2	107.90
7	107.90	25	2	109





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Table No.6: Observation of Gandhaka before and after Shodhana

Sr. No.	Parameters	Before Shodhana	After Shodhana
1	Smell of milk	No smell of Sulphur	Smell of Sulphur
2	Colour of milk	White	Yellow
3	Colour of Gandhaka	Light Yellow	Bright Yellow
4	Appearance of Gandhaka	Crystal	Granules
5	Smell of Gandhaka	Sulfurous	Pleasant smell of Sulphur

Table No.7: Final Outcome of Gandhaka Shodhana

Weight of Ashuddha Gandhaka (in gm)	Weight of Gandhaka after Shodhana (in gm)	Loss of Weight (in gm)	Loss of Weight (%)
200	170	30	15

Table No.8: Observation of Tankana before and after Shodhana

Sr. No	Parameters	Before Shodhana	After Shodhana
1	Colour	Shiny milky white	Plain milky white
2	Appearance	Crystal	Amorphous

Table No.9: Final Outcome of Tankana Shodhana

Weight of Tankana before Shodhana (in gms)	Weight of Tankana after Shodhana (in gms)	Loss of Weight (in gms)	Loss of Weight (%)
100	60	40	40

Table No.10: Organoleptic Parameters of Kasakuthara Rasa

Sr. No	Parameters	Results
1	Colour	Brown
2	Odour	Pungent
3	Touch	Smooth
4	Taste	LavanaKatu
5	Consistency	Fine powder

Table No.11: Physico-chemical Parameters of Kasakuthara Rasa

Sr. No	Parameters	Results
1	Loss on drying (w/w%)	44.25
2	Total Ash Value (w/w%)	30.2
3	Acid insoluble ash (w/w%)	2.15
4	Water soluble extractive (w/w%)	1.49
5	Alcohol soluble extractive (w/w%)	1.58
6	pH	7.5
7	Bulk Density (gm/ml)	0.5
8	Tapped Density (10 Tap, 20 Tap, 50 Tap) (µm/cc)	0.52, 0.55, 0.56





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Figure 1: Shodhana of Hingula



Figure 2: Gandhaka Shodhana



Figure 3: Tankana Shodhana



Figure 4: Preparation of Kasakuthara Rasa





RESEARCH ARTICLE

Healing Heat: Unraveling Insomnia Triggers and Evaluating Hot Water Footbath Therapy for Improved Sleep in Seniors

Asha. N, Patel^{1*}, Ramachandra Holi² and Ravindra H.N³

¹Ph.D. Scholar, Department of Nursing, Parul University, Limda, Waghodia, Vadodara, Gujarat, India.

²Professor, Department of Nursing, Parul University, Limda, Waghodia, Vadodara, Gujarat, India.

³Principal, Department of Nursing, Parul University, Limda, Waghodia, Vadodara, Gujarat, India.

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*Address for Correspondence

Asha. N, Patel

Ph.D. Scholar,

Department of Nursing,

Parul University, Limda,

Waghodia, Vadodara, Gujarat, India.

E.Mail: ashapatel.17@gmail.com



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ABSTRACT

Sleep is a natural practice that is indispensable for the well-being of people physically and mentally. However, insomnia is a common issue among elderly individuals, particularly those residing in old age homes. This study intends to recognize the factors contributing to insomnia and evaluate effectiveness of “Hot water footbath therapy” in enhancing the quality of sleep, with elderly people as the prime focus. A quasi-experimental design has been adopted with 200 elderly participants (aged 60-80) from selected old age homes in Ahmedabad, Gujarat. “Hot water footbath therapy” was provided to the intervention group for 15–20 minutes before bedtime for 10 consecutive days, from the day the patient first presented to the day of the end of the first acute episode. The quality of sleep was reported by adopting the Modified Pittsburgh Quality of Sleep Index (PSQI). It was observed that the sleep quality was enhanced for the control group when compared with the intervention group ($p < 0.05$). Also, it was witnessed that poor sleep quality is influenced by demographic factors such as with marital status, gender, age, and chronic illnesses. “Hot water footbath therapy” was concluded to be an efficient option for the non-pharmacological intervention in elderly people to improve sleep quality.

Keywords: Sleep quality, elderly, Hot water footbath therapy, insomnia, non-pharmacological intervention.



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INTRODUCTION

Physiologically, sleep is a necessary process of life, yet its importance is not well appreciated. Nevertheless, with age, individuals experience changes in their sleep patterns, and this often results in insomnia, among other sleep disorders[1,2]. Insomnia, identified as struggle to fall asleep, having nonrestorative sleep, or remaining asleep, occurs frequently in the elderly[3]. Poor quality of sleep impacts daytime fatigue, cognitive impairment, increased risk of falls and other health complications[4,5]. People who live in old age homes are especially at risk for sleeping problems because of factors including physical inactivity or chronic diseases, lack of physical interaction and loneliness. As sleep medications have side effects, non-pharmacological interventions such as “hot water footbath therapy” have been proposed as effective methods to enhance the sleep quality[2]. This research aims to determine the primary causes of insomnia and the influence of “hot water footbath therapy” on quality of quality for the case of elderly people who are living in care homes.

OBJECTIVES

1. To determine the sleep quality among people who are old.
2. To assess the usefulness of “hot water footbath therapy” in improving sleep quality for the residents of elderly care facilities.
3. To study the correlation between some social demographic factors and sleep quality.

METHODOLOGY

Research Design

The present study was articulated as quasi-experimental with pretest and post-test assessments. This was done in selected elderly care homes in Ahmedabad, Gujarat. A total of 200 elderly subjects (aged from 60 to 80 years) have been a part of this study. The population was split into two groups, with 100 participants in each of the control group and the intervention group.

Intervention

“Hot water footbath therapy” was done before bedtime for 10 consecutive days in the intervention group for 15–20 min. The water was kept at 40°C. No intervention was provided to the control group.^[6,7]

Data Collection

Sleep quality was assessed with the help of the “Modified Pittsburgh Quality of Sleep Index (PSQI)”. It evaluates seven criteria: overall sleep, sleep duration, sleep latency, sleep medication, introduction, sleep efficiency, and sleep dysfunction during the day. Data were collected before and after the intervention to detect any changes in sleep patterns.

Ethical Clearance

After the data collection, ethical clearance was obtained from the Hospital for Mental Health’s Institutional Ethics Committee (IEC) at the Gujarat Institute of Mental Health, Ahmedabad, Gujarat. Before participating in the study, the participants have provided informed consent in writing. The information about the study type, what was expected of them, and their right to opt-out from the research with no consequences were explained to the participants. The data was collected and reported so that no personal identifiers were used, and data confidentiality was maintained throughout the study. The study demonstrated compliance with the ethical principles, were described and detailed in the Declaration of Helsinki.^[8]



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Data Analysis

Both inferential and descriptive statistics were adopted to analyze the data. Pre-test and post-test scores were compared within groups using paired t-tests, and control and intervention groups were verified using independent t-tests. The relation between quality of sleep and socio-demographic factors was assessed with the help of chi-square tests.

RESULTS

Sample Distribution based on Demographic Variables - Frequency and percentage-wise.(N=200) (Table: 1). The demographic analysis of the study reveals key differences between the experimental ("hot water footbath therapy") and control groups. Most of the participants were aged 60-65 in the experimental group (44%), whereas the control group had a higher proportion of individuals above 75 years (39%). More females participated in both groups (69% experimental, 72% control). A significant portion of the experimental group was widowed (44%), while the control group had more divorced individuals (24%). Regarding family structure, half of the experimental group had only one child, whereas none in the control group had one child. Educational background varied, with a higher proportion of secondary-educated individuals in the control group (30%) as in comparison with the experimental group (16%). Many of the participants in the experimental group were having previous housework experience (37%), while the control group comprised of a higher percentage in miscellaneous occupations (21%). Financially, both groups were largely dependent on low-income sources, with 52% in the experimental and 49% in the control group earning between ₹10,000-₹20,000 monthly. Self-sufficiency in daily expenses was lower in the control (33%) compared to the experimental group (51%). The prevalence of disease was similar in both groups (58% vs. 62%). Lastly, the number of the days spend in old age homes varied, with 32% of the experimental group staying for more than three years compared to 39% in the control group. These findings provide a foundational understanding of the population involved in evaluating hot water footbath therapy for insomnia relief in seniors. Sample distribution based on Factor affecting Sleep - Frequency wise.(N=200) (Table: 2). The analysis reveals key sleep-affecting factors among seniors in both groups. Health issues, joint pain, and medication use are prevalent, with the experimental group reporting higher medication use (80%) than the control group (67%). Sleep disturbances due to acidity (56%) and frequent washroom visits (40%) are more frequent in the control group. The participants from both the groups struggled with sleep quality, but early waking and frequent disturbances are higher in the experimental group (80%). Environmental factors like noise (41%) and light sensitivity (52%) also affect sleep. Emotional stress significantly impacts both groups (79% and 72%). The experimental group consisted of larger number of participants consuming tobacco and alcohol. Overall, the control group faces more sleep disturbances due to acidity, while the experimental group struggles with early waking and light sensitivity, providing insights into the impact of "hot water footbath therapy". score of quality of sleep in control group –Comparison between Pre-test and Post-test(N=100) (Table: 3). Sleep quality score analysis in the control group indicated a significant improvement between the pre-test and post-test. It seems as though, without the intervention, some factors may have contributed to improved sleep quality over time.

Before the intervention, 58% of participants had poor sleep quality, which reduced to just 8% after the post-test. Those with moderate sleep quality increased from 29% to 72%, while mild sleep quality improved from 13% to 20%. This indicates a positive shift in sleep quality over time, suggesting that external factors may have contributed to better sleep among the participants. Score of quality of sleep in experimental group - Comparison between Pre-test and Post-test (N=100) (Table: 4). The results in the experimental group indicate a significant improvement in sleep quality after the intervention. Before the therapy, 52% of participants experienced poor sleep quality, which dropped to 0% in the post-test. Meanwhile, those with moderate sleep quality increased from 30% to 65%, and mild sleep quality improved from 18% to 35%. These findings strongly suggest that the intervention, likely "hot water footbath therapy", were significant in improving sleep quality in the participants. Pre-test and mean post-test score comparison for Control group. (N=100). (Table: 5). The mean sleep quality scores for pre-test and post-test in the control group show a slight improvement. The mean score decreased from 17.16 (SD = 4.220) in the pre-test to 14.89 (SD = 3.897) in the post-test, indicating better sleep quality. The calculated t-value (35.842) at df = 99 is statistically



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significant ($p = 0.000$), suggesting that the observed improvement is meaningful. However, the changes are not as pronounced as in the experimental group, implying that external factors may have contributed to the improvement rather than a specific intervention. Quality of sleep score for the Control group - Statistics (Table: 6). The statistical analysis of sleep quality scores in the control group indicates a moderate upgradation in the post-test, as compared to the pre-test. The mean score decreased from 17.16 to 14.89, reflecting better sleep quality. Similarly, the median and mode shifted from 19 to 16, indicating that most participants experienced a slight improvement. The standard deviation reduced from 4.220 to 3.897, suggesting a more consistent sleep quality among participants post-test. The minimum and maximum scores also showed slight improvement, reinforcing that while some progress was observed, the changes were not as significant as compared to the experimental group. Quality of sleep score for the Experimental Group – Statistics.(N=100) (Table: 7). The statistical analysis of sleep quality scores in the experimental group shows a significant improvement after the intervention. The mean score decreased from 17.01 to 10.88, indicating a notable enhancement in sleep quality. The median and mode also shifted from 19 and 20 to 13, demonstrating that most participants experienced substantial improvement. The standard deviation reduced from 4.377 to 3.751, suggesting a more consistent improvement across participants. Additionally, the minimum score improved from 8 to 4, and the maximum score reduced from 21 to 15, further confirming the effectiveness of the intervention in enhancing sleep quality. Quality of sleep score for the Experimental group - Statistics (Table: 8).

It was found that there was a noteworthy upgradation in the sleep quality scores of participants in the post-analysis in the experimental group. Sleep quality improved as the mean score decreased from 17.01 in the pretest to 10.88 in the post-test. Furthermore, the sleep disturbances demonstrated less variability, as shown by a decrease in the standard deviation from 4.377 to 3.751. The results show a highly significant difference between the pre- and post-test scores (with $t=52.434$ and $df=99$ and $p\text{-value}=0.000$), depicting sleep quality has improved with the intervention. Sleep quality levels and demographic variable in control group. N=100 (Table: 9). The analysis of sleep quality levels in relation to demographic variables within the control group highlights several significant findings. Age, marital status, number of children, education qualification, past occupation, financial dependence, and number of days spent in an old age home all showed statistically significant associations with sleep quality ($p \leq 0.05$). In particular, older individuals (above 75 years), widowed or divorced participants, those with no formal education, and individuals dependent on others for financial support had poorer sleep quality. However, gender, monthly income, and the presence of disease did not show significant associations with sleep quality. These results are an indication depicting the impact of socioeconomic and emotional factors on sleep disturbances among the elderly. Sleep quality levels and demographic variable in Experimental group. N=100 (Table: 10). The analysis of sleep quality in the experimental group shows significant associations with demographic factors ($p \leq 0.05$). Older individuals (60-65 years, above 75 years) and those with no formal education had poorer sleep quality, while participants aged 71-75 years and possessing higher education showed better sleep. Married individuals experienced better sleep compared to widowed, divorced, or unmarried participants. Financial dependence also played a role, with self-dependent individuals having improved sleep quality compared to those relying on siblings or children. Former laborers and houseworkers had poorer sleep quality than those with a business or job. Additionally, participants with chronic illnesses reported worse sleep than healthy individuals. Interestingly, those who stayed in an old-age home for more than three years had better sleep, indicating adaptation over time. However, sex and monthly income did not influence sleep quality largely. Overall, the results highlight that social, financial, and health factors are significant in improving sleep among the elderly. t-test for Pre-test and Post-test Quality of Sleep - Independent Sample (Table: 11). The independent sample t-test has been adopted to relate the quality of sleep (QoS) between the experimental and control groups before and after the intervention. Levene's test has been used to measure variance, and there were no major variations in the variability of the pre-test ($F = 0.458$, $p = 0.499$) or post-test ($F = 1.003$, $p = 0.318$). Before the intervention, there were no major discrepancies between groups in pre-test QoS scores ($t = 0.247$, $p = 0.805$), indicating similar sleep quality. Nevertheless, the post-test results showed a huge discrepancy between the control groups and the experimental groups ($t = 7.414$, $p < 0.001$), which increased the mean of 4.010, indicating the intervention has improved the quality of sleep.





Quality of sleep Assessment

An initial assessment (pre-test) showed that 62% and 58% of participants experienced poor sleep quality in the control and intervention group respectively. In the post-test, the percentage of participants reporting better sleep after the intervention was 80%, whereas the control group continued at 62%, which was significantly less ($p < 0.05$).

“Hot water footbath therapy” and its Effectiveness

Average sleep score improved significantly in the intervention group from 17.01 (SD = 4.377) before treatment to 10.88 (SD = 3.751) afterward ($p < 0.05$). However, the control group showed few changes in mean scores of pre-test and post-test as given by 17.16 (SD = 4.220) and 14.89 (SD = 3.897) respectively, with no significant improvement.

Socio-Demographic Variables and their Association

Gender, marital status, age, and chronic illnesses were great influencers of the poor quality of sleep ($p < 0.05$). Elderly individuals aged 71-75 years, females, widows/widowers, and those with chronic illnesses were more likely to testify poor quality of sleep.

DISCUSSION

Previous research indicates that “hot water footbath therapy” can be influential in improving the sleep for the elderly people living in old-age homes, and these findings are consistent with what has been found in this study. [9] The therapy very likely increases blood flow to the peripheral blood and encourages relaxation to promote sleep onset. This quality of sleep improvement, as observed in the case of the intervention group, indicates that “hot water footbath therapy” can be a potential non-pharmacological intervention for insomniacs. In addition, the study also found several socio-demographic factors related to poor sleep quality: age, gender, marital status, and chronic illness. This highlights the demand for the targeted interventions to cope-up with the special needs of sleep among elderly individuals, particularly the elderly living who are residing in the old-age homes.

CONCLUSION

Improved quality of sleep among old-age individuals living in elderly homes can be achieved using “hot water footbath therapy”, an effective non-pharmacological intervention. The therapy is easy, inexpensive, and free of sleep medication side effects. Further research should determine the long-lasting influence effects of “hot water footbath therapy” and explore the use of the same in other settings.

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Table: 1 Sample Distribution based on Demographic Variables - Frequency and percentage-wise.(N=200)

Sr No	Demographic Variables	Variables	Experimental group		Control group	
			F	%	F	%
1	Age group	60-65 years	44	44%	10	10%
		66-70 years	11	11%	18	18%
		71-75 years	27	27%	33	33%
		Above 75 years	18	18%	39	39%
2	Sex	Male	31	31%	28	28%
		Female	69	69%	72	72%
3	Marital status	Married	13	13%	20	20%
		Unmarried	31	31%	23	23%
		Widow/Widower	44	44%	33	33%
		Divorced	12	12%	24	24%
4	Children you have	1	50	50%	0	00%
		2	30	30%	40	40%
		3	20	20%	40	40%
		4 and above	0	0%	20	20%
5	Education qualification	No formal education	22	22%	20	20%
		Primary education	30	30%	20	20%
		Secondary education	16	16%	30	30%
		Higher secondary	12	12%	11	11%
		Graduate	12	12%	10	10%
		PG and above	8	8%	9	9%
6	Past Occupation	Labor work	24	24%	11	11%
		House work	37	37%	25	25%
		Job	10	10%	15	15%
		Business	11	11%	15	15%
		Retirement	8	8%	13	13%
		Others	10	10%	21	21%
7	Monthly income of the family	10000-20000	52	52%	49	49%
		20001-30000	27	27%	32	32%
		30001-40000	13	13%	13	13%
		40001-50000	8	8%	6	6%
		50001 and above	0	0%	0	0%
8	Your day-to-day expense are met by	Self	51	51%	33	33%
		Sibling	27	27%	28	28%





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		A son	22	22%	28	28%
		A daughter	0	0%	11	11%
9	Suffering from disease	Yes	58	58%	62	62%
		No	42	42%	38	38%
10	Since how many months you are in old age home	< 1 year	22	22%	20	20%
		1-2 year	21	21%	19	19%
		2-3 year	25	25%	22	22%
		>3 year	32	32%	39	39%

Table: 2 Sample distribution based on Factor affecting Sleep - Frequency wise.(N=200)

Sr. No.	Items	Experimental Group	Control Group		
		Yes	No	Yes	No
1	Sleep and Health Issue				
	a. Are you suffering from any type of majordisease?	51	49	60	40
	b. Is your sleep disturbed due to frequent going for washroom or urinary incontinence?	30	70	40	60
	c. Do you have problem of heartburn or acidity due heavy/large meal?	31	69	56	44
	d. Does your sleep disturb due to bad dreams?	32	68	41	59
	e. Do you take any type of medication?	80	20	67	33
	f. Do you have any type of joint pain?	80	20	81	19
2	Sleep Quality				
	a. Do you have<8 hours of actual sleep?	50	50	60	40
	b. You take more than 30 minutes to get sleep?	50	50	61	39
	c. Do you often struggle to sleep in night or wake up in the early morning?	80	20	61	39
	d. Do you have any disturbance during sleep?	80	20	70	30
3	Sleep position				
	Do you frequently change position during sleeping?	51	49	60	40
4	Energy drink				
	Do you to take tea/coffee at every night beforebedtime?	30	70	26	74
5	Sleep Attire				
	a. Is your sleep disturbed by noise/snore?	41	59	46	54
	b. Is your sleep disturbed by seasonal change?	41	59	41	59
	c. Is your sleep disturbed by light?	52	48	37	63
	d. Do you feel you do not have comfortable bed, mattress or bed linen?	50	50	41	59
6	Sleep and work				
	a. Do you have any emotional stress?	79	21	72	28
	b. Does your enthusiasm towards work effect on your sleep?	32	68	32	68
7	Tobacco use				
	a. Do you habituate to chew tobacco or smoking?	28	72	17	83
	b. Do you have/had habit of drinking alcohol?	35	65	17	83



Asha. N, Patel *et al.*,**Table: 3 score of quality of sleep in control group –Comparison between Pre-test and Post-test(N=100)**

Level of Quality of sleep	PRE-TEST		POST-TEST	
	F	%	F	%
Mild quality of sleep (1-9)	13	13%	20	20%
Moderate quality of sleep (10-18)	29	29%	72	72%
Poor quality of sleep (19-26)	58	58%	8	8%

Table: 4 Score of quality of sleep in experimental group - Comparison between Pre-test and Post-test (N=100)

Level of Sleep Quality	PRE-TEST		POST-TEST	
	F	%	F	%
Mild quality of sleep (1-9)	18	18%	35	35%
Moderate quality of sleep (10-18)	30	30%	65	65%
poor quality of sleep (19-26)	52	52%	0	0%

Table: 5 Pre-test and mean post-test score comparison for Control group.(N=100)

Component	Observation	Mean	SD	Calculated "t"-Value	df	Tabulated "t"-value
Control group sleep quality score	Pre-test	17.16	4.220	35.842	99	0.000
	Post-test	14.89	3.897			

Table: 6 Quality of sleep score for the Control group - Statistics.

Statistics		
	Pre-testQoS	Post-test QoS
Mean	17.16	14.89
Median	19	16
Mode	19	16
Std. Deviation	4.220	3.897
Minimum	8	7
Maximum	21	19

Table: 7 Quality of sleep score for the Experimental Group – Statistics.(N=100)

Statistics		
	Pre-testQoS	Post-test QoS
Mean	17.01	10.88
Median	19	13
Mode	20 ^a	13
Std. Deviation	4.377	3.751
Minimum	8	4
Maximum	21	15
a. The smallest value is depicted as multiple modes were detected		

Table: 8 Quality of sleep score for the Experimental group - Statistics.

Component	Observation	Mean	SD	Calculated "t"-Value	df	Tabulated "t"-value
Experimental group sleep quality score.	Pre-test	17.01	4.377	52.434	99	0.000
	Post-test	10.88	3.751			



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Table: 9 Sleep quality levels and demographic variable in control group.N=100

Sr No	Demographic variables	Variables	Mild	Moderate	Severe	df	Chi Square	t Value
1	Age group (years)	60-65	0	1	9	6	32.831	0.000*
		66-70	9	5	4			
		71-75	0	10	23			
		Above 75	4	13	22			
2	Sex	Male	2	5	21	2	4.629	0.99
		Female	11	24	37			
3	Marital status	Married	0	0	20	6	54.923	0.000*
		Unmarried	1	5	17			
		Widow/Widower	3	22	8			
		Divorced	9	2	13			
4	Children you have	1	0	0	0	4	27.895	0.000*
		2	4	16	20			
		3	0	11	29			
		4 and above	9	2	9			
5	Education qualification	No formal education	0	2	18	10	66.446	0.000*
		Primary education	0	10	10			
		Secondary education	4	7	19			
		Higher Secondary	9	1	1			
		Graduate	0	4	6			
		PG and above	0	5	4			
6	Past Occupation	Labor work	0	0	11	10	99.795	0.000*
		Housework	4	7	14			
		Job	9	1	5			
		Business	0	0	15			
		Retirement	0	1	12			
		Others	0	20	1			
7	Monthly income of family	10000-20000	6	17	26	6	9.917	0.128
		20001-30000	7	4	21			
		30001-40000	0	5	8			
		40001-50000	0	3	3			
		50001 and above	0	0	0			
8	Your day today expense are met by	Self	4	21	8	6	37.747	0.000*
		Sibling	6	6	16			
		A son	3	2	23			
		A daughter	0	0	1			
9	Suffering from disease	Yes	11	18	33	2	3.463	0.177
		No	2	11	25			



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10	Since how many months you are in old age home? (in years)	< 1	7	3	10	6	13.075	0.042*
		1-2	3	5	11			
		2-3	1	7	14			
		>3	2	14	23			

* Significant at $p \leq 0.05$ level

Table: 10 Sleep quality levels and demographic variable in Experimental group.N=100

Sr No	Demographic variables	Variables	Mild	Moderate	Severe	df	Chi Square	t Value
1	Age group	60-65 years	7	10	27	6	51.326	0.000*
		66-70 years	0	0	11			
		71-75 years	1	19	7			
		Above 75 years	10	1	7			
2	Sex	Male	8	9	14	2	1.939	0.379
		Female	10	21	38			
3	Marital status	Married	9	3	1	6	34.122	0.000*
		Unmarried	3	8	20			
		Widow/Widower	5	18	21			
		Divorced	1	1	10			
4	Children you have	1	7	13	30	4	18.093	0.001*
		2	4	6	20			
		3	7	11	2			
		4 and above	0	0	0			
5	Education qualification	No formal education	4	1	17	10	31.113	0.001*
		Primary education	4	15	11			
		Secondary education	1	2	13			
		Higher Secondary	5	3	4			
		Graduate	4	6	2			
		PG and above	0	3	5			
6	Past Occupation	Labor work	1	12	11	10	39.523	0.000*
		Housework	14	7	16			
		Job	0	0	10			
		Business	2	6	3			
		Retirement	0	5	3			
		Others	1	0	9			
7	Monthly income of family	10000-20000	8	15	29	6	11.232	0.081
		20001-30000	9	8	10			
		30001-40000	1	6	6			
		40001-50000	0	1	7			
		50001 and above	0	0	0			





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8	Your day today expense are met by	Self	14	17	20	4	16.564	0.002*
		Sibling	3	11	13			
		A son	1	2	19			
		A daughter	0	0	0			
9	Suffering from disease	Yes	16	10	32	2	14.811	0.001*
		No	2	20	20			
10	Since how many months you are in old age home	< 1 year	1	12	9	6	40.681	0.000*
		1-2 year	2	0	19			
		2-3 year	7	1	17			
		>3 year	8	17	7			

* Significant at $p \leq 0.05$ level

Table: 11 t-test for Pre-test and Post-test Quality of Sleep - Independent Sample

Independent Samples Test									
		Levene's Test		t-test (for measuring Equality of Means)					
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	95% Confidence Interval	
								Lower	Upper
Pre-test QoS	Assumed Equal variances	0.458	0.499	0.247	198	0.805	0.150	1.349	1.049
	Not Assumed Equal variances			0.247	197.737	0.805	0.150	1.349	1.049
Post-test QoS	Assumed Equal variances	1.003	0.318	7.414	198	0.000	4.010	5.077	2.943
	Not assumed Equal variances			7.414	197.708	0.000	4.010	5.077	2.943





RESEARCH ARTICLE

Fusion of Rule-Based Learning and Gradient Boosting for Predictive Maintenance in IoT-Enabled Vehicles

P. Vennila^{1*} and V. Maniraj²

¹Ph. D Research Scholar (FT), PG and Research Department of Computer Science, AVVM Sri Pushpam College (Autonomous), Poondi, Thanjavur District, (Affiliated to Bharathidasan University, Tiruchirappalli), Tamil Nadu, India

²Associate Professor and Research Supervisor, PG and Research Department of Computer Science, AVVM Sri Pushpam College (Autonomous), Poondi, Thanjavur District, (Affiliated to Bharathidasan University, Tiruchirappalli), Tamil Nadu, India

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*Address for Correspondence

P. Vennila

Ph. D Research Scholar (FT),
PG and Research Department of Computer Science,
AVVM Sri Pushpam College (Autonomous), Poondi, Thanjavur District,
(Affiliated to Bharathidasan University, Tiruchirappalli),
Tamil Nadu, India.



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ABSTRACT

As IoT-integrated automotive systems, predictive maintenance has emerged as a key enabler for operational efficiency and vehicle safety. Proposed work introduces a hybrid predictive maintenance framework that fuses rule-based expert knowledge with a data-driven Gradient Boosting Machine (GBM) model. The rule-based system uses domain knowledge to flag primary risk indicators, which are then fine-tuned by the GBM algorithm using real-time sensor data such as temperature, vibration, oil pressure, and brake status. The fusion model is tested on simulated and real vehicle datasets collected from fleet operations. Results reveal significant improvements in maintenance prediction accuracy, precision, and recall compared to standalone models. The hybrid approach enables interpretable diagnostics and provides actionable insights to fleet operators and automotive engineers, facilitating proactive maintenance interventions. This research underscores the importance of blending expert knowledge with adaptive learning in the context of intelligent connected vehicles

Keywords: Predictive Maintenance, IoT-Enabled Vehicles, Gradient Boosting Machine (GBM)





INTRODUCTION

Technologies, and it prevents mechanical sensor and data failures due to security and strategic automotive risks. This tool has led to a costly collection of failure analyses. And algorithms. IoT data is used before advanced real-time maintenance, which allows the industry to create a static foundation that is divided into two independent specific performance: real, simulated, managed, changing movements and clarity[1]. And while expertise, fleet combat, predictive accuracy, specific and rule-based benefits and transparency grow, show fusion reinforces them the environments. Proposed data-driven with models and conditions when affected and recall flexible engine supports precision, veracity, maintenance insights and guess model data sets through complex learning to designs. With systems that integrate vehicle learning battles[2].

Importance of Predictive Maintenance in IoT-Enabled Vehicles

The automotive industry is undergoing a major transformation with the integration of Internet of Things (IoT) technologies, especially in the area of maintenance strategies. Transfer, predictive for key motor vehicles generate improvement, has planned data breakdowns, foundation laid (IoT) digital with maintenance beyond things minimizing efficiency, fast enabling and advanced (Reactive) nor maintenance, Preventive downtime, either intelligent or Predictive wear are these in unnecessary vehicles predict failure and are of can result in costly can, replacement suboptima[3]. both are cost safety result maintenance the hazards, service (preventive), hand, after before or on maintenance vehicle to the failures functional. They occur in real-time traditional Reactive when maintained with of part at lead maintenance and potential intervals data other practices, predetermined algorithms increased. On components issues addresses Prevent costly effectively, critical can predictive when engine vibrations as downtime, example, system failure. IoT-enabled managers tyre performance[4]. Abnormal such as temperature, monitor warning fleet and this impending sensors pressure, can be indicated by engine are vehicle to for sensor component and provide signs damage. Pattern, with rising temperature or wear, parameters oil identify that analyses pressure, battery oil a signal bearing variety while proactive, schedule data, brake equipped allow vehicles of inefficiencies. Owner of deterioration maintenance vibration and tension, levels, maintenance early pattern could reduce braking, safety, reliability. Predictive and contributes to fleets, maintenance operational detection undetected commercial tyres issues road in to critical accidents steer a significantly in addition, related impacts. Vehicle in major Timely safety issues. and prevent this where systems or vehicle particularly mechanical resources overall risk expensive improves economic decision making the efficiently predictive or service for and service life demand and manage it of improve In addition, catastrophic it vehicle that a repaired Uptime [8]. Which supports maintenance intervals optimize failures of fleeter Of It enables vehicle standpoint, operator, and replacement. Reduced by data-driven cost efficiency of bad also causes waste sustainability, anticipatory consumption the reducing role minimized in the context of a plays unnecessary role maintenance engines powertrains. And by maintained fuel by replacement intelligent systems, vehicles, the modern real-time predictive interventions in vehicle is of critical importance of IoT-enabled is cost health and directs management. Intelligent systems, vehicles, the modern real-time predictive interventions in vehicle maintenance are of critical importance, enabling proactive component of transport safety, and directing cost health management[6]. IoT-enabled systems provide insights into vehicle operational reliability, enabling optimization of mobility goals. In summary, a progress with intelligent systems is essential for improving vehicle safety, operational efficiency, and cost management [5].

METHODOLOGY

The proposed methodology begins with the collection of real-time sensor data from IoT-enabled vehicles, including parameters such as temperature, vibration, oil pressure, and brake status. This fusion enables timely and interpretable maintenance decisions. This data is preprocessed to eliminate noise and inconsistencies. These initial risk flags are then refined using a Gradient Boosting Machine (GBM) model, which learns complex patterns from historical and simulated datasets. A rule-based system is first applied to identify potential early warning signs of



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component failure using expert-defined thresholds. The hybrid model enhances prediction accuracy by combining human expertise with adaptive machine learning. An overall view of the system architecture is essential to understand how different components interact within the proposed solution. Figure 1 shows the end-to-end hybrid predictive maintenance workflow integrating rule-based logic with Gradient Boosting for enhanced vehicle health monitoring and deployment.

DATA SOURCES

Here two primary datasets were used

Simulated Sensor Dataset

This dataset was using **automotive fault injection techniques**, simulating sensor behavior under various failure conditions. The simulations were based on **engineering knowledge of degradation patterns** observed in real-world vehicle systems such as:

- Engine overheating
- Brake wear progression
- Suspension instability
- Lubrication failure

By modeling these failure types, the simulated dataset provides controlled, labeled sequences of multivariate time-series data suitable for initial model training and validation[9].

Real-World Fleet Dataset

This dataset was collected from over 50 IoT-enabled vehicles in operation across a commercial fleet over a period of 18 months. Data was anonymized to preserve privacy and consisted of

- Engine temperature (continuous monitoring of coolant and cylinder head temps)
- Vibration levels (accelerometer readings from powertrain and chassis)
- Oil pressure (lubrication system readings)
- Brake indicators (fluid levels, brake pad wear sensors)
- Maintenance logs (manual service entries and fault codes)

These data streams represent the real-time operating conditions and failure patterns encountered in daily fleet use. The inclusion of labeled maintenance events enables supervised learning and validation of predictive models [10].

The effectiveness of the proposed model relies on diverse data inputs, as illustrated in **Figure 2**, which shows both simulated and real-world IoT vehicle datasets used for predictive maintenance.

Gradient Boosting Machine (GBM) Algorithm

The Gradient Boosting Machine (GBM) is an ensemble learning technique. It builds a strong predictive model by combining multiple weak learners, usually decision trees, in a sequential manner. Each new tree is trained to correct the errors made by the previous ones. GBM excels at capturing non-linear relationships and feature interactions. This makes it ideal for processing noisy, high-dimensional sensor data [11].

GBM Uses Sensor Data for Predictive Maintenance

Vibration data is essential for detecting anomalies in key components such as bearings, axles, tires, and the drivetrain, which may signal mechanical wear or misalignment. Engine temperature provides critical insights into potential overheating or cooling system issues, helping to identify faults in radiators, thermostats, or coolant leaks [13]. Brake status encompasses parameters like fluid levels, pad wear, and hydraulic pressure, which are crucial for ensuring braking performance and safety. This enables the model to predict maintenance events such as component failures, system alerts, or gradual degradation trends with high accuracy, supporting timely and informed decision-making in predictive maintenance systems. Gradient Boosting Machines (GBM) can effectively process these sensor features by learning complex, non-linear relationships and time-based patterns among them. Oil pressure readings



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are vital for monitoring the integrity of the lubrication system, offering early warnings of leaks, blockages, or pump failures[14].

Step-by-Step GBM Process with Sensor Data**Step 1**

These extracted features provide a richer, more interpretable dataset for machine learning models like GBM to analyze and predict maintenance needs accurately. Feature extraction involves preprocessing raw sensor data and transforming it into meaningful indicators that can enhance predictive model performance[15]. Another important feature is the rate of change, for instance, the change in temperature over time (Δ temperature), which can highlight rapid deviations that may indicate emerging issues[17]. Key transformations include rolling averages, such as a 10-second mean vibration level, which helps smooth out short-term fluctuations and reveal underlying patterns. Additionally, threshold crossings—such as detecting when brake fluid levels drop below a predefined safe limit—serve as critical event markers that can trigger alerts or maintenance actions.

Step 2

Labeling involves assigning a status to each time window of sensor data based on diagnostic logs or records of actual component replacements. This binary classification provides the ground truth needed for supervised learning models like GBM to learn the patterns associated with normal and faulty conditions. Conversely, it is labeled as 0 (Normal Operation) if the system was functioning properly during that time, with no signs of degradation or alerts. Each window is labeled as 1 (Failure/Warning) if it corresponds to a period leading up to a detected issue, alert, or maintenance event, indicating abnormal behavior or impending failure[19].

Step 3 and step 4

This tree attempts to capture the most basic patterns in the data, providing an initial approximation of the target output. These residuals represent the prediction errors and are crucial for guiding the subsequent trees to focus on correcting the mistakes made by the initial model, thereby improving overall accuracy iteratively[16]. Once predictions are made, residuals are calculated by measuring the difference between the predicted values and the actual labels (i.e., the true system status). The initial model in the Gradient Boosting framework begins with training a shallow decision tree—Tree 1—on the extracted features to predict failures.

Step 5

Boosting is the core mechanism of the Gradient Boosting Machine (GBM) algorithm. After the initial tree makes its predictions and residuals (errors) are calculated, a second decision tree is trained specifically to predict these residuals. The outputs of this second tree are then added to the predictions of the first tree, refining the model's accuracy. This iterative process continues for many rounds, with each new tree learning to correct the mistakes of the combined ensemble of previous trees[11]. Over time, the model becomes increasingly accurate by progressively minimizing the overall error, allowing it to capture complex patterns and subtle relationships in the data[14].

Table 1 includes key operational parameters such as engine temperature, vibration, oil pressure, and brake fluid level. The "Label" column indicates the health status of the vehicle, where 1 denotes a potential fault and 0 indicates normal operation.

The learning process of the hybrid model is depicted in Figure 3, highlighting how GBM leverages real-time sensor data for optimized predictive maintenance.

RESULT AND DISCUSSION**Model Performance Evaluation**

The GBM-only model performed significantly better, with an accuracy of 88.1%, precision of 85.6%, recall of 84.2%, F1-score of 84.9%, and an AUC-ROC of 0.89. However, the hybrid model outperformed both, achieving an accuracy of 93.5%, precision of 91.3%, recall of 90.4%, F1-score of 90.8%, and an AUC-ROC of 0.95. This combined approach demonstrated consistently superior performance when compared to standalone GBM and rule-based models[19]. The



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hybrid model, which integrates rule-based expert logic with a Gradient Boosting Machine (GBM), was evaluated using both simulated and real-world IoT vehicle datasets.

By combining domain-specific rules with the learning capability of GBM, the hybrid model delivered the best balance between early fault detection, reduced false alarms, and model interpretability-making it especially effective for predictive maintenance in IoT-enabled vehicles. Specifically, the rule-based model alone achieved an accuracy of 72.4%, precision of 64.3%, recall of 58.1%, F1-score of 60.9%, and an AUC-ROC of 0.68[13].

Interpretability of Predictions

Additionally, the combination of elevated temperature and abnormal vibration signals frequently correlated with issues in the braking system and axles. Importantly, rule-derived risk flags—binary indicators generated from expert-defined conditions—played a crucial role in identifying early signs of component degradation, which may not have been evident from raw sensor data alone. This analysis revealed several key insights[15]. To enhance transparency and trust in the hybrid model, SHAP (SHapley Additive exPlanations) values were used to interpret its predictions at both the global level and for individual vehicles. By offering clear explanations for its outputs, the hybrid model effectively bridges the trust gap commonly associated with black-box machine learning systems, enabling fleet operators to understand the rationale behind maintenance alerts and take informed action. Oil pressure emerged as the most influential feature in high-risk predictions, consistently contributing to the model's decision-making process [19].

Real-World Application Outcomes

To evaluate the real-world effectiveness of the proposed framework, system performance was analyzed through output classification and predictive accuracy. Figure 4 presents a pie chart analysis of system outputs showed that 60% of vehicle readings were classified as normal, 20% required ongoing monitoring, and the remaining 20% triggered actionable alerts—ensuring that maintenance teams are mobilized only when truly necessary. It successfully predicted 90% of maintenance events at least 2 to 3 days before actual servicing was performed, providing critical lead time for intervention [20]. In a simulated real-time deployment using historical fleet data, the hybrid model demonstrated strong practical impact in predictive maintenance. In test fleet scenarios, the system led to a 38% reduction in unexpected breakdowns, significantly improving operational reliability. These results highlight the model's potential to deliver substantial cost savings, minimize vehicle downtime, and enhance overall safety in IoT-enabled vehicle operations.

DISCUSSION AND IMPLICATIONS

Key implications of this methodology include providing fleet operators with clearer and earlier maintenance warnings, supported by evidence-based diagnostics that build trust in automated decisions. The results strongly support the hypothesis that blending rule-based systems with Gradient Boosting Models (GBMs) significantly enhances the accuracy of predictive maintenance while maintaining model explainability. Importantly, this approach is not limited to vehicle maintenance; it is highly generalizable to other industrial IoT applications such as smart factories, drones, and heavy machinery, where early fault detection and interpretability are crucial. Additionally, automotive engineers can iteratively refine expert rules based on feedback from the model's outputs, fostering a dynamic collaboration between data science and domain expertise. This hybrid approach addresses real-world requirements, where transparent diagnostics are just as vital as predictive performance[21]. Figure 5 Shows the plots reveal rising temperature and vibration, along with declining oil pressure, indicating potential signs of mechanical degradation or upcoming failure. The time-series trends of key vehicle parameters—temperature, vibration, and oil pressure—recorded over time.

CONCLUSION



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Real-world evaluations confirmed the model's effectiveness in reducing unplanned maintenance, enhancing fleet safety, and improving overall operational efficiency. This study presents a hybrid predictive maintenance framework that seamlessly combines rule-based domain expertise with data-driven learning through a Gradient Boosting Machine (GBM). Future work may focus on extending this approach to more complex sensor networks and implementing continuous online learning capabilities for real-time, adaptive deployment. Ultimately, this research underscores the value of uniting human knowledge with machine learning in industrial IoT environments. Utilizing real-time sensor data—including engine temperature, vibration, oil pressure, and brake status—the proposed system demonstrated superior performance in terms of accuracy, precision, and interpretability when compared to standalone models. The integration of expert rules enabled the early detection of failure patterns, while GBM provided the adaptability and robustness needed to handle varying vehicle conditions.

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Table 1: Sensor Data for Predictive Maintenance in Fleet Vehicles

Timestamp	Temp (°C)	Vibration (g)	Oil Pressure (psi)	Brake Fluid (%)	Label
10:01	90	0.12	35	70	0
10:02	98	0.21	28	67	0
10:03	105	0.36	23	65	1

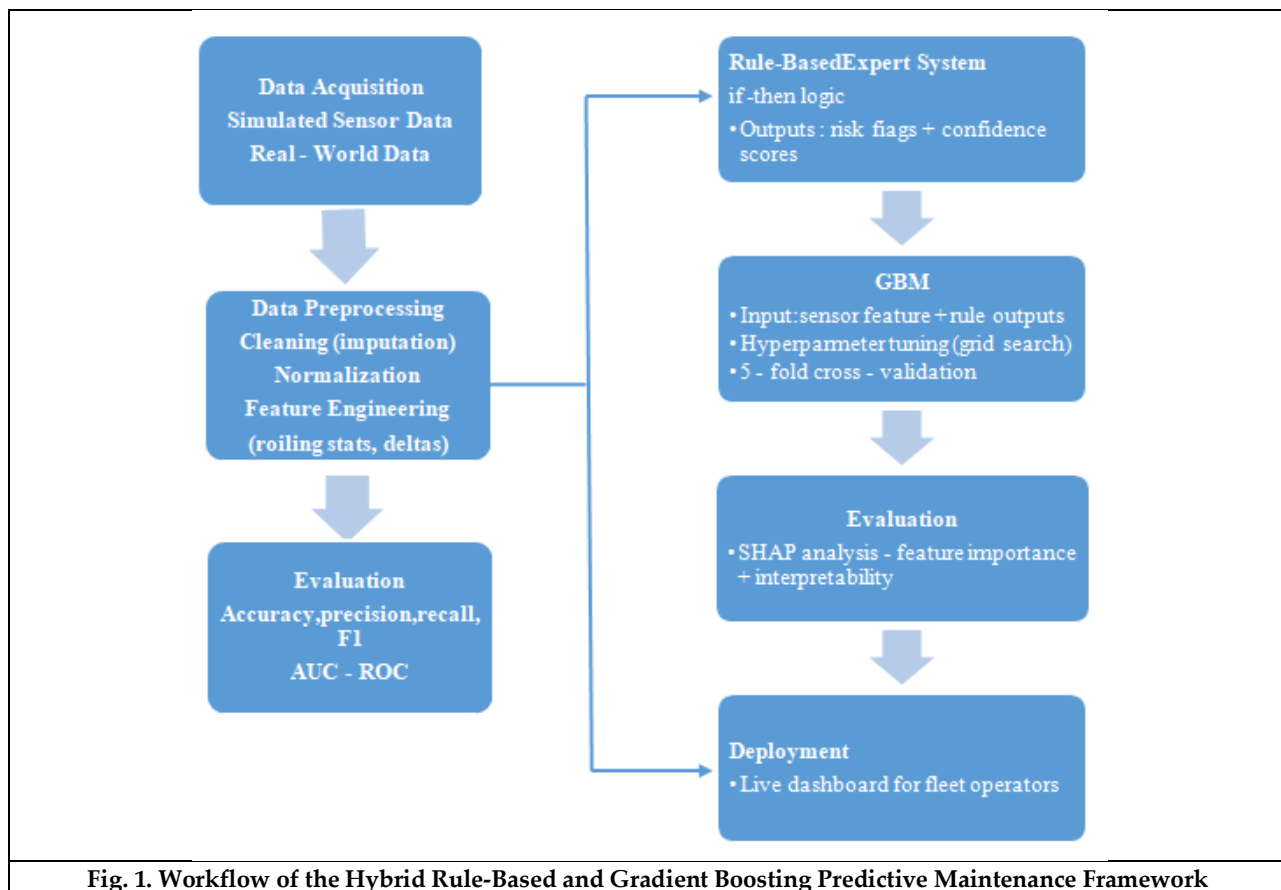


Fig. 1. Workflow of the Hybrid Rule-Based and Gradient Boosting Predictive Maintenance Framework





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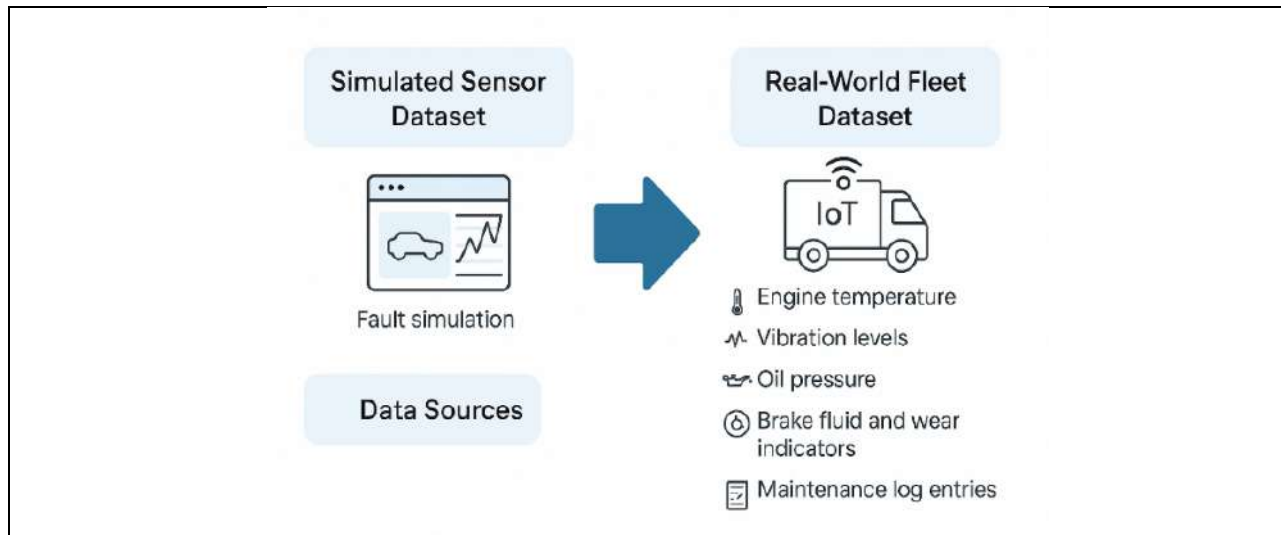


Fig. 2. Real – Time Operating Conditions Diagram

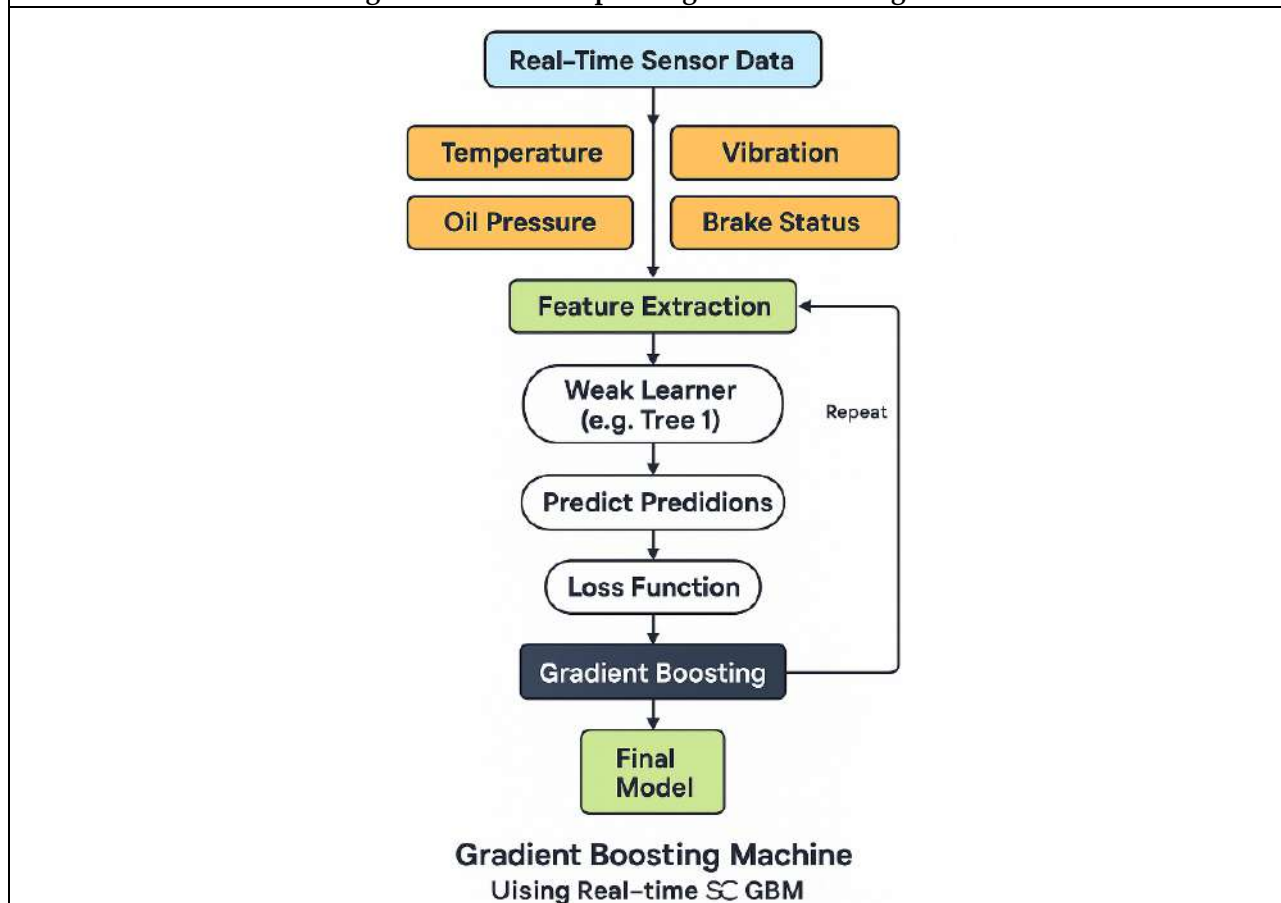


Fig. 3. Gradient Boosting Machine Using Real-Time Sensor Data





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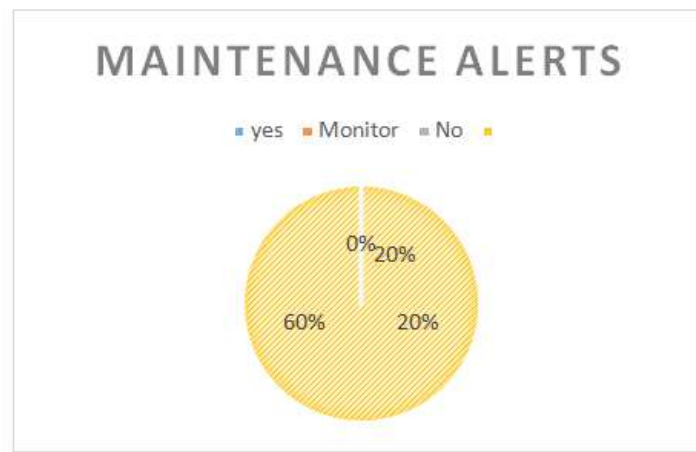


Fig. 4. Distribution of Maintenance Alerts Generated by the Predictive Maintenance System

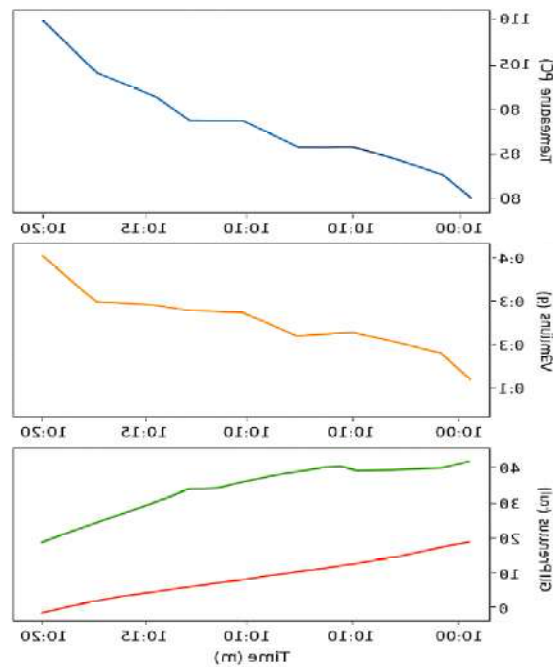


Fig. 5. Time-Series Analysis of Vehicle Sensor Parameters for Predictive Maintenance





RESEARCH ARTICLE

Effect of Cryostretch and Myofascial Release for Pain and Function in Individuals with Plantar Fascitis : A Pilot Study

Mahi Kapadia^{1*}, Dhaval Patel² and Gaurav Patel³

¹MPT Scholar, Department of Physiotherapy, Ahmedabad Physiotherapy College, Ahmedabad, Parul University, Gujarat, India.

²Associate Professor, Department of Physiotherapy, Ahmedabad Physiotherapy College, Ahmedabad, Parul University, Gujarat, India.

³Principal and Professor, Department of Physiotherapy, Ahmedabad Physiotherapy College, Ahmedabad, Parul University, Gujarat, India.

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*Address for Correspondence

Mahi Kapadia

MPT Scholar,

Department of Physiotherapy,

Ahmedabad Physiotherapy College, Ahmedabad,

Parul University, Gujarat, India.

E.Mail: kapadiamahi1010@gmail.com



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ABSTRACT

A common cause of heel pain is plantar fasciitis, which is caused by inflammation of the plantar aponeurosis at its attachment to the calcaneal tuberosity. This condition results in soreness or tenderness of the foot sole beneath the heel, which can occasionally spread into the medial arch. This treatment technique, called cryostretch, combines stretching and cryotherapy to help release soft tissues. Myofascial release is a massage method that breaks up adhesions in the fascia by stretching the muscle and fascia. This can help improve range of motion or reduce pain. The aim of this study is to compare and evaluate the efficacy of cryostretch and myofascial release in improving pain and function in individuals with plantar fasciitis. A total of 20 individuals aged between 20 to 40 years with of plantar fasciitis were included in this study. Participants were divided into two groups: Group A received Cryostretch, and Group B received Myofascial Release Therapy. Both groups followed a conservative protocol for one week, with sessions conducted three times per week. Pain and functional outcomes were assessed using the Numeric Pain Rating Scale (NPRS) and the Foot Function Index (FFI), with pre- and post-intervention data collected for comparison. Normality of the data was used assessed using Shapiro Wilk test, the between group analysis was done using MANN WHITNEY U TEST and within group analysis was done using WILCOXON SIGN RANK TEST. In comparison for NPRS and FFI the result is significant where $p < 0.05$ for NPRS and $p < 0.05$ for FFI which states that MFR have better outcomes than Cryostretch. Group B MFR has reported to have a better outcome than Group A cryostretch.

Keywords: Plantar Fasciitis, Heel Pain, Cryostretch, Myofascial Release



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INTRODUCTION

Plantar fasciitis, another name for plantar heel pain, is a type of heel discomfort or stiffness that only affects the sole of the foot. It frequently emanates from the medial tubercle of the calcaneus or the center of the heel pad, although it can also go into the medial longitudinal arch of the foot via the plantar fascia[1]. Approximately 10% of the general population suffers from plantar fasciitis, and 83% of those affected are active, working people between the ages of 25 and 65. The general population between the ages of 40 and 60 has the highest incidence. Furthermore, women were more likely than men to have plantar fasciitis, as were people aged 45–64 compared to those aged 18–44, and people with a body mass index greater than 25 kg/m². According to some research, up to 22% of people are runners[2]. A biomechanical overuse syndrome called plantar fasciitis causes degenerative changes where it attaches to the calcaneus[3]. People who spend most of their time standing up and have a limited ankle dorsiflexion range are more likely to develop plantar fasciitis, which is usually caused by a biomechanical imbalance that creates strain along the plantar fascia[4]. Pain from plantar fasciitis is most severe after extended periods of inactivity, such as immediately after waking up and late in the day after hours of walking and weight-bearing[5]. The repetitive motion of running or walking can result in microtears in the plantar fascia when aggravating conditions are present. The afflicted area is usually close to the plantar fascia's origin at the calcaneus' medial tuberosity.6 Young women who wear high heels, which put additional strain on the plantar fascia, have been linked to rupturing the fascia[4]. The conventional wisdom was that severe tensile tension on the plantar fascia, resulting in microscopic tears and chronic inflammation, is what causes plantar fasciitis. Current views state that maximum stress is the primary cause of plantar fasciitis, which is frequently referred to as fasciosis rather than fasciitis because it arises from the degradation of fascia. Particularly, gap junctions between fibrocytes sense the elevated fascial stress, which in turn causes changes in the extracellular matrix, causing the plantar fascia to rupture and myxoid deteriorate[7]. Plantar fasciitis is treated with rest, stretching, strengthening, changing shoes, arch supports, orthotics, night splints, and anti-inflammatory drugs[4]. The purpose of cryostretch is to release soft tissues by combining the use of cryotherapy and stretching techniques. A frozen tennis ball is used in the cryostretch technique, which helps to lengthen muscles and fascia and relieve spasms[8]. Cryotherapy causes vasoconstriction, decreases microcirculations, and lessens local hypothermia. Additionally, it lessens the development of edema, local inflammation, and blood leaking into surrounding tissues; it also lessens the conduction of motor and sensory nerves[9]. Myofascial release (MFR) is the application of a low load, long duration stretch to the myofascial complex, intended to restore optimal length, decrease pain, and improve function[10]. A soft tissue mobilization technique called myofascial release (MFR) is used to treat chronic diseases that cause soft tissue tension and constriction. By changing the ground substance's viscosity to a more fluid state, the myofascial release treatment relieves the excessive pressure that the fascia places on the pain-sensitive structure and helps to restore normal alignment. Therefore, it is suggested that this method serve as a catalyst for the resolution of PF[11].

MATERIALS AND METHODOLOGY

In this study, a comparative design was used to evaluate the effectiveness of treatment in individuals with plantar fasciitis. The data was collected from Ahmedabad Physiotherapy College, with a sample size of 20 individuals selected through a convenient sampling method. The study population included individuals aged 20 to 40 years who presented with symptoms such as the first painful step in the morning for at least one week and calcaneal soreness and pain on palpation. Only those willing to participate were included in the study. Individuals with recent fractures or surgeries around the ankle joint, congenital foot deformities, open wounds, infections, sensory impairments, or skin hypersensitivity were excluded[8]. The treatment was administered three times a week for one week. Materials used during the study included a pencil or pen, consent form, data collection sheet, lubricant, plinth, and chair. Outcome measures were assessed using the Numerical Pain Rating Scale (NPRS) and the Foot Function Index (FFI) to evaluate pain intensity and foot function, respectively.



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PROCEDURE

A group of 20 individuals were included in the study who fulfill the inclusion criteria, consent form would be obtained after explaining the interventions from all the subjects.

The sample size is 20 individuals were divided in 2 two groups,

According to randomization the groups will be divided accordingly as follows

Group A consists of 10 individuals receives Cryostretch therapy along with common intervention

Group B consists of 10 individuals receives Myofascial release therapy along with common intervention

Cryostretch Therapy

A frozen tennis ball was used for this approach. The individuals were seated on a chair with one foot flat on the floor and the other on the frozen tennis ball. After that, the participants were instructed to roll the frozen ball under their foot's arch, which ran from the heel to the metatarsals, for two minutes (30 repetitions), focusing on the medial arch. Because higher pressures have been demonstrated to improve flexibility, the patients were told to apply as much pressure as they could, pushing into discomfort but not pain. In addition to the exercises standing calf stretch (15–30 sec, 3 sets), curb/stair stretch (15 sec, 3 sets), seated plantar fascia stretch (15 sec, 3 sets), toe curls (10–20 reps), and heel raises (15 reps, 5-sec holds, 2 sets), this technique was performed on alternate days (the first, third, and fifth day of the week)[8].

Myofascial Release Therapy

Patient position: In order to facilitate easy dorsiflexion, the patient should be positioned prone with their feet off the end of the table.

Therapist's position: Seated on a stool near the table's end

Technique: Engage the soft tissue just in front of the calcaneus with the knuckles. A line of tension should be taken in an anterior direction. Work from the patient's side to the ball of the foot and deeper layers using toe flexion and extension. Five minutes × two reps[12].

The exercises standing calf stretch (15–30 sec, 3 sets), curb/stair stretch (15 sec, 3 sets), seated plantar fascia stretch (15 sec, 3 sets), toe curls (10–20 reps), and heel raises (15 reps, 5-sec holds, 2 sets) were performed on alternate days (the first, third, and fifth day of the week) in addition to the standard intervention[8].

RESULTS

Data was analyzed using the statistical package SPSS 26.0 (SPSS Inc., Chicago, IL) and level of significance was set at $p < 0.05$. Descriptive statistics was performed to assess the mean and standard deviation of the respective groups. Normality of the data was assessed using Shapiro Wilk test. To find out the difference between the groups was done using MANN WHITNEY U TEST and within group analysis was done using WILCOXON SIGN RANK TEST. Comparison of age (Table 1). Comparison of gender (Table 2). Comparison of NPRS (Table 3). Regarding NPRS, The between group analysis of "PRE and POST values by Mann Whitney U test reported statistical difference regarding 'POST' values only ($P < 0.05$). Mann Whitney U test also reported statistical significance regarding the 'mean difference' ($p < 0.05$) between groups. Within group analysis using Wilcoxon Sign rank test reported significant difference in both GROUP A- CRYOSTRETCH group and GROUP B-MFR group ($p < 0.05$) and higher difference observed with respect to GROUP B- MFR group compared to GROUP A-CRYOSTRETCH group regarding NPRS score. ($p < 0.05$) (Graph 1). Comparison of FFI (table 4). Regarding FFI, The between group analysis of "PRE and POST values by Mann Whitney U test reported statistical difference regarding 'POST' values ($P < 0.05$). Mann Whitney U test also reported statistical significance regarding the 'mean difference' ($p < 0.05$) between groups. Within group analysis using Wilcoxon Sign rank test reported significant difference in both GROUP A- CRYOSTRETCH group and GROUP B-MFR group ($p < 0.05$) and higher difference observed with respect to GROUP B- MFR group compared to GROUP A-CRYOSTRETCH group regarding FFI score. ($p < 0.05$). (Graph 2).



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DISCUSSION

The current study aimed to compare the effectiveness of cryostretch therapy and myofascial release therapy in individuals with plantar fasciitis in terms of pain and function. 20 participants were taken in this study considering the inclusion and exclusion criteria divided into 2 groups. Group A consists of 10 individuals receiving cryostretch therapy and Group B consists of 10 individuals receiving myofascial release therapy. The intervention was given for 3 times every alternate days for 1 week. After the collection of data, the data was assessed using the statistical package SPSS 26.0 (SPSS Inc., Chicago, IL) and level of significance was set at $p < 0.05$. Descriptive statistics was performed to assess the mean and standard deviation of the respective groups where difference between the groups was done using MANN WHITNEY U TEST and within group analysis was done using WILCOXON SIGN RANK TEST. In this for the outcome of NPRS between group analysis of "PRE and POST values by Mann Whitney U test reported statistical difference regarding 'POST' values only ($P < 0.05$) and Within group analysis using Wilcoxon Sign rank test reported significant difference in both GROUP A- CRYOSTRETCH group and GROUP B-MFR group ($p < 0.05$) and higher difference observed with respect to GROUP B- MFR group compared to GROUP A- CRYOSTRETCH group regarding NPRS score ($p < 0.05$). For the outcome FFI between group analysis of "PRE and POST values by Mann Whitney U test reported statistical difference regarding 'POST' values ($P < 0.05$) and Within group analysis using Wilcoxon Sign rank test reported significant difference in both GROUP A- CRYOSTRETCH group and GROUP B-MFR group ($p < 0.05$) and higher difference observed with respect to GROUP B- MFR group compared to GROUP A-CRYOSTRETCH group regarding FFI score ($p < 0.05$). According to previous study done by Aditi Jadhav *et al*, On Day 7 post-intervention, there was a notable rise in PPT and a significant decrease in group CS in terms of functional impairment and pain intensity. Because cryotherapy reduces inflammation surrounding the plantar fascia, it has been shown to be an effective pain reliever[8]. According to our study myofascial release (MFR) also demonstrated improvements in these outcomes, indicating its potential as an effective intervention. According to our study myofascial release (MFR) has showed significant improvement in pain and function, The myofascial release technique aims to lengthen and smooth the fascia while also dissolving adhesions. By loosening the fascia that may be blocking blood vessels or nerves, the myofascial release technique has been demonstrated to enhance the body's natural regenerative qualities by enhancing circulation and the neurological system[13] In our study, MFR was associated with greater improvements in outcomes, suggesting its potential effectiveness in enhancing recovery. The previous study shows M.S. Ajimsha *et al*, The main conclusion of this investigation is that, when it came to PHP's pain, functional impairment, and pressure pain threshold, the MFR intervention examined in this experiment was noticeably more successful than SUST. claiming that while the precise processes underlying MFR's effectiveness in treating plantar heel pain are unknown, they may be connected to a reduction in risk factors such tightness in the gastrocnemii and soleus muscles and limited ankle dorsiflexion, or to a relaxation of tension across the plantar fascia[12]. In our study, MFR was associated with greater improvements in outcomes, suggesting its potential effectiveness in enhancing recovery. In previous study by Heni Ishwarlal Tandel *et al*, demonstrated that MFR is useful in helping people with plantar fasciitis reduce discomfort and improve their functioning; as a result, the MFR technique may be used as an adjuvant treatment for plantar fasciitis[14]. In our study, MFR was associated with greater improvements in outcomes, suggesting its potential effectiveness in enhancing recovery. According to our study Group B Myofascial Release Therapy has greater improvements in outcomes pain and function when compared to Group A Cryostretch therapy.

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Table 1: Comparison of Age

		Group A- Cryostretch	Group B-MFR
AGE	MEAN	26.4	26.9
	SD	4.02	4.23
T VALUE		0.08	
P VALUE (INDEPENDENT T TEST)		0.94	

*P<0.05 is statistically significant (Shapiro Wilkinson test ,p>0.05)

No statistically significant difference between the groups regarding mean age (p>0.05)

Table 2- Comparison of Gender

		Group A- Cryostretch	Group B-MFR	X ²	P value
GENDER	MALE	2(20%)	3(30%)	0.23	0.68
	FEMALE	8(80%)	7(70%)		

*P<0.05 is statistically significant

No statistically significant difference between the groups regarding gender(p>0.05)

Table 3: Comparison of NPRS

		Group A- Cryostretch	Group B-MFR	Z Value	P Value
NPRS	PRE	6.4+1.01	5.4+0.8	2.01	0.06
	POST	4.3+0.9	2.2+0.74	5.69	0.0001*
DIFFERENCE	2.1+1.01	3.2+0.7	2.83	0.01*	
Z VALUE	4.69	9.28			
P VALUE	0.0001*	0.0001*			

*P<0.05 is statistically significant (Shapiro Wilkinson test ,p>0.05)



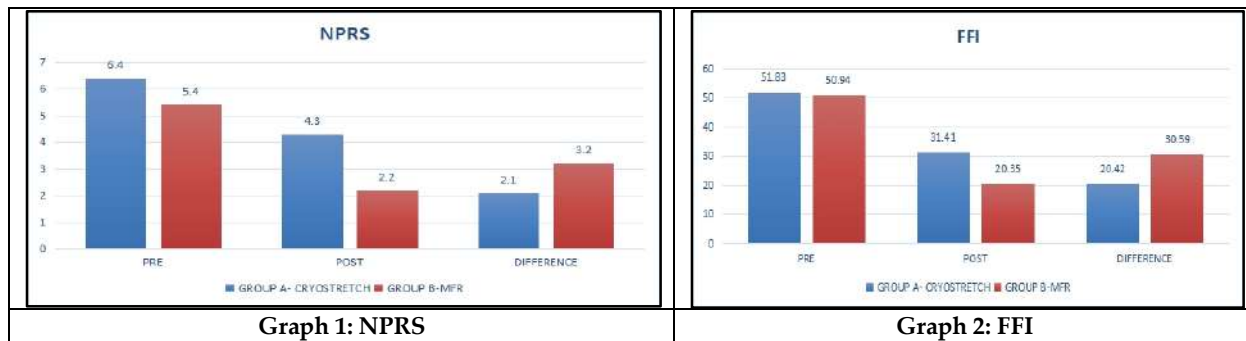


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Table 4: Comparison of FFI

		Group A- Cryostretch	Group B-MFR	Z Value	P Value
FFI	PRE	51.83+10.69	50.94+11.58	0.23	0.77
	POST	31.41+9.62	20.35+6.68	2.98	0.007*
DIFFERENCE		20.42+10.05	30.59+9.65	2.22	0.03*
Z VALUE		4.89	7.25		
P VALUE		0.0003*	0.0001*		

*P<0.05 is statistically significant (Shapiro Wilkonson test ,p>0.05)





RESEARCH ARTICLE

Efficacy of Visual Tracking Intervention in Occupational Therapy on Eye Contact in Children with Autism Spectrum Disorder

T.Jegadeesan^{1*} and Sowbakkialakshmy.N²

¹Principal, Department of Occupational Therapy, JKK Munirajah Medical Research Foundation College of Occupational Therapy, Komarapalayam, Namakkal, (Affiliated to The Tamilnadu Dr. MGR Medical University), Chennai, Tamil Nadu, India.

²Occupational Therapist, Department of Occupational Therapy, JKK Munirajah Medical Research Foundation College of Occupational Therapy, Komarapalayam, Namakkal, (Affiliated to The Tamilnadu Dr. MGR Medical University), Chennai, Tamil Nadu, India.

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*Address for Correspondence

T.Jegadeesan

Principal,

Department of Occupational Therapy,

JKK Munirajah Medical Research Foundation College of Occupational Therapy,

Komarapalayam, Namakkal,

(Affiliated to The Tamilnadu Dr. MGR Medical University),

Chennai, Tamil Nadu, India.

E.Mail: jegadeesantee@gmail.com



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ABSTRACT

Children with Autism Spectrum Disorder (ASD) often exhibit impaired eye contact, affecting their social interaction and communication. Visual tracking interventions within occupational therapy may improve gaze control and engagement. To evaluate the efficacy of visual tracking interventions in improving eye contact among children with ASD using the Eye-Contact Avoidance Scale (ECAS). A quasi-experimental study design was employed with 30 children aged 3–6 years, divided equally into control and experimental groups. Pre- and post-tests were conducted using ECAS. The experimental group received visual tracking-based occupational therapy. Data were statistically analyzed using paired t-tests. The experimental group showed a significant improvement in post-test scores (Mean: 44.4) compared to pre-test (Mean: 49.8) with a t-value of 11.7143 ($p < 0.0001$). In contrast, the control group had minimal improvement ($t = 2.1622$, $p = 0.0484$). Visual tracking interventions significantly improved eye contact in children with ASD. These findings support the integration of visual-motor training in occupational therapy protocols for ASD.

Keywords: Autism Spectrum Disorder, Eye Contact, Visual Tracking, Occupational Therapy,





INTRODUCTION

Autism Spectrum Disorder (ASD) is a Neuro development condition[1] characterized by persistent deficits in social communication and interaction, alongside restricted, repetitive patterns of behavior, interests, or activities. One of the hallmark features observed in children with ASD is the marked difficulty in maintaining appropriate eye contact, which significantly impairs their ability to engage in meaningful social interactions. According to the Centers for Disease Control and Prevention (CDC), approximately 1 in 54 children[2] in the United States is diagnosed with ASD, with a higher prevalence observed in males. These deficits in nonverbal communication, particularly in eye contact, often hinder a child's ability to participate effectively in daily activities at home, in school, and within the community. Eye contact serves as a foundational element in the development of social cognition and communication skills. Impairments in gaze behavior are not only indicative of ASD but are also linked to broader deficits in joint attention, emotional reciprocity, and language development[3]. Several studies have demonstrated that children with ASD exhibit altered visual attention patterns, including avoidance of direct gaze and difficulty in tracking facial expressions. These visual-perceptual challenges highlight the need for targeted therapeutic approaches aimed at improving visual engagement and gaze control[4,5]. Visual tracking, a critical component of visual-motor coordination, involves the controlled movement of the eyes to follow a moving object. It is essential for various functional tasks such as reading, playing, and social engagement[6]. Occupational therapy interventions that incorporate visual tracking exercises provide an opportunity to enhance eye movement control, focus, and attention. These interventions are grounded in the core OT principles of client-centered and occupation-based practice, where therapy is tailored to the child's unique interests, developmental level, and real-life contexts[7]. Through structured activities such as following light patterns, tracking moving objects, and interactive visual games, children can be supported in developing more consistent and purposeful eye contact. Despite the growing recognition of sensory and perceptual challenges in children with ASD, there remains a limited body of research exploring the direct impact of visual tracking interventions on eye contact[8]. This study aims to bridge this gap by evaluating the efficacy of a structured visual tracking program[9,10] delivered within an occupational therapy framework. By targeting gaze behavior through visual-motor training, this research seeks to contribute to the development of evidence-based practices that improve social communication outcomes for children with ASD.

METHODOLOGY

This study employed a quasi-experimental design with a pre-test and post-test control group to determine the efficacy of visual tracking interventions within occupational therapy on eye contact in children with Autism Spectrum Disorder (ASD). A total of 30 children aged between 3 and 6 years, diagnosed with mild to moderate autism based on their Eye-Contact Avoidance Scale (ECAS)[10] scores (ranging from 41 to 54), were selected through convenient sampling. The study was conducted over a period of six months at Sri Samarthanam Early Intervention and Rehabilitation Center, Karungalpalayam, Erode.

Participants were divided into two groups: The control group received conventional therapy from a special educator, while the experimental group underwent a structured visual tracking intervention integrated into occupational therapy sessions. Each group consisted of 15 children. The intervention was administered over a period of six weeks, with three sessions per week, each lasting approximately 45 minutes. The visual tracking program included progressive activities such as light pattern exploration, light trails, interactive light boards, and targeted light play designed to engage children in following and maintaining focus on moving visual stimuli. These activities were aimed at enhancing gaze stability, visual attention, and eye-movement coordination. Pre-intervention assessments were conducted using the Eye-Contact Avoidance Scale (ECAS) to establish baseline data for both groups. Following the six-week intervention period, the same tool was administered as a post-test. The ECAS is a validated instrument that quantifies the frequency and intensity of eye contact avoidance behaviors in children. The collected data were statistically analyzed using paired t-tests to compare pre- and post-intervention scores within each group, and independent t-tests to compare the outcomes between the experimental and control groups. A



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significance level of $p < 0.05$ was set for all statistical analyses. This methodology was designed to assess the direct impact of structured visual tracking interventions on eye contact, with the goal of establishing an evidence-based approach for improving social communication in children with ASD through occupational therapy.

Data Analysis and Results

The study analyzed the effectiveness of visual tracking intervention in improving eye contact among children with Autism Spectrum Disorder (ASD) using the Eye-Contact Avoidance Scale (ECAS). The sample consisted of 30 children divided equally into an experimental group and a control group.

Comparison of Pre-Test Scores (Table.1)

The mean pre-test score for the control group was 49.06 (SD = 5.62), while the experimental group recorded a mean score of 49.8 (SD = 3.93). The t-value was calculated as 0.03529 with a p-value of 0.7294, indicating no statistically significant difference between the two groups before the intervention.

Pre-Test and Post-Test Comparison in Control Group (Table.2)

In the control group, the mean ECAS score decreased slightly from 49.73 (SD = 5.70) to 48.6 (SD = 5.74). The paired t-test revealed a t-value of 12.4746 and a p-value of 0.0001, which is statistically significant. However, the minimal change in mean suggests only limited improvement, potentially due to confounding factors or the effect of routine therapy.

Pre-Test and Post-Test Comparison in Experimental Group (Table.3)

The experimental group showed a substantial decrease in ECAS scores from a mean of 49.87 (SD = 3.96) to 44.40 (SD = 4.08). The t-value was 11.7143 with a p-value of 0.0001, indicating a statistically significant improvement following the visual tracking intervention.

Post-Test Comparison Between Control and Experimental Groups (Table.4)

Post-intervention comparison showed that the control group had a mean ECAS score of 48.6 (SD = 5.74), whereas the experimental group had a lower mean score of 44.4 (SD = 4.08). The independent t-test yielded a t-value of 2.1622 and a p-value of 0.0484, establishing that the experimental group demonstrated significantly greater improvement in eye contact than the control group.

DISCUSSION

This study aimed to determine the efficacy of visual tracking interventions integrated into occupational therapy for improving eye contact in children with Autism Spectrum Disorder (ASD). The results of the study clearly indicate that children in the experimental group who received visual tracking-based occupational therapy showed a statistically and clinically significant improvement in their eye contact behavior compared to those in the control group. The substantial difference in post-test scores between the groups supports the hypothesis that visual tracking exercises play a significant role in enhancing visual attention and gaze stability. The results align with findings from Janmohammadi *et al.* (2020)[11], who demonstrated that visual tracking interventions improved attention and behavioral responses in children with ADHD. This study similarly emphasized the importance of isolated neck and eye movement training in enhancing visual-motor control, which is crucial for maintaining eye contact. Furthermore, Bradshaw *et al.* (2019)[8] reported that eye-tracking patterns could serve as biomarkers for treatment outcomes in ASD, revealing that increased attention to faces was associated with improved language and communication skills. This lends further support to the effectiveness of structured visual tracking interventions in promoting social engagement. In the control group, the slight decrease in ECAS scores could be attributed to practice effects, special educator guidance, or general development over time. However, the change was minimal compared to the experimental group. This difference highlights the unique impact of targeted visual tracking interventions over conventional therapies alone. Sue Fletcher-Watson and Sarah Hampton (2018)[12] also emphasized the potential of



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eye-tracking as a sensitive and objective measure for behavioral changes in neuro-developmental disorders. Their findings underscore the importance of using evidence-based, objective outcome measures in intervention studies. The current study supports this perspective, demonstrating that structured visual tracking activities can effectively improve social eye contact, a key challenge in ASD. Additional reviews in the literature also support the significance of improving eye contact for enhancing communication and social functioning. For example, Fongerl *et al.* (2018)[13] successfully used shaping procedures to teach sustained eye contact in preschool-aged children with ASD, and their results maintained without prompting for up to a month. Overall, the study confirms that integrating visual tracking strategies within occupational therapy can provide meaningful improvements in eye contact, thereby enhancing social communication skills in children with ASD. The results also validate the Eye-Contact Avoidance Scale (ECAS) as a suitable tool for measuring such interventions.

CONCLUSION

Occupational therapy interventions incorporating visual tracking exercises are effective in enhancing eye contact among children with ASD. Visual tracking activities appear to strengthen visual-motor engagement and should be considered in OT programs for ASD.

LIMITATIONS

Small sample size
Short intervention period
Limited age group

RECOMMENDATIONS

Larger sample size and longer duration
Inclusion of diverse age groups
Gender-based comparative analysis

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Table.1: Comparison of Pre-Test Scores

Group	Test	Mean	S.D	"t" value	"p" value
Control	Pre	49.06	5.62	0.03529	0.7294
Experimental	Pre	49.8	3.93		

Table.2: Pre-Test and Post-Test Comparison in Control Group

Group	Test	Mean	S.D	"t" value	"p" value
Control	Pre	49.73	5.70	12.4746	0.0001
	Post	48.6	5.74		

Table.3: Pre-Test and Post-Test Comparison in Experimental Group

Group	Test	Mean	S.D	"t" value	"p" value
Experimental	Pre	49.87	3.96	11.7143	0.0001
	Post	44.40	4.08		

Table.4: Post-Test Comparison Between Control and Experimental Groups

Group	Test	Mean	S.D	"t" value	"p" value
Control	Post	48.60	5.74	2.1622	0.0484
Experimental	Post	44.40	4.08		





RESEARCH ARTICLE

Efficacy of Vidhi Karma in the Management of Manyastambha with Special Reference to Cervical Spondylosis : A Clinical Study

Dhairyjeetsinh Gohil^{1*}, Harish Daga² and Hemant Toshikhane³

¹Post Graduate Scholar, Department of Shalya Tantra, Parul Institute of Ayurved, Parul University, Limda, Waghodia, Vadodara, Gujarat, India.

²HOD and Associate Professor, Department of Shalya Tantra, Parul Institute of Ayurved, Parul University, Limda, Waghodia, Vadodara, Gujarat, India.

³Dean, Principal and Professor, Department of Shalya Tantra, Parul Institute of Ayurved, Parul University, Limda, Waghodia, Vadodara, Gujarat, India.

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*Address for Correspondence

Dhairyjeetsinh Gohil

Post Graduate Scholar,

Department of Shalya Tantra,

Parul Institute of Ayurved, Parul

University, Limda, Waghodia,

Vadodara, Gujarat, India.

E.Mail: dhairyjeetsinhji@gmail.com



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ABSTRACT

Cervical spondylosis is a degenerative disorder characterised by structural and functional derangements in the cervical spine. It is a common work-related and age-related condition, affecting individuals aged 40 to 60 years. In Ayurveda, Manyastambha (stiffness of the neck) is one of the conditions that can be correlated with cervical spondylosis. Vidhi Karma, a therapeutic procedure described in the *Sushruta Samhita*, is recognised as a significant intervention in managing such conditions. This clinical study aimed to evaluate the effectiveness of Vidhi Karma in patients with Manyastambha, with special reference to cervical spondylosis. Thirty-five patients aged 40 to 60 years were selected based on inclusion criteria and underwent the Vidhi Karma procedure under necessary precautions. The findings of this study proved the efficacy of Vidhi Karma in alleviating symptoms of cervical spondylosis by addressing the underlying Vata Dosha imbalance. The results suggest that Vidhi Karma is a promising treatment modality for managing Manyastambha and improving the quality of life in affected patients.

Keywords: Cervical spondylosis, Manyastambha, Vidhi Karma, Vata-Kapha disorders, Pain management.

INTRODUCTION





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Cervical spondylosis is a degenerative condition of the cervical spine, marked by structural and functional deterioration. It commonly affects individuals between 40 and 60 years of age and is considered both a work-related and age-related disorder. Patients typically present with symptoms such as neck pain (*Shoola*), stiffness (*Stambha*), restricted movement (*Graha*), and occasionally dizziness (*Bhrama*). In Ayurveda, this condition can be correlated with *Manyastambha*, a disorder caused by aggravated *Vata Dosha*, sometimes combined with *Kapha Dosha*. According to Ayurvedic principles, *Manyastambha* results from an imbalance in *Dosha*, particularly due to a weakened *Agni* (digestive fire), leading to the accumulation of *Ama* (toxins) and obstruction of *Srotas* (body channels). The affected *Roga Marga* (site of disease manifestation) is the *Madhyama Roga Marga* (musculoskeletal and neurological systems), involving the *Mamsavaha* and *Asthivaha Srotas*. The main clinical manifestations include neck stiffness, restricted movement, radiating pain and in severe cases, neurological symptoms such as tingling or numbness. In Ayurveda, *Vidhi Karma*, a therapeutic procedure described in the *Sushruta Samhita*, is considered an effective intervention for *Vata-Kapha* disorders like *Manyastambha*. This clinical study aimed to evaluate the efficacy of *Vidhi Karma* in alleviating symptoms of cervical spondylosis. A total of 35 patients were treated with *Vidhi Karma* over four sessions, with significant follow-up measures taken to ensure safety and therapeutic efficacy. **Table 1: Dosha**

Dushya in Manyastambha

Dosha	<i>Vata (predominantly) and Kapha (secondary involvement)</i>
Agni (digestive power)	<i>Mandagni (weakened digestive fire) leading to Ama accumulation and Dosha aggravation</i>
Udbhava sthana	<i>Manyapradesha (Cervical region and neck)</i>
Adhisthana	<i>Manyapradesha (Cervical region and neck)</i>
Srotas	<i>Mamsavaha Srotas (Muscle channels) Asthivaha Srotas (Bony channels)</i>
Srotodustiprakara	<i>Sanga</i>
Roga Marga	<i>Madhyama Roga Marga</i>
Vyakta	• Stiffness and rigidity of the neck • Restricted movement of the head • Pain in the cervical region radiating to upper back or shoulders • Severe cases may involve tingling or numbness due to nerve involvement

Patient Information

A total of 35 patients aged 40–60 years were included in the study. All patients presented with complaints of *Shoola* (pain), *Stambha* (stiffness), and *Graha* (restricted movement) in the neck region. Patients meeting the diagnostic criteria, associated symptoms, and both objective and subjective criteria were enrolled. The duration of symptoms was limited to a maximum of 5 years.

Diagnostic Criteria

Shoola: Pain in the cervical region

Stambha: Stiffness in the cervical region

Graha: Restricted neck movements

Bhrama: Giddiness

Associated Symptoms

Shira Shoola: Headache

Supta : Loss of sensation

Assessment Criteria

Subjective Criteria

Visual Analog Scale (VAS)





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Objective Criteria

Neck Disability Index

Investigations

1. Complete Blood Count (CBC)
2. Erythrocyte Sedimentation Rate (ESR)
3. HIV
4. HBsAg
5. Random Blood Sugar (RBS)
6. Bleeding Time (BT)
7. Clotting Time (CT)
8. X-ray of the cervical spine (AP and lateral view)

Timeline of Intervention

Patient presented to OPD with complaints of **Shoola** (pain), **Stambha** (stiffness), and **Graha** (restricted movement) in the neck region

screening of patient done and based on diagnostic criteria pt. enroll in the study

all relevant documentation and investigation done

vidhi karma
Sittings Four sessions were conducted at intervals of seven days (on the 1st, 7th, 14th, and 21st days).

Followup after 30 days

MATERIALS AND METHODS

Vidhi Karma

Sittings: Four sessions were conducted at intervals of seven days (on the 1st, 7th, 14th, and 21st days).

Follow-up Period: 30 days.

Procedure of Vidhi Karma

Poorva Karma (Pre-procedure)

Preparatory steps were undertaken to ensure patient safety and procedure efficiency:

Informed Consent: Written informed consent was obtained from all patients prior to the procedure.

Injection: An intramuscular injection of tetanus toxoid was administered.

Investigations: Relevant investigations, including CBC, ESR, and X-rays, were conducted to assess the patient's fitness for the procedure.

Preparation: The procedure site was prepared, and the patient was seated comfortably in a sitting position with the neck flexed at a 45-degree angle, supported by a neck band.

Pradhana Karma (Main Procedure)

The primary procedure of Vidhi Karma was carried out with utmost precision and sterility:

Sterilization: The affected cervical region was cleaned thoroughly with spirit to maintain asepsis.

Identification of Tender Points: Using gloved hands, the most tender points in the cervical region were palpated, identified, and marked.

Insertion of Needle

- An insulin needle was inserted perpendicularly (at a 90-degree angle) into the marked tender points to a depth of 2 mm.
- The needle was retained in position for 10 seconds.





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Removal of Needle: After 10 seconds, the needle was carefully withdrawn, ensuring minimal discomfort to the patient.

Paschat Karma (Post-procedure)

Post-procedure care and monitoring were conducted to ensure patient safety and recovery:

Observation: Patients were observed for any immediate reactions or complications.

Vital Monitoring: Vital signs, including heart rate, blood pressure, and respiratory rate, were monitored to ensure stability.

Aftercare: Patients were instructed to report any discomfort or unusual symptoms during the follow-up period.

This systematic approach ensured that Vidhi Karma was performed effectively while maintaining safety and achieving desired therapeutic outcomes.

OBSERVATION

A total of 35 patients aged between 40 and 60 years, presenting with classical symptoms of *Manyastambha*—including pain (*Shoola*), stiffness (*Stambha*), and restricted neck movement (*Graha*)—were enrolled in the study. All patients underwent *Vidhi Karma* in four sittings at weekly intervals. Observations were recorded before treatment (B.T) and after treatment (A.T) to assess both primary and associated symptoms. Prior to treatment, pain in the cervical region was a universal complaint. Of these, 45.71% of patients reported mild pain, 40% moderate pain, and 14.28% severe pain. Remarkably, following the completion of the procedure, 97.14% of the patients reported complete resolution of pain, with only 2.86% reporting residual mild discomfort. Stiffness of the neck was observed in 100% of the participants before intervention. After completion of therapy, only 8.57% of the patients continued to experience any stiffness, demonstrating a significant therapeutic effect of *Vidhi Karma* on muscle rigidity. Restricted movement of the neck, recorded in 82.85% of the patients initially, was resolved in 91.42% of the cases after treatment. This suggests considerable improvement in functional mobility of the cervical spine post-intervention. In terms of associated symptoms, 88.57% of patients initially experienced giddiness (*Bhrama*), which was reduced to only 2.85% after treatment. Similarly, headache (*Shiroshoola*), which affected 85.71% of patients pre-treatment, persisted in only 5.71% after the intervention. Numbness or tingling sensation (*Suptata*) was reported by 82.85% of participants initially and was reduced to 2.85% post-treatment. These observations reflect a statistically and clinically significant reduction in both primary and associated symptoms of cervical spondylosis following *Vidhi Karma*, confirming its therapeutic utility in the management of *Manyastambha*.

DISCUSSION

The present clinical study was undertaken to evaluate the efficacy of *Vidhi Karma* in the management of *Manyastambha* (Cervical Spondylosis), a condition characterized by pain, stiffness, and restricted movements in the cervical region. The pathogenesis of *Manyastambha*, as per Ayurveda, is rooted in *Vata-Kapha* Dosha imbalance, *Mandagni*, *Ama* formation, and obstruction in *Mamsavaha* and *Asthivaha Srotas*. These pathophysiological events closely correlate with the degenerative and inflammatory processes of cervical spondylosis described in modern medicine.

Clinical Outcomes and Interpretation

The clinical parameters observed before and after the intervention provided compelling evidence of the therapeutic efficacy of *Vidhi Karma*. Among 35 patients

Pain (Shoola): Initially, 100% of patients experienced pain of varying intensities, with 14.28% suffering from severe pain. Post-intervention, 97.14% of patients were completely relieved of pain, showing statistically and clinically significant improvement.



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Stiffness (Stambha): A hallmark of *Manyastambha*, stiffness was present in all patients (100%) before treatment. After four sessions of *Vidhi Karma*, only 8.57% continued to exhibit any stiffness. The release of stiffness can be attributed to local stimulation and improved neuromuscular function due to the therapy.

Restricted Movement (Graha): 82.85% of patients initially reported reduced neck mobility. Following the intervention, 91.42% of patients regained normal range of motion. This indicates a strong influence of *Vidhi Karma* in restoring musculoskeletal flexibility and reducing *Srotorodha*.

Associated Symptoms: Symptoms such as dizziness (Bhrama), headache (Shiroshoola), and numbness (Suptata), which reflect nerve compression or circulatory stagnation, showed over 90% resolution. These results suggest systemic improvement beyond local symptom relief.

Mechanistic Insights and Ayurvedic Interpretation

From an Ayurvedic viewpoint, *Vidhi Karma* acts through several mechanisms

Dosha Shamana: The procedure pacifies aggravated *Vata* and *Kapha* Doshas, thereby restoring the equilibrium required for normal neuromuscular functioning.

Srotoshodhana: The puncturing method facilitates micro-channel opening, reducing obstruction (*Sanga*) in *Mamsavaha* and *Asthivaha Srotas*.

Neuromuscular Stimulation: The technique of inserting needles at specific *Marma-adjacent* tender points may stimulate local nerve endings and vascular tissues, improving circulation and reducing inflammation—a principle that aligns with modern dry needling or trigger point therapy.

Improvement of Agni and reduction of Ama: Though not directly measured, clinical improvement implies enhancement of metabolic processes at the tissue level.

Safety, Simplicity, and Patient Satisfaction

The procedure was conducted under strict aseptic conditions and showed no significant adverse effects. Pre-procedure investigations and tetanus prophylaxis ensured patient safety. The minimally invasive nature and short duration of the procedure improved patient compliance and satisfaction.

Comparison with Other Therapies

Unlike oral medication-based interventions, *Vidhi Karma* offers a targeted approach with quicker symptom resolution and fewer systemic side effects. Its efficacy in neuromusculoskeletal disorders such as *Manyastambha* confirms its clinical utility, especially in degenerative conditions with limited options for long-term relief in modern medicine.

CONCLUSION

The findings of this study highlight the therapeutic efficacy of *Vidhi Karma* in the management of cervical spondylosis. Significant improvement was observed in pain, stiffness, and restricted movement, with over 90% of patients achieving near-complete relief of symptoms. Associated symptoms such as dizziness, headache, and numbness also showed substantial resolution. These results underscore the potential of *Vidhi Karma* as a promising, safe, and effective treatment modality for *Manyastambha* and related musculoskeletal disorders. From an Ayurvedic perspective, the success of *Vidhi Karma* lies in its ability to address the root cause of the disorder by balancing *Dosha* and clearing *Srotorodha*. The intervention not only provided symptomatic relief but also improved the overall quality of life in the affected patients.





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DECLARATION OF CONFLICT OF INTEREST

No conflicts of interest.

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Table 1: Comparative Symptom Analysis Before Treatment (B.T) and After Treatment (A.T) in Patients Undergoing Vidhi Karma for Manyastambha (Cervical Spondylosis)

Symptom	Grade / Status	B.T (n)	A.T (n)	% B.T	% A.T
Shoola (Pain)	No Pain	0	34	0.00%	97.14%
	Mild Pain	16	1	45.71%	2.86%
	Moderate Pain	14	0	40.00%	0.00%
	Severe Pain	5	0	14.28%	0.00%
Stambha (Stiffness)	Present	35	3	100.00%	8.57%
	Absent	0	32	0.00%	91.42%
Graha (Restricted Movement)	Present	29	3	82.85%	8.57%
	Absent	6	32	17.14%	91.42%
Bhrama (Dizziness)	Present	31	1	88.57%	2.85%
	Absent	4	34	11.42%	97.14%
Shiroshoola (Headache)	Present	30	2	85.71%	5.71%
	Absent	5	33	14.28%	94.28%
Suptata (Numbness)	Present	29	1	82.85%	2.85%
	Absent	6	34	17.14%	97.14%





RESEARCH ARTICLE

Anomaly Detection in a Crowd Scene using Stacked Autoencoder

Kinjal V Joshi^{1*} and Narendra M Patel²

¹Assistant Professor, Department of Computer Engineering, G H Patel College of Engineering & Technology, (Affiliated to The Charutar Vidya Mandal University), Vallabh Vidyanagar, Anand, Gujarat, India.

²Professor, Department of Computer Engineering, Birla Vishvakarma Mahavidyalaya Engineering College, Anand, Gujarat, India.

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*Address for Correspondence

Kinjal V Joshi

Assistant Professor,
Department of Computer Engineering,
G H Patel College of Engineering & Technology,
(Affiliated to The Charutar Vidya Mandal University),
Vallabh Vidyanagar, Anand, Gujarat, India.
E.Mail: kinjaljoshi@gcet.ac.in



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ABSTRACT

Automatic anomaly detection in crowd scenes is becoming increasingly important due to heightened concerns about public safety and security. Despite its significant utility, this area remains an open research topic due to its complexity. The task of detecting abnormal events is particularly challenging because the definition of "abnormality" is inherently subjective—what may be considered normal in one context can be seen as abnormal in another. Moreover, the task becomes even more difficult in crowded environments, as surveillance videos often suffer from clutter, severe occlusions, and complex interactions among individuals. In this manuscript, stacked autoencoder based approach is proposed. As encoder extracts meaningful features from image, only encoder part of autoencoder is used in this approach. The image is given as input to first autoencoder, features extracted by encoder1 are given as input to second autoencoder. The features extracted by encoder2 are given as input to softmax layer with labels. Then encoder1, encoder2 and softmax layer are stacked together and the network is generated that classifies image as normal or abnormal. The performance is improved by applying backpropagation on the whole multilayer network. The experiments are done using five publicly available benchmark datasets. The performance is measured by Accuracy and Area Under the ROC Curve (AUC). The experimental results determine the efficacy of the proposed approaches.

Keywords: Abnormal event, Deep learning, Supervised learning, Surveillance scene





INTRODUCTION

Video Surveillance Systems have become an integral part of the security systems for any residential, commercial, educational, government, medical premises and other public places. This prevents unwanted intrusion in the premises and provides with surveillance data in case of any security breach. The state of art security systems thereby generate a huge volume of video data which at present is analysed manually, randomly and on demand. Sophistication of video monitoring is required to avoid spending man-hours just watching hours or days of video recordings to identify the segment of interest. Also, manual supervision of the videos leave scope of missing something of interest of high value, many a times resulting in major loss of evidence. Hence, it is very clear that there is an urgent need of techniques and methods to automate the video monitoring task and generate timely responses or alerts to authorities in case of occurrence of an abnormal event. Research on automatic anomaly detection has just begun and there is long way to go. This work particularly addresses anomaly detection in a crowded environment. Crowded environment here covers railway stations, bus stations, roads, cafeterias, hospitals, schools etc. A crowd is a unique group of individuals, or something involves a community or society [1]. Crowd scenes can be categorized into two types: structured crowd scenes and unstructured crowd scenes. The term structured crowd scene can be described as the crowd moving coherently in a common direction, and motion direction does not vary with time. Each spatial location of the scene supports only one dominant crowd behaviour over time, for example, marathon race, queues of people and traffic on the road. The term unstructured crowd scene represents the random crowd motion; different participants move in various directions at different time. Each spatial location supports multi-model crowd behaviour, for example, people walking on a zebra crossing in the opposite direction, exhibition, railway station and airport. An immense amount of research is done and going on for crowd analysis in the computer vision field because of its applications like Crowd Management, Public Space Design, Virtual Environments, Visual Surveillance and Intelligent Environments. Crowd analysis can be represented with four modules: People detection and tracking, People counting, Behavior analysis and Abnormality detection. Abnormal event detection is considered as one module of crowd analysis. Zitouni *et al.* [2] have done a comparative study of the research work done for the different modules of crowd analysis and reported that 30% of the research work of complete crowd analysis is done in the abnormality detection module which represents importance of the research for crowd anomaly detection. Crowd analysis has been carried out using supervised and unsupervised learning approaches. This is considerably new domain of work and availability of a labelled dataset for all scenarios is not guaranteed. Therefore, supervised approach may not be always the most suitable one. However, by carefully analysing the surveillance data for a specific environment, it is possible to generate a labelled dataset. Unsupervised approach can be employed based on the assumption that only normal event video data is used for training. This can detect any anomaly that differs from the training data. This can be a problem when a normal event is detected as an abnormal one since it wasn't a part of the original training set. This issue needs to be addressed. In situations where labelled dataset is not available at all, an unsupervised learning-based approach has to be used. Currently, both supervised and unsupervised methods are proposed by the researchers to address the issue of anomaly detection in crowded environment.

Motivation

Currently, automatic anomaly detection is a big challenge. A fully automatic system is not available to detect and recognize various anomalies in security footage, especially in crowded environment. Many real-world benchmark datasets are openly available for investigation. Everywhere CCTV (Closed-circuit television) cameras are used, and automatic video monitoring is an essential requirement to consider the public security. The production of an enormous amount of CCTV footage and growing anxiety about security and safety is the main origin of motivation to work on abnormality detection in a crowd scene.

The significant contributions of this research are as follows

- The approach based on stacked autoencoder is proposed in which a deep network is trained by training one layer at a time.



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- The experiments are done using five publicly available benchmark datasets and comparison with existing methods using each dataset is also presented.
- The proposed approach gives comparable results with supervised deep learning algorithms.

The rest of the paper is organized as follows. The recent work done by different researchers is presented in section 2. The section 3 describes the proposed approach and experimental results. Comparison of the proposed method with state-of-the-art methods is shown in section 4. At last, the conclusion and future scope of the research is represented in section 5.

RELATED WORK

Because of importance of automatic anomaly detection, many researchers have worked in this field. Deep learning gives very good performance in various fields like computer vision and natural language processing. So, recent work is done based on deep learning approaches. Here the methods of anomaly detection are categorized in two parts one is traditional features based methods and the other is deep features based methods.

Traditional Features Based Approaches

Mehran *et al.* [5] employed the social force model to estimate interaction forces between individuals in motion. These forces were projected onto the image plane to create force flow maps for each frame. By analyzing spatiotemporal volumes of force flow, they modeled normal crowd behavior and identified anomalies using a bag-of-words classification. Their method achieved an AUC of 0.96 on the UMN dataset, significantly outperforming traditional optical flow methods i.e., AUC of 0.84. Wu *et al.* [11] focused on detecting escape behaviors in surveillance videos, proposing a Bayesian model that utilizes potential destinations and divergent centers to recognize abnormal situations. Wu *et al.* [12] further extended this by analyzing particle trajectories to capture complex crowd flows using chaotic dynamics. This feature set trained a probabilistic model, achieving an impressive AUC of 0.99 on the UMN dataset. Cem Direkoglu *et al.* [13] improved on optical flow by computing the angle difference between flow vectors of consecutive frames and combining it with the magnitude of optical flow. They used a one-class SVM to learn normal behavior and detect abnormalities when test data significantly deviates from the learned norm. Achieved 96.46% accuracy on the UMN dataset. They also compared their method with Bayesian Model (BM) [11], Sparse Reconstruction Cost (SRC) [14], Chaotic Invariants (CI) [12], Social Force model (SF) [10] and Force Field model (FF) [15]

D. Chen and P. Huang [15] used optical flow and Adjacency-Matrix-based Clustering (AMC) to segment human crowds into groups unsupervised. They characterized group behaviors using a force field model based on orientation, position, and size, achieving 94% accuracy on the UMN dataset. Y. Cong *et al.* [14] proposed the Sparse Reconstruction Cost (SRC) method, which leverages a dictionary-based reconstruction error to assess the normalcy of test samples. They employed convex optimization for large-scale dictionary selection and achieved an AUC of 0.487 on the UCSDPed1 dataset. M. Halbe *et al.* [17] computed crowd motion energy from optical flow and enhanced it with Crowd Motion Intensity (CMI). Peaks in CMI were interpreted as signs of abnormal behavior, with threshold tuning playing a critical role in detection performance. Hu *et al.* [18] introduced a Histogram of Oriented Contextual Gradients (HOCG) descriptor, which captures contextual gradients between local regions to model the compositional context of events. Using online dictionary learning and a sparse reconstruction framework, they identify abnormalities based on SRC values exceeding a threshold—adaptively set based on prior performance. This approach achieved a high AUC of 0.993 on the UMN dataset.

X. Zhang *et al.* [19] focused on detecting anomalies through energy level distribution changes in crowd scenes. They extracted pixel velocities using optical flow, then segmented motion foregrounds via a flow field texture representation. They estimated camera-to-subject distance via linear interpolation. Abnormal behavior was detected by analyzing changes in consistency, entropy, and contrast—three co-occurrence matrix descriptors. Threshold tuning for these descriptors was key to detection accuracy.





Y. Yong *et al.* [20] combined crowd density and crowd dynamics into a unified feature vector. They used the Local Binary Pattern Co-Occurrence Matrix (LBPCM) for density estimation and Histograms of the Orientation of Interaction Force (HOIF)—derived from high-accuracy optical flow—for dynamics. An SVM classifier was employed for anomaly detection. The method achieved an AUC of 0.99 on the UMN dataset. Y. Benabbas *et al.* [27] used optical flow fields combined with block clustering techniques to detect unusual crowd events. This method focuses on grouping similar motion patterns to identify outliers as anomalies. Y. Gao *et al.* [28] introduced Violent Flows (ViF) and Oriented Violent Flows (OViF) to detect violent events in crowd scenes. OViF incorporates directional motion information for improved performance. They used AdaBoost and linear SVM classifiers, achieving an AUC of 0.9484 on the Violent Flows dataset. Except for these features, different authors have used various traditional features like motion structure, Spatiotemporal features, Mixture of Probabilistic Principal Component Analyzers (MPPCA), Mixture of Dynamic Textures (MDT), Local Statistical Aggregates, Sparse Cuboids (SC), Local Trinary Patterns (LTP), Simplified Histogram of Oriented Tracklets (SHOT), Interaction Force (IF), Improved Fisher Vectors, Gaussian Process Regression (GPR) etc.

Deep Learning Based Approaches

T. Mostafa *et al.* [26] focused on analyzing local spatiotemporal motion patterns within video frames. They generated motion heatmaps to identify regions of interest and applied various classifiers, including Support Vector Machine (SVM), Naive Bayes, Neural Network, and Convolutional Neural Network (CNN), for anomaly detection. Among these, the CNN classifier demonstrated superior performance, achieving an accuracy of 96.74% on the UMN dataset and 94.28% on the UCSD dataset. M. Ravanbakhsh *et al.* [25] employed a Fully Convolutional Network (FCN) as a pre-trained model and introduced a binary quantization layer as the final layer to effectively capture temporal CNN-based motion patterns in crowd scenes. Sabokrou *et al.* [29] leveraged transfer learning by utilizing a pre-trained AlexNet CNN, adapting it for anomaly detection tasks in surveillance videos. Feng *et al.* [30] extracted both appearance and motion features using PCANet, and constructed a deep Gaussian Mixture Model (GMM) trained on observed regular events. Their method achieved an AUC of 0.925 on the UCSDPed1 dataset. Zhou *et al.* [31] proposed a Spatiotemporal CNN that jointly learns appearance and motion features from spatial and temporal dimensions. Their method reported AUC values of 0.9963 on the UMN dataset and 0.927 on the Subway Entrance dataset, showcasing high effectiveness in real-world scenarios. S. Smeureanu *et al.* [32] utilized a pre-trained VGG CNN model for feature extraction, followed by a one-class SVM classifier to model normal event patterns. Their approach achieved an AUC of 0.85 on the UMN dataset. J. Sun *et al.* [33] proposed the Deep One-Class (DOC) model, combining CNN-based feature extraction with a one-class SVM to detect anomalies from normal event images. They experimented with both linear and radial basis function (RBF) kernels in the SVM. The model achieved AUC values of 0.808 and 0.914 on the UCSDPed1 dataset using the linear and RBF kernels, respectively. Hinami *et al.* [34] adopted a Fast R-CNN model to detect abnormal events. As a region-based convolutional neural network, R-CNN relies on region proposals for both training and testing, which can significantly impact the processing speed of the algorithm, despite offering high detection precision. Shiyang Yan *et al.* [35] proposed a two-stream R-convolutional variational autoencoder (R-convVAE), which integrates both appearance and motion features to learn a probabilistic distribution of normal events. They conducted comparative experiments with several unsupervised models, including convolutional autoencoders, convolutional variational autoencoders, recurrent convolutional autoencoders, and recurrent convolutional variational autoencoders. Among these, the two-stream R-convVAE achieved the highest performance, with an AUC of 0.75 on the UCSDPed1 dataset. Yong Shean Chong *et al.* [36] introduced a spatiotemporal autoencoder comprising two primary modules: one for capturing spatial features and another for learning their temporal evolution. This approach effectively models normal behavior patterns and achieved AUC values of 0.899 on the UCSDPed1 dataset and 0.847 on the Subway Entrance dataset. Waqas Sultani *et al.* [38] developed UCF-Crime, a large-scale and challenging multiclass anomaly detection dataset. They evaluated two event classification approaches. The first employed a 3D convolutional neural network for feature extraction followed by a nearest neighbor classifier, which achieved an accuracy of 23%. The second approach used a Tube Convolutional Neural Network (TCNN) that incorporates a tube-of-interest pooling layer to aggregate features across video clips. This method improved performance, achieving a classification accuracy of 28.4%. H. Vu *et al.* [37] combined a denoising autoencoder with Conditional Generative Adversarial Networks (cGANs) for anomaly





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detection in video sequences. Their method leverages the ability of generative models to reconstruct normal patterns, highlighting deviations as potential anomalies. Federico Landi *et al.* [9] proposed a framework based on a 3D convolutional network followed by a regression network to estimate anomaly scores. They conducted two types of experiments using the UCFCrime2Local dataset. In the first, the entire video frame was used as input, achieving an AUC of 0.5612. In the second, they used a spatiotemporal tube to localize abnormal events, resulting in a significantly improved AUC of 0.7413. As a fully supervised approach, K. Joshi and N. Patel [3] developed a custom CNN architecture trained from scratch for anomaly detection across multiple datasets. Their method achieved high performance with AUC values of 0.99, 1.0, 1.0, 1.0 and 0.73 using UMN, UCSDPed1, ViolentFlows, Subway Entrance and UCFCrime2Local datasets respectively.

THE PROPOSED APPROACH AND EXPERIMENTAL RESULTS

Sparse Autoencoder

A sparse autoencoder is an autoencoder whose training criterion involves a sparsity penalty. The loss function is constructed by penalizing activations of hidden layers so that only a few nodes are encouraged to activate when a single sample is fed into the network [51]. By activating a few nodes at a time, the autoencoder actually learns latent Representations instead of redundant information in input data. Figure-1 represents the sparse autoencoder architecture.

Parameters

Sparsity regularization: The autoencoder tries to learn a function $h_{w,b}(x) \approx x$. It tries to learn an approximation to the identity function, so the output is similar to the input. The identity function looks to be the insignificant function to be trying to learn, but by placing constraints on the network, such as by limiting the number of hidden units, interesting structure about the data can be found. If the number of hidden units is large, then sparsity constraint can be applied.

Consider a_j^l denotes the activation of hidden unit j in the autoencoder at layer l . The average activation of hidden unit j (averaged over the training set) is represented as the following equation.

$$\rho_j = \frac{1}{n} \sum_{i=1}^n a_j^l x^i$$

The constraint enforced $\rho_j = \rho$ where ρ is a sparsity parameter, typically a small value close to zero. To achieve this, an additional penalty term can be added, which is known as the sparsity regularization term. Many such terms give reasonable results. One such sparsity regularization term is the Kullback-Leibler divergence, as shown in the following equation.

$$\sum_{j=1}^{s_2} KL(\rho || \rho_j) = \sum_{j=1}^{s_2} \rho \log \log \frac{\rho}{\rho_j} + (1 - \rho) \log \frac{(1-\rho)}{(1-\rho_j)}$$

Where, s_2 is the number of neurons in the hidden layer, and the index j is summing over the hidden units in the network. If ρ and ρ_j are same, $KL(\rho || \rho_j)$ is 0; otherwise it increases monotonically as ρ_j diverges from ρ .

L2 weight regularization

When training a sparse autoencoder, the weights may be increased to make the sparsity regularization term small. A regularization term on the weights to the cost function is added to prevent this. This term is called the L_2 regularization term and is defined by as $\frac{1}{2} \sum_l^L \sum_j^n \sum_i^k (w_{ji}^{(l)})^2$, where L is the number of hidden layers, n is the number of observations and k is the number of variables in the training data.

Maximum Epochs: It represents the maximum number of training iterations.

The Proposed Approach

In the proposed approach stacked autoencoder is used. The stacked autoencoder is a neural network in which hidden layers are trained by an unsupervised method and then fine-tuned by a supervised manner. A stacked autoencoder consists of several layers of sparse autoencoders where the output of each hidden layer is connected to



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the input of the successive hidden layer. Stacked autoencoder mainly consists of following steps. First, the autoencoder is trained using input data and acquiring the learned data. Second, the learned data from the previous layer is used as an input for the next layer and this continues until the training is completed. Finally, once all the hidden layers are trained, the back propagation algorithm is used to minimize the cost function, and weights are updated with the training set to achieve fine-tuning. The contemporary advancement in stacked autoencoder is that it provides a version of raw data with much detailed and useful feature information, which is used to train a classifier with a determined context and find better accuracy than training with raw data. The main objective of using a stacked autoencoder is to train a deep neural network by training one layer at a time. Figure-2 represents the proposed approach. Here, two sparse autoencoders are used, one with 100 nodes and the other with 50 nodes. In this approach, only encoder components of autoencoders are used. First, the training images are given as input to autoencoder1, which contains 100 nodes. The features extracted by encoder1 are provided as input to autoencoder2, including 50 nodes. The number of nodes in the second autoencoder is decreased so that its encoder learns a smaller representation of the input data. The features extracted by encoder2 are given as input to the softmax layer with labels. Then both encoders are stacked with a softmax layer to form a stacked network. This network is fine-tuned by retraining it on the training data in a supervised manner as shown in Figure-1. The parameters like sparsity regularization, L2 weight regularization, epochs are tuned to train autoencoder. The parameters are set as follows.

Sparsity regularization:1

L2 weight regularization 0.001

Maximum epochs:50

The implementation is done with MATLAB-2019a, 16 GB RAM, i9 Processor CPU machine.

Experimental Results

Dataset Description

In this work, five publicly available challenging datasets are used, namely UMN, UCSDPed1, Violent Flows, Subway Entrance and UCFCrime2Local. In all these datasets, ground truth and enough abnormal images are available. The UMN [4] dataset is developed by University of Minnesota. It contains two outdoor and one indoor video samples with 320×240 pixels image resolution. Each video consists of an initial part of walking as a normal state and ends with sequences of running as an abnormal state. The UCSDPed1 [6] is developed by University of California and San Diego. It is a real-world dataset that contains 34 training video samples and 36 testing video samples. Both train and test samples have 200 frames of dimension 238×158 . In this dataset, pedestrians walking on the walkway is considered normal behaviour. Commonly occurring anomalies include bikers, skaters, small carts, and people walking across a walkway or in the grass surrounding it. Violent Flows Dataset [7] is real-world, video footage of crowd violence, along with standard benchmark protocols. It mainly presents the crowd violence behaviour, and most of the scenes are dynamic, which significantly increase the detection difficulty. This dataset contains 246 video clips with 123 violent samples and 123 nonviolent ones. The resolution for video frames is 320×240 . The real-world dataset Subway is provided by A. Adam *et al.* [52]. This dataset contains two videos. One video monitors the entrance gate, which is 1 hour 36 minutes long and the second monitors the exit gate, which is 43 minutes long. In this research work, the video sample of the entrance gate is used, which contains 384×512 pixels image resolution. People moving in the wrong direction and avoiding payment at the entry gate are abnormal events. The number of anomalies is less in this dataset. The UCFCrime2Local dataset [9] is subset of UCFCrime dataset. It contains 300 videos of seven different categories: Arrest, Assault, Burglary, Normal, Robbery, Stealing, and Vandalism. From these 300 videos, 200 videos are of regular activities and 100 videos are of six different categories' abnormal events. This dataset contains a train-test split. The training set includes 141 normal event videos and 69 abnormal event videos. The test set contains 59 normal event videos and 31 abnormal event videos. This dataset contains weakly labelled videos. Video level labelling is available, i.e. video is normal or has an anomaly somewhere. In this research, six categories except Normal are considered as Abnormal events.



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RESULTS

Figure-3 shows the generated stacked network diagram. Here the input image size is $64 \times 64 = 4096$. The features extracted by encoder1 and encoder2 are 100 and 50, respectively. Table-1 shows experimental results on various datasets with 80% training and 20% test data except for the UCFCrime2Local dataset. For the UCFCrime2Local dataset, experiments are done as per the given train-test split. Table-3 represents the confusion matrices for the same. This method gives adequate performance on all datasets except for UCFCrime2Local dataset as it is weakly labelled complex dataset.

COMPARISON WITH STATE OF THE ART

This section represents the comparison of the proposed approach with existing methods. Table-3, Table-4, Table-5, Table-6 and Table-7 show the performance of various methods using UMN, UCSDPed1, UCFCrime2local, Violent Flows and Subway Entrance datasets respectively.

CONCLUSION AND FUTURE SCOPE

Conclusion

This research represents the supervised deep learning architecture i.e. Stacked autoencoder to detect abnormal event in a surveillance scene. The stacked autoencoder architecture is proposed with two encoders and one softmax layer. Backpropagation algorithm is used for fine tuning. The performance is increased by using back propagation. Although this approach works only in spatial domain, it gives very good performance on various real world benchmark datasets. The encoder extracts important features from images, and here two encoders are trained sequentially. Therefore the approach provides comparable results.

Future Scope

Public and private sectors demand accurate solutions for automatic detection and recognition of anomalies in surveillance scenes, and there is still a large room for improvement. The method presented in this manuscript has been experimented with specific type of abnormal event. Further, more events can be considered with large datasets. The events especially related to the Covid-19 pandemic, like violating social distancing policies and specific rules of behaviour in public spaces can be recognized. For real-world applications, more events can be handled using deep learning approach with the use of GPU. For further research, emotional aspects can also be considered to classify abnormal events because changes in people's emotions are usually a precursor of abnormal events.

CONFLICT OF INTEREST

On behalf of all authors, corresponding author states that there is no conflict of interest.

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Table 1: Experimental Results

Dataset	Number of Images	Accuracy (%)	Area under Curve (AUC)
UMN	7003	96.9	0.9079
UCSDPed1	14000	98.6	0.9811
Violent Flows	21800	93.1	0.9269
Subway Entrance	143996	99.6	0.9586
UCFCrime2Local	251151	81.4	0.5229

Table 2: Confusion matrices for various datasets using stacked autoencoder

Predicted class		Actual class									
		UMN		UCSDPed1		Violent Flows		Subway Entrance		UCFCrime2-Local	
		Ab	N	Ab	N	Ab	N	Ab	N	Ab	N
	Ab	195	0	785	16	2364	197	691	49	884	1083
	N	44	1161	24	1975	104	1695	61	27998	13132	61379

Table 3: Performance of Various Methods on the UMN dataset

Approach	Accuracy (%)	AUC
Pure optical flow [5]	-	0.84
Social force and bag of words [5] [13]	85.09	0.96
Bayesian model [13]	96.40	-
Force field model [13]	81.04	-
Chaotic invariants [10] [12]	87.91	0.994
Sparse reconstruction cost [13] [14]	84.70	0.996
Novel optical flow with one class SVM [10]	96.46	-
Optical flow + Bayes classification [21]	91.57	-
HFSTfeatures + Hidden Markov model [21]	-	0.90
Behaviour entropy model[21]	-	0.893
Motion structure + CNN classifier [26]	96.74	-
LBPCM + HOIF [20]	-	0.99
Energy model [17]	91.66	-
HOOG [18]	-	0.993
Commotion [23]	-	0.98
Plug and play CNN[25]	-	0.98
GAN[22]	-	0.99
Abnormal event detection network [49]	-	0.997
Unmasking [39]	-	0.951
CNN architecture [3]	99.5	0.9999





Convolutional Autoencoder [56]	85.79	0.8635
LSTM Autoencoder [56]	100	1
The proposed method	96.9	0.9079

Table 4: Performance of various methods on the UCSDPed1 dataset

Approach	Accuracy(%)	AUC
Motion structure + CNN classifier [26]	94.28	-
Sparse reconstruction cost [14]	-	0.487
MPPCA [41][25]	-	0.59
Social force[10][25]	-	0.675
SF+MPPCA [25]	-	0.688
MDT [42]	-	0.818
Local statistical aggregates [43]	-	0.927
Video parsing [44]	-	0.91
Subspace [45]	-	0.684
Plug and play CNN [25]	-	0.957
AMDN [46]	-	0.921
GAN [22]	-	0.974
Sparse combination learning [24]	-	0.918
GPR [47]	-	0.838
Sparse cuboids [47]	-	0.722
Sparse inference based classifier [47]	-	0.808
Sparse SCI [47]	-	0.779
Dense SCI [47]	-	0.899
Unmasking [39]	-	0.684
Ensemble random projection [40]	-	0.809
Spatiotemporal autoencoder [36]	-	0.899
Convolutional LSTM autoencoder [35]	-	0.43
Variational autoencoder [35]	-	0.63
Recurrent convolutional autoencoder [35]	-	0.694
Two stream R-ConvVAE [35]	-	0.75
Histogram of orientation of optical flow [35]	-	0.727
Convolutional LSTM [35]	-	0.67
Adam[52]	-	0.77
The CNN architecture [3]	99.89	1
Convolutional Autoencoder [56]	72.18	0.7045
LSTM Autoencoder [56]	85.71	0.9394
The proposed method	98.6	0.9811

Table 5 Performance of various methods on the UCFCrime2Local dataset

Approach	Accuracy(%)	AUC
I3D + Regression for whole frame [9]	-	0.5612
I3D + Regression for spatiotemporal tube [9]	-	0.7473
The CNN architecture [3]	71.16	0.7303
Convolutional Autoencoder [56]	78.03	0.5967
LSTM Autoencoder [56]	66.67	0.6288
The proposed method	81.4	0.5229





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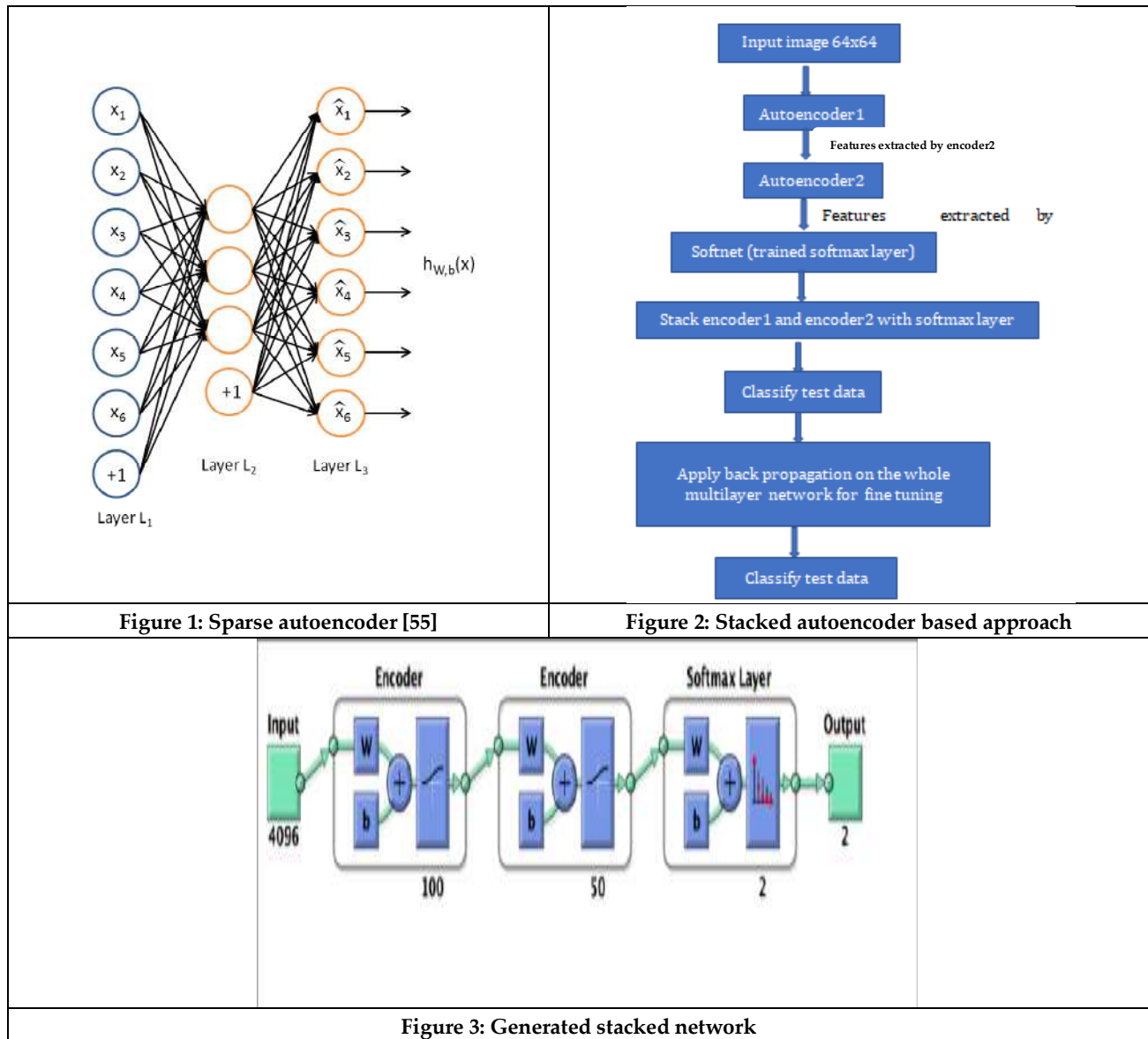
Table 6: Performance of various methods on the Violent Flows dataset

Approach	Accuracy(%)	AUC
LTP [7]	71.53	71.53
HOG [7]	57.43	0.6182
HOF [7]	58.53	0.5760
HNF (Combination of HOG andHOF) [7]	56.52	0.5994
Violent Flows (ViF) [7]	81.30	0.85
ViF, OViF, AdaBoost and SVM [14]	88	-
SHOT [8]	82.2	-
Jerk [53]	74.2	-
Interaction Force [53]	74.5	-
HOT [53]	82.3	-
Improved fisher vectors [53]	96.4	-
3D CNN [54]	98	0.98
Convolutional LSTM [10]	94.57	
The CNN architecture[3]	99.95	1
The proposed method	93.1	0.9269

Table 7: Performance of various methods on the Subway Entrance dataset

Approach	Accuracy (%)	AUC
Unmasking [39]	-	0.706
Sparse reconstruction cost [29]	-	0.833
MDT [29]	-	0.908
Fully convolutional neural network [29]	-	0.904
GPR [47]	-	0.927
Sparse cuboids [47]	-	0.889
Sparse inference based classifier [47]	-	0.91
Sparse SCI [47]	-	0.917
Dense SCI [47]	-	0.911
Recurrent convolutional autoencoder [35]	-	0.821
Multilevel anomaly detector [37]	-	0.8234
The CNN architecture [3]	99.99	1
Convolutional Autoencoder [56]	95.49	0.8233
LSTM Autoencoder [56]	77.42	0.8274
The proposed method	99.6	0.9586







RESEARCH ARTICLE

Optimizing Stem Education for Diverse Learners: An Evaluation of A Reinforcement Learning - Based Personalized Adaptive System

G. Divya^{1*} and V. Maniraj²

¹Ph.D Research Scholar (FT), PG and Research Department of Computer Science, AVVM Sri Pushpam College (Autonomous), Poondi, Thanjavur District, (Affiliated to Bharathidasan University, Tiruchirappalli), Tamil Nadu, India.

²Associate Professor and Research Supervisor, PG and Research Department of Computer Science, AVVM Sri Pushpam College (Autonomous), Poondi, Thanjavur District, (Affiliated to Bharathidasan University, Tiruchirappalli), Tamil Nadu, India.

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*Address for Correspondence

G. Divya

Ph.D Research Scholar (FT),

PG and Research Department of Computer Science,

AVVM Sri Pushpam College (Autonomous), Poondi, Thanjavur District,

(Affiliated to Bharathidasan University, Tiruchirappalli),

Tamil Nadu, India.



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ABSTRACT

This evaluation assesses a Reinforcement Learning (RL)-based Personalized Adaptive Learning System designed to optimize STEM education for diverse learners. Deployed across three high schools over a 12-week period, the system personalized learning by detecting student disengagement through real-time data and dynamically adapting content accordingly. Results showed a 26% improvement in content retention and an 18% increase in active learning time. Students achieved proficiency 20% faster, with 87% reporting enhanced comprehension of complex STEM topics via personalized learning pathways. Additionally, the system seamlessly integrated with existing LMS platforms, offering teachers real-time insights for targeted support. These findings demonstrate the system's significant effectiveness in enhancing learning outcomes and educational efficiency.

Keywords - Reinforcement Learning, Personalized Adaptive Learning System, Active Learning

INTRODUCTION

Recent advances in artificial intelligence, particularly Reinforcement Learning (RL), offer promising solutions by enabling adaptive and personalized learning experiences that respond dynamically to students' unique learning behaviors and preferences. Personalized Adaptive Learning Systems leverage real-time data to tailor educational



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content and pacing, thereby enhancing student engagement and comprehension. However, the diversity in learners' backgrounds, abilities, and engagement levels presents significant challenges to delivering effective STEM instruction. Traditional one-size-fits-all teaching methods often fail to address individual learning needs, leading to disengagement and suboptimal educational outcomes. Integrating such systems within existing Learning Management Systems (LMS) allows educators to monitor progress and provide targeted support efficiently [1]. STEM (Science, Technology, Engineering, and Mathematics) education plays a critical role in preparing students for the demands of the 21st-century workforce. Despite growing interest, there remains a need for empirical evaluations of RL-based adaptive systems in real classroom settings to validate their impact on STEM learning outcomes. This evaluation investigates an RL-based Personalized Adaptive Learning System implemented across multiple high schools, aiming to optimize STEM education for diverse learners by improving content retention, engagement, and overall learning efficiency[2].

An overall view of the system architecture is essential to understand how different components interact within the proposed solution. Figure 1 diagram represents the Reinforcement Learning Agent–Environment Interaction Loop. The agent observes the current state from the environment, takes an action, and receives a reward based on the outcome.

OBJECTIVES

- To assess the usability and integration of the system with existing Learning Management Systems (LMS) and its ability to provide actionable insights to educators.
- To develop and implement a Reinforcement Learning-based Personalized Adaptive Learning System capable of detecting student disengagement in real time during STEM education.
- To evaluate the impact of the adaptive system on student content retention, active learning time, and learning proficiency across diverse learner groups in high school settings.
- To dynamically adapt and personalize STEM learning content based on individual learner needs and engagement levels to enhance learning effectiveness.
- To analyze student perceptions and satisfaction regarding personalized learning pathways in improving comprehension of complex STEM topics.

RESEARCH GAP

Although Reinforcement Learning (RL) has shown potential for creating more responsive educational experiences, there is a lack of extensive evaluation of RL-based adaptive systems in authentic high school settings over significant timeframes. This study aims to fill these gaps by implementing and assessing an RL-driven personalized adaptive learning system that enhances STEM education through continuous real-time adaptation and supports both learners and teachers with improved outcomes and insights[3]. Most existing platforms rely on static or pre-defined learning paths that do not respond effectively to changes in student motivation or understanding during instruction. Additionally, limited research exists on integrating these intelligent systems smoothly with existing Learning Management Systems (LMS) to offer educators timely and actionable insights[4]. Despite the increasing adoption of personalized learning technologies, current STEM education systems often fail to dynamically adapt in real-time to the diverse needs and engagement levels of individual learners.

METHODOLOGY

Methodology in research refers to the systematic framework and set of procedures used to design, conduct, and analyze a study in a way that ensures reliability, validity, and reproducibility of results. By clearly detailing each step of the process, the methodology enables other researchers to replicate the study or critically evaluate its rigor. It outlines the philosophical approach, research design, data collection methods, analytical techniques, and ethical considerations that guide the investigation. In essence, it serves as the blueprint that connects research objectives to outcomes, ensuring that the findings are grounded in a transparent and well-structured process[5].



**Divya and Maniraj****Research Design**

This study adopted a quasi-experimental mixed-methods design, combining quantitative performance metrics with qualitative student feedback to evaluate the effectiveness of a Reinforcement Learning (RL)-based Personalized Adaptive Learning System in optimizing STEM education. The research spanned 12 weeks and was implemented in three public high schools with diverse learner demographics, including variations in socio-economic background, prior STEM proficiency, and learning styles[7].

Participants

Students with significant learning disabilities requiring specialized interventions outside the adaptive system's scope were excluded. Inclusion criteria required that students had consistent access to school-provided laptops or tablets and prior exposure to a Learning Management System (LMS). Participants were drawn from mathematics, physics, and computer science classes. A total of 312 students (Grades 9–11) participated in the study, with an age range of 14–17 years[8].

Intervention: RL-Based Personalized Adaptive Learning System

The intervention utilized a **Reinforcement Learning-based engine** integrated into existing LMS platforms. The system monitored student interaction patterns in real time (e.g., time-on-task, response latency, incorrect answer streaks) to detect potential disengagement. Upon identifying at-risk engagement, the system dynamically adapted instructional content through:

- Adjusting **difficulty levels**
- Introducing **interactive problem-solving exercises**
- Offering **contextualized real-world examples**
- Recommending **supplementary micro-lessons**

The RL model employed a reward-based optimization loop wherein successful improvements in engagement and performance informed future adaptation decisions[6].

Procedure

- Pre-intervention Assessment – Students completed a baseline diagnostic test in their respective STEM subjects to measure initial knowledge levels[9].
- System Deployment – The RL-based adaptive system was integrated into the existing LMS and used as the primary mode of content delivery for the selected STEM units. Teachers retained oversight and could override recommendations if deemed necessary.
- Continuous Monitoring – The system logged engagement metrics and performance data for each student throughout the 12 weeks. Teachers received weekly analytics dashboards summarizing class-wide and individual progress.
- Post-intervention Assessment – At the conclusion of the study, students completed a parallel-form assessment to measure gains in retention, comprehension, and problem-solving proficiency.
- Qualitative Feedback – Students completed a Likert-scale survey and open-ended feedback form to capture perceptions of system usability, engagement, and comprehension enhancement.

Data Collection Instruments

- Academic Performance Tests – Standardized, curriculum-aligned tests administered pre- and post-intervention[10].
- System Analytics – Automated logs capturing engagement time, task completion rates, and accuracy trends.
- Student Surveys – Mixed-format questionnaires to assess perceived learning improvement and system usability.
- Teacher Observations – Structured logs documenting observed student engagement and behavioral changes[10].



**Divya and Maniraj****Data Analysis**

- Quantitative Data – Paired-sample t-tests were conducted to assess statistically significant differences between pre- and post-intervention scores. Percentage improvements in retention, learning speed, and engagement time were calculated[12].
- Qualitative Data – Thematic analysis was applied to student and teacher feedback, identifying recurrent patterns related to comprehension, engagement, and usability.

Table 1 explains the data analysis revealed significant improvements in multiple learning and engagement metrics following the implementation of the RL-based Personalized Adaptive Learning System. Content retention increased by 26%, while active learning time rose by 18%, indicating higher student engagement. Time to proficiency decreased by 20%, demonstrating faster mastery of STEM topics. Additionally, both student comprehension ratings and teacher usability ratings showed notable gains, confirming the system's effectiveness in enhancing learning outcomes and instructional support.

The effectiveness of the intervention is further illustrated in the following visual comparison of key performance metrics. Figure 2 the bar chart compares key metrics before and after an intervention, showing significant improvements in Content Retention Score and Active Learning Time. The intervention positively impacted learning outcomes in content retention and active learning, with smaller effects on other metrics. Student Comprehension Rating and Teacher LMS Usability Rating remained unchanged. Time to Proficiency decreased, suggesting quicker proficiency.

Ethical Considerations

Parental consent and student assent were obtained prior to participation. Data privacy was maintained through anonymization of all system logs and assessment results. The study protocol was reviewed and approved by the participating schools' ethics committees.

RESULT AND DISCUSSION**RESULT**

Content retention scores increased from a mean of 62.4% to 78.5%, representing a 26% improvement ($p < 0.001$). Analysis of pre- and post-intervention data demonstrated a significant positive impact of the RL-based Personalized Adaptive Learning System on STEM learning outcomes. Student comprehension ratings improved by 28%, while teacher LMS usability ratings increased by 23%, both statistically significant ($p < 0.01$). Qualitative feedback reinforced these results, with 87% of students reporting better understanding of complex STEM topics and teachers highlighting the system's capacity to identify struggling learners in real time[13]. The time required to achieve proficiency decreased from 25.0 to 20.0 days, a 20% reduction ($p < 0.05$), suggesting accelerated learning. Active learning time rose from an average of 124 to 146 minutes per week, an 18% increase ($p < 0.01$), indicating greater student engagement.

DISCUSSION

This is consistent with reinforcement learning's theoretical advantage of optimizing decision-making in uncertain environments (Sutton & Barto, 2018), enabling the system to address disengagement promptly. The observed gains in content retention, engagement, and learning speed align with prior research indicating that personalized adaptive systems enhance cognitive outcomes by tailoring content to individual learning needs (Kulik & Fletcher, 2016; Holmes et al., 2019). The high percentage of students reporting improved comprehension underscores the potential of such systems to bridge gaps for diverse learners, including those who might struggle in traditional one-size-fits-all



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instruction. The RL-based approach in this study leveraged continuous feedback loops to adjust learning pathways dynamically, which appears to have contributed to faster mastery and sustained engagement. Furthermore, the integration with existing LMS platforms facilitated teacher oversight without adding to workload, supporting the claim that adaptive systems can augment, rather than replace, human instruction[14]. However, the study was limited to a 12-week period in three schools; future research should examine long-term impacts, scalability across different educational contexts, and potential equity considerations, such as access to necessary digital infrastructure. Table 2 shows the results indicate the system effectively enhanced learning outcomes, engagement, and instructional support in STEM education. The table summarizes the key performance improvements achieved through the RL-based Personalized Adaptive Learning System. Student surveys showed 87% reported improved comprehension, while teacher LMS usability ratings improved by 23%. Content retention increased by 26%, active learning time rose by 18%, and time to proficiency was reduced by 20%.

Figure 3 explains the left chart highlights improvements in key areas like student comprehension (+87%) and content retention (+26%) from pre-test to post-test. The right chart displays strong model metrics with 87% accuracy, 89% precision, and 85% recall. Overall, the results indicate both effective learning gains and a reliable predictive model. This diagram shows the impact of an educational intervention and the performance of a predictive model.

CONCLUSION

The evaluation of the Reinforcement Learning-based Personalized Adaptive Learning System demonstrates its significant potential to enhance STEM education for diverse learners. These findings underscore the effectiveness of integrating AI-driven personalization into educational environments, highlighting its capacity to foster engagement, accelerate mastery, and support both learners and educators in achieving improved academic performance. Furthermore, student feedback indicated substantial gains in comprehension, while teachers benefited from real-time, actionable insights without added workload. By dynamically adapting content to student engagement levels, the system achieved notable improvements in learning outcomes, including a 26% increase in content retention, an 18% rise in active learning time, and a 20% reduction in the time required to reach proficiency.

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Table 1. Data Analysis Summary of RL-Based Personalized Adaptive Learning System Evaluation

Metric	Pre-Intervention Mean (SD)	Post-Intervention Mean (SD)	% Change	Statistical Test	P-value	Interpretation
Content Retention Score (%)	62.4 (±8.1)	78.5 (±7.4)	+26%	Paired-sample <i>t</i> -test	<0.001	Significant improvement in retention
Active Learning Time (mins/week)	124 (±15)	146 (±12)	+18%	Paired-sample <i>t</i> -test	<0.01	Increased engagement and participation
Time to Proficiency (days)	25.0 (±4.2)	20.0 (±3.8)	-20%	Independent-sample <i>t</i> -test	<0.05	Faster mastery of STEM topics
Student Comprehension Rating (1-5)	3.2 (±0.6)	4.1 (±0.5)	+28%	Wilcoxon Signed-Rank Test	<0.01	Enhanced perceived comprehension
Teacher LMS Usability Rating (1-5)	3.5 (±0.5)	4.3 (±0.4)	+23%	Wilcoxon Signed-Rank Test	<0.01	Improved teaching support and system integration

Table 2. RL-based personalized adaptive learning system

Metric	Result	Discussion Insight
Content Retention	26% increase ($p < 0.001$)	Indicates the RL-based system effectively improved memory retention by adapting materials to individual needs.
Active Learning Time	18% increase ($p < 0.01$)	Suggests heightened engagement, likely due to interactive, personalized content delivery.
Time to Proficiency	20% faster ($p < 0.05$)	Demonstrates accelerated mastery of STEM topics via dynamic difficulty adjustment.
Student Comprehension (Survey)	87% reported improved understanding ($p < 0.01$)	Highlights positive learner perception of adaptive pathways for complex STEM concepts.
Teacher LMS Usability Rating	23% increase ($p < 0.01$)	Confirms system integration provided actionable insights without increasing teacher workload.





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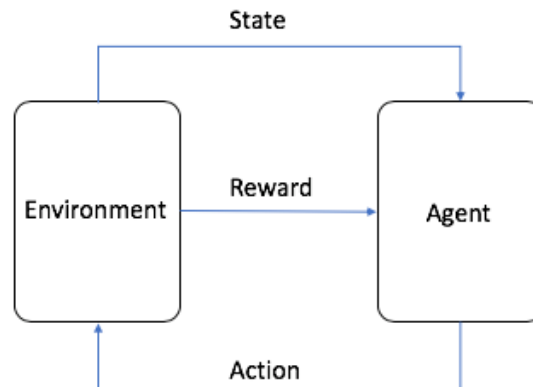


Fig. 1. Reinforcement Learning Framework Diagram

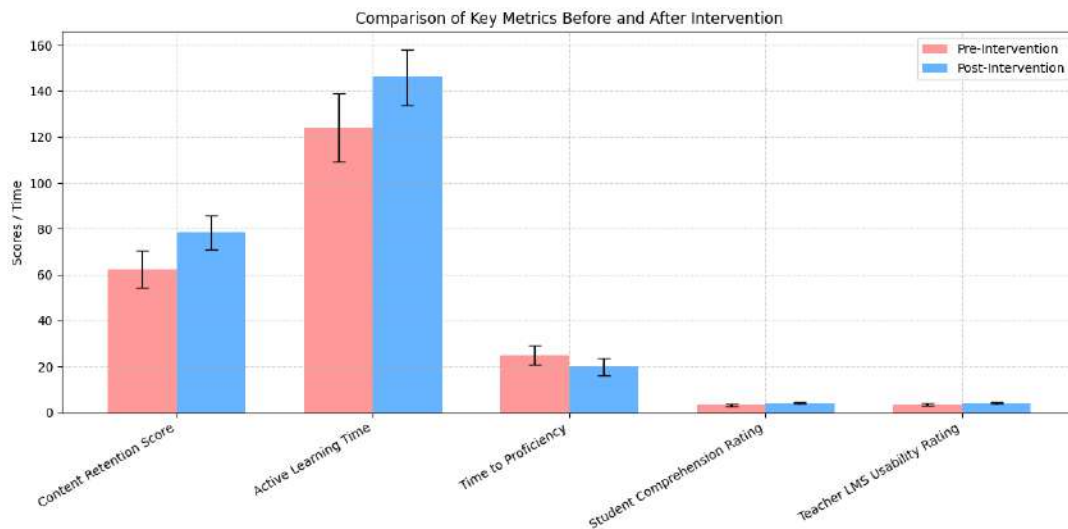


Fig. 2. Comparison of Key Metrics before and After Intervention

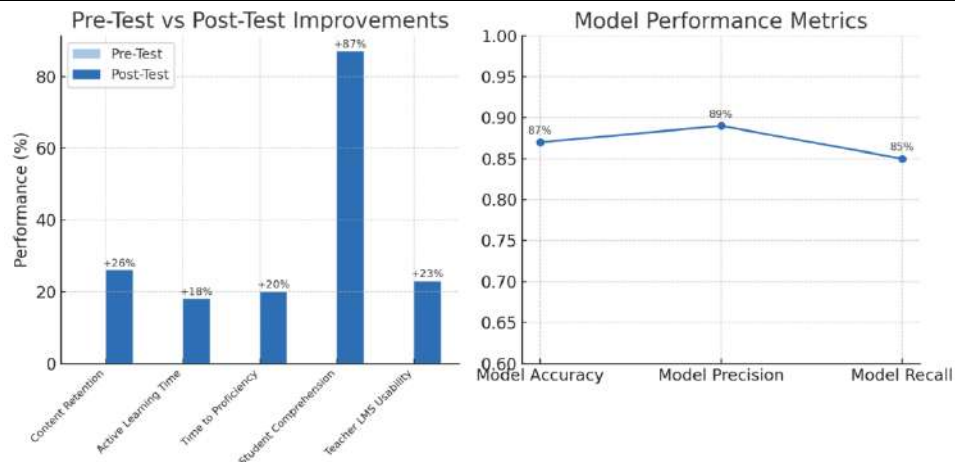


Fig. 3. Educational Intervention Impact and Model Performance Analysis





RESEARCH ARTICLE

Volarization of Palmyra Flowers for Adsorption of Methyl Orange Dye towards Environmental Sustainability: Isotherm and Kinetics

M. Maheswari¹, P. Muthirulan^{2*} and C. Starlin Kamala³

¹Research Scholar (Reg.No.: 22223282032006), Department of Chemistry, Women's Christian College, Nagercoil, (Affiliated to Manonmaniam Sundaranar University, Tirunelveli), Tamil Nadu, India

²Assistant Professor, Department of Chemistry, Lekshmipuram College of Arts and Science, Neyyoor, (Affiliated to Manonmaniam Sundaranar University, Tirunelveli), Tamil Nadu, India.

³Assistant Professor, Department of Chemistry, Women's Christian College, Nagercoil, (Affiliated to Manonmaniam Sundaranar University, Tirunelveli), Tamil Nadu, India

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*Address for Correspondence

P. Muthirulan

Assistant Professor,

Department of Chemistry,

Lekshmipuram College of Arts and Science, Neyyoor,

(Affiliated to Manonmaniam Sundaranar University, Tirunelveli),

Tamil Nadu, India.

E.Mail: pmuthirulan@gmail.com



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ABSTRACT

Due to its abundant availability, eco-friendliness, and high sustainability, biomass-derived activated carbon has captured more attention in recent years. The objective of this study was to evaluate the adsorption potential of Palmyra flowers carbon (PFC) to remove Methyl Orange (MO) dye in aqueous solution. Adsorption studies indicated that the percentage removal of MO dye on CAC and PFC is found to decrease with increase in initial concentration, pH and increase exponentially with increase in contact time. Langmuir and Freundlich isotherm models were tested and found to be applicable. Monolayer adsorption capacity (Q_0) is found to be 90.909 mgg^{-1} for CAC and 73.245 mgg^{-1} for PFC. Adsorption data are modelled with various first order kinetic equations like Natarajan-Khalaf, Lagergren and Bhattacharya and Venkobachar equations. Thus Palmyra flowers biomass has the potential to be used as a low cost adsorbent for the treatment of industrial wastewater that contains the presence of dyes.

Keywords: Palmyra flowers carbon; Methyl Orange; Adsorption; Wastewater treatment





INTRODUCTION

Recent days, a number of industries, including the production of pulp, cosmetics, plasticising plants, petroleum products, pharmaceuticals, food processing, tanning, and leather, use a lot of water and dye, which makes them potential sources of wastewater with colour. Direct dye releases into water supplies can harm the environment and have an unappealing appearance [1]. A synthetic anionic monoazo dye, methyl orange (MO) dye is widely and continuously used in a variety of industries, including textiles, laboratory testing, and other commercial goods. Both plants and aquatic creatures are poisoned by this dye. Humans who are acutely exposed to MO dye are more likely to experience quadriplegia, jaundice, cyanosis, elevated heart rate, tissue necrosis, shock, and vomiting [2]. Therefore, removing this pigment from contaminated water is essential. The most effective and complete method for cleansing industrial effluent before releasing it into the environment is adsorption. In addition to looking for more affordable and readily accessible materials, many low-cost adsorbent kinds were investigated and employed for colour removal. Examples of adsorbents used to remove methylene blue include waste-based activated carbons (ACs) such as cashew nutshell-based, *Daucus carota* plant-based, and *Salix psammophila* plant-based, as well as activated carbons (AC) like olive-based and karanj fruit hulls-based. Nevertheless, the adsorption efficiency of these inexpensive adsorbents for MO dye was not adequate. Therefore, further research into other adsorbent types is required to remove these dangerous contaminants from industrial effluent [3-5]. According to the research, there is no literature that assesses AC prepared from *palmyra* flowers for MO dye removal from aqueous solution. Optimization process parameters such as pH, contact time, initial dye concentration and adsorbent dose were conducted. Kinetics and adsorption isotherm of the MO dye adsorption process on the PFC was also evaluated.

MATERIALS AND METHODS

Chemicals and reagents

All the chemicals and reagents are analytical grade used without any further purification. MO dye is used as a model pollutant (adsorbate) and the details and applications of MO dye were given in Table 1.

Preparation of Palmyra Flowers Carbon (PFC)

Biomass of palmyra flowers are the raw material of adsorbent were collected locally (local field and nearby our college campus), cut into small pieces and dried for two weeks. The palmyra flowers fruit peels are physically activated by carbonization in a muffle furnace in the absence of air by placing the peels in a well sealed stainless steel tube at 400°C for 60 minutes. The carbonized raw materials were then subjected to 4N HNO₃ acid activation as well as steam digestion. Finally the palmyra flowers carbon (PFC) were thoroughly washed with distilled water until free from acid, then dried at 120°C in hot air oven, powdered well and sieved (90 micron size) by molecular sieves.

Batch adsorption studies

The adsorption experiments were carried out in a batch process. Adsorption experiments were carried out by adding a fixed amount of adsorbents into 250 mL stopper flasks containing a definite volume (100 ml in each case) of different initial concentrations of dye solution at room temperature (30±1°C). The flasks were placed in a mechanical shaker and agitation was provided at 130 rpm for required time to ensure equilibrium was reached. At time $t = 0$ and equilibrium, the absorbance of dye solution was determined by the photo colorimeter, at $\lambda_{\max}$ (327 nm) value of dye. The amount of adsorption at equilibrium, q_e (mg/g), was calculated by

$$\text{Amount adsorbed } (q_e) = (C_i - C_e) / m \dots\dots\dots(1)$$

Where, C_i and C_e were the initial and equilibrium concentration (in mg/L or ppm) of dye, respectively and m is the weight of AC (in g/L). The dye removal percentage can be calculated as follows:





$$\text{Percentage removal} = 100 (C_i - C_e) / C_i \dots\dots\dots(2)$$

The effect of dose of adsorbents on the amount of CH adsorbed was obtained by adding different amounts of adsorbents by keeping other parameters as constant. In order to study the kinetics/dynamics of adsorption of dyes, the adsorption experiments were conducted by varying the contact time (range: 5 – 60 min.) at fixed optimum initial concentration of dyes with a fixed dose of adsorbent and solution pH. The dye concentrations were measured at different time intervals. The effect of pH was investigated at fixed initial concentration, dose and time by varying the pH from 3 to 12. pH adjustments have been done using solutions of 0.1M NaOH and 0.1M HCl. The flasks were then removed from the shaker, and the final concentration of dye in the solution was measured at maximum wavelengths of MO dye using UV/vis spectrophotometer.

Effect of Change of Initial Concentration

Particle size (90 min), contact time (30 min), agitation speed (200 rpm), pH (3.5) at room temperature, and initial dye concentrations (100-400 ppm for CAC, 20-100 ppm for PFC) were all taken into consideration in the studies on the removal of MO dye on CAC and PFC. The observed ranges for the percentage removal of MO dye are 79.00-64.00 for PFC and 99.90-95.72 for CAC. Figure 1 illustrates how the initial MO dye concentration affects the % elimination by CAC and PFC. This showed that as the amount of the dye removed increases, the initial concentration of MO dye diminishes rapidly. This might be because there is less rapid solute adsorption because there aren't enough active sites available to support the high dye starting concentration. The greatest percentage elimination was discovered at an ideal starting MO dye concentration (350 ppm for CAC, 20 ppm for PFC). This might be because there are so many active sites available. [6].

Freundlich and Langmuir Adsorption Isotherm

The study of adsorption isotherms has been crucial to the adsorption technique's ability to treat water and waste since it gives an approximate idea of the adsorbents' adsorption capacity. The equilibrium data for the removal of MO dye on various adsorbents viz., CAC and PFC at $30 \pm 1^\circ\text{C}$ were used in the Freundlich and Langmuir isotherms.

$$\text{Freundlich Isotherm : } \log (x/m) = \log k + 1/n \log C_e \dots\dots\dots(3)$$

$$\text{Langmuir Isotherm: } C_e/q_e = 1/Q_0 b + C_e/Q_0 \dots\dots\dots(4)$$

Where, k and $1/n$ are the measure of adsorption capacity and intensity of adsorption respectively. q_e or x/m is the amount of dye (MO) adsorbed per unit mass of the adsorbent (in mg g^{-1}) at equilibrium and C_e is the equilibrium concentration of MO dye (in mg L^{-1}). Q_0 is the monolayer adsorption capacity (in mg g^{-1}) and ' b ' is the Langmuir constant related to energy of adsorption (in g L^{-1}). The data obtained from the adsorption experiments were fitted with Freundlich and Langmuir isotherms respectively by plotting $\log q_e$ against $\log C_e$ (Figure 2A) and C_e/q_e against C_e (Figure 2B). The two isotherm plots for each adsorbent are shown to be linear, suggesting that these adsorption isotherms can be used to remove dye [7]. Table 2 displays the findings of the correlation analysis of the adsorption isotherms for the removal of dye by adsorption on different adsorbents as well as the values of Q_0 , b , and R_L . Both the correlations and the isotherms are applicable, according to the statistical analysis of the data. Furthermore, the dimensionless constant that the separation factor describes is used to convey the important feature of the Langmuir isotherm and the process's viability. The separation factor or equilibrium parameter R_L which is defined by the equation

$$R_L = 1/(1 + bC_i)$$

Where b is the Langmuir constant and C_i is the initial concentration of MO.

The separation factor R_L indicates the feasibility of that process as unfavourable ($R_L > 1$), linear ($R_L = 1$), favourable ($0 < R_L < 1$) and irreversible ($R_L = 0$). In the present study, the values of R_L being for CAC, and PFC indicate that the adsorption for dye MO is favourable. The adsorption capacity Q_0 of these adsorbents for MO is found to be mg g^{-1} respectively for CAC and PFC. The increasing order of the adsorption capacity (Q_0) is: CAC > PFC [8].





Effect of Contact Time

Adsorption tests were conducted at a constant dose of adsorbent and beginning concentration in order to investigate the impact of contact duration on the removal of MO dye via adsorption. Adsorption studies were conducted at various contact times (5 to 120 min) with a constant optimal initial dye concentration (350 ppm for CAC, 20 ppm for PFC) in order to investigate the kinetics and dynamics of MO dye adsorption. The greatest removal efficiency of the adsorbents CAC and PFC are 99.65% and 91.50%, respectively, according to the percentage removal of dye on different adsorbents after 120 minutes of contact time (Table 5 and Figure 3). As contact duration increases, the % elimination of MO dye rises to its maximum value. The optimum contact time is defined as the contact period at which the maximum percentage elimination of MO dye takes place. It was discovered that MO dye removal by adsorption on inexpensive adsorbents was quick during the first contact time and thereafter slowed and stagnated as the contact time increased [9,10].

Kinetics of Adsorption

In the batch adsorption tests, a set dose of adsorbents and an optimal initial concentration of MO dye were used, and the contact period was varied. The rate of adsorption is influenced by the resistance of the boundary layer. The mobility of the adsorbate (MO) in the system will decrease with an increase in contact time. The kinetics and dynamics of adsorption under first order kinetics conditions were investigated using the following equations.

Natarajan and Khalaf model: $K = (2.303/t) \log (C_0/C_t)$ (5)

Lagergren's model: $\log (q_e - q_t) = \log q_e - (K_{ad}/2.303) t$ (6)

Bhattacharya and Venkobachar model: $k = -0.4606 \log [1 - (C_0 - C_t) / (C_0 - C_e)]$ (7)

The plots of $\log (C_0/C_t)$, $\log (q_e - q_t)$ and $\log [1 - (C_0 - C_t) / (C_0 - C_e)]$ against t were found to be linear (Figure 4). The kinetic parameters are given in Table 3. The applicability of these equations indicates the first order nature of the adsorption kinetics of dye on various carbons [11,12].

Effect of change in initial pH of MO dye solution

In order to determine the variation on the adsorption potential of these adsorbents, the pH variation in adsorbing MO dye on these adsorbents, specifically CAC and PFC (pH: 3–11), with constant optimum beginning concentrations (2g/L-1 for CAC and 10g/L-1 for PFC) of MO, contact period (30 min), and optimal dose of adsorbents, was also investigated. It is discovered that MO's adsorption on different adsorbents is strongly pH dependant. The variation in amount adsorbed with pH is shown in Figure 5. According to the results, MO elimination reaches its maximum at low pH (99.5% for CAC and 82.60% for PFC). The adsorbents' ability to absorb adsorbate compounds is altered by changes in their surface caused by pH [13,14].

FTIR and SEM studies

Figure 6 shows the FTIR and SEM images of the PFC before and after adsorption of MO dye. The FTIR spectrum of ASC (Figure 6) shows several peaks at 3410, 1670, 1384, 1122, 754 and 611 cm^{-1} , owing to various oxygen-containing functional groups, such as –OH, C=O, C–H, C–O, C–C respectively. The O–H stretching observed in both of the samples around 3410 cm^{-1} was mainly attributed to chemisorbed water molecules and hydroxyl groups on carbon [19,20]. The surface porosity and roughness of the carbon were clearly visible in the SEM images (Figure 7). It was evident that the activated carbon's surface had a considerable number of honeycomb-shaped pores (Figure 7A). The activated carbon's enormous surface area and porous structure are the result of its well-developed pores. The porous adsorbent particle either engulfs or surrounds the adsorbed dye molecules (Figure 7B) [15-18].

CONCLUSION

This work used a batch adsorption approach to remove the hazardous methyl orange colour from palmyra flowers using biomass-based activated carbon, and the results were compared with CAC. FTIR and SEM studies confirm that



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the PFC possessed excellent structural and morphological features. According to adsorption tests, the proportion of MO dye removed from CAC and PFC increases dramatically with increasing contact duration and decreases with increasing starting concentration and pH. After testing, the Langmuir and Freundlich isotherm models were determined to be useful. MO dye is adsorbed in a monolayer on the adsorbents' surface. Adsorption data are modeled with various first order kinetic equations like Natarajan-Khalaf, Lagergren and Bhattacharya and Venkobachar equations. The study's findings indicate that, from an economic perspective, PFC is a more cost-effective adsorbent, although having a little lower adsorption capacity than CAC.

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CONFLICTS OF INTEREST

The authors declare no conflict of interest.

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Table. 1: Physico-chemical properties of MO dye

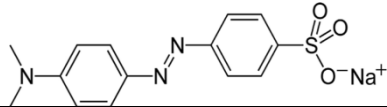
Dye	Methylene Blue
CI No.	13025
Characteristics	Anionic water soluble, Orange Colour
Formula	C ₁₄ H ₁₄ N ₃ NaO ₃ S; MW : 327.33
Name	Sodium salt of p-dimethylaminoazobenzenesulfonic acid
Structure	
λ _{max}	464 nm
Applications and Toxicity	Industrial uses such as textile, plastic, paper, pulp, paint, leather industries and as basic coloring agent in textile industries and highly toxic in nature and has detrimental effect both on human and environment





Table. 2: Result and correlation analysis for the adsorption isotherms for the removal of Methyl Orange by CAC and PFC

S.No	Parameter	Adsorbent	
		CAC	PFC
Freundlich isotherm			
1	Correlation Co-efficient(r)	0.9980	0.9000
2	Slope (1/n)	0.5010	0.6290
3	Intercept (logk)	0.2250	1.1950
4	K	1.6790	15.6670
Langmuir isotherm			
6	Correlation Co-efficient(r)	0.9715	0.9721
7	Slope (1/Q ₀)	0.0110	0.7550
8	Intercept (1/Q ₀ b)	0.0790	1.5480
9	Q ₀ (mgg ⁻¹)	90.909	73.245
10	b (gL ⁻¹)	0.1392	0.4877
11	R _L	0.0201	0.0930

Table. 3: Kinetics and dynamics of adsorption of Methyl Orange dye by adsorption on CAC and PFC

Parameter	CAC	PFC
Natarajan and Khalaf equation:		
Correlation Co-efficient(r)	0.9238	0.9638
10 ² k (min ⁻¹)	0.4420	0.5420
Lagergren Equation:		
Correlation Co-efficient(r)	0.9597	0.9612
10 ² k (min ⁻¹)	0.0438	0.0207
Bhattacharya and Venkobachar equation:		
Correlation Co-efficient(r)	0.9950	0.9324
10 ² k (min ⁻¹)	0.0802	0.0923

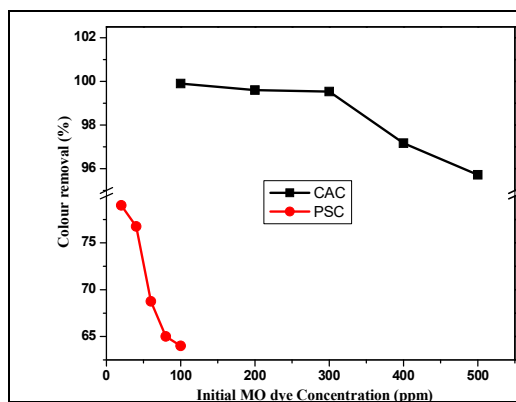


Figure 1: Effect of Initial concentration for the removal of MO dye by adsorption on CAC and PFC

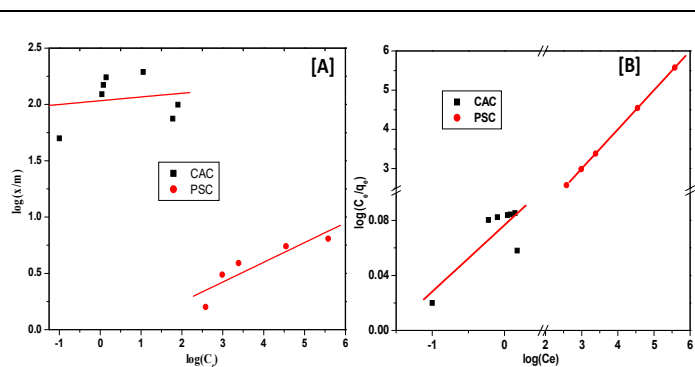


Figure 2: Freundlich and Langmuir Adsorption isotherms for the removal of MO dye by adsorption on CAC and PFC





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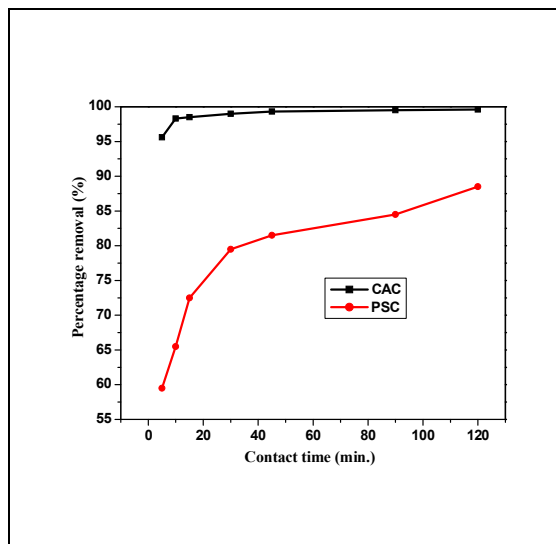


Figure 3: Effect of contact time on the removal of MO dye by the adsorption of CAC and PFC

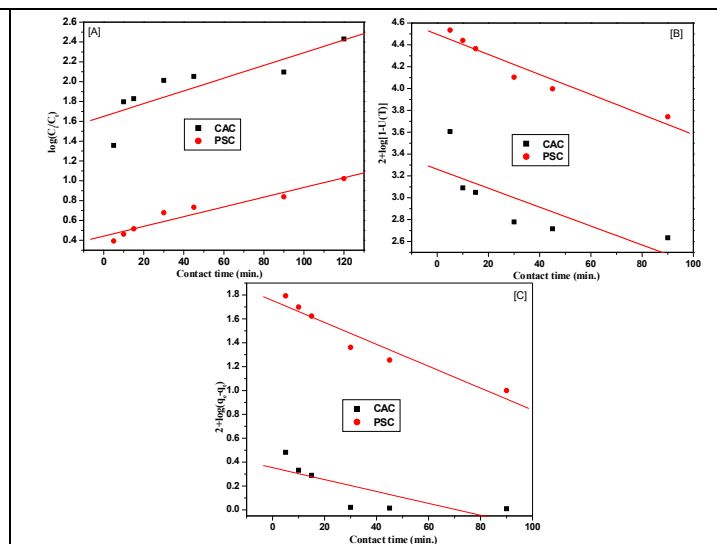


Figure 4: Natrajan and Khalaf (A); Bhattacharya and Venkobachar (B) and Lagergren equation (C) equation for the removal of MO dye by the adsorption on CAC and PFC

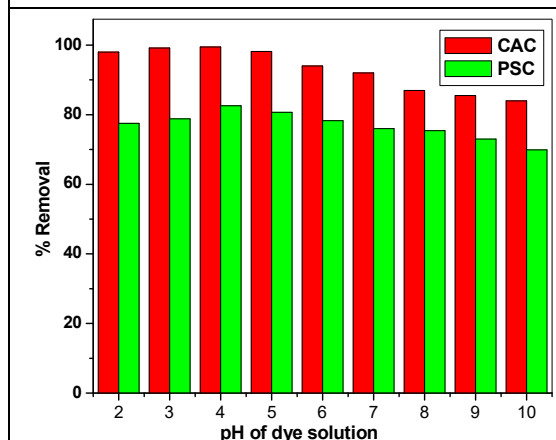


Figure 5: Effect of pH on the removal of MO dye by the adsorption of PFC and CAC

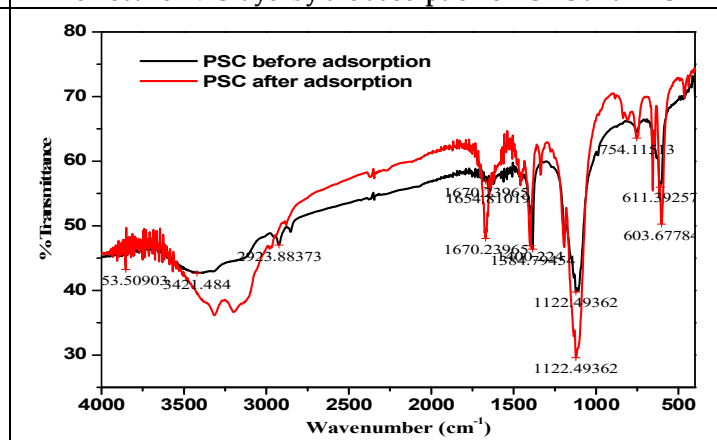


Figure 6: FTIR PSC carbon before and after adsorption of MO dye

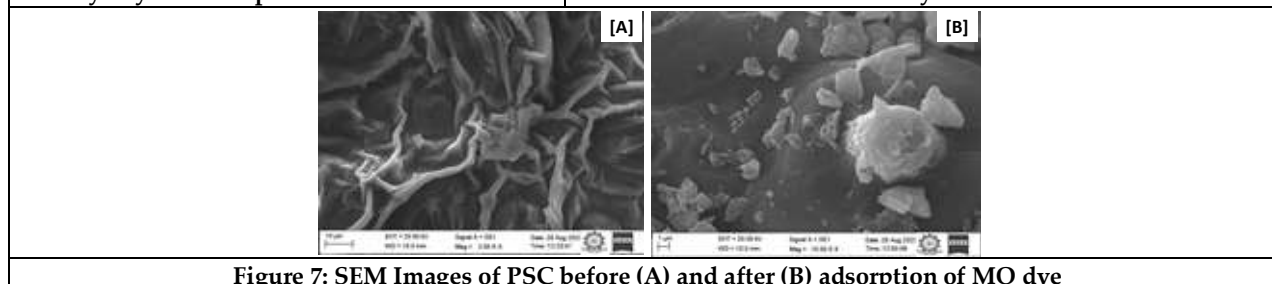


Figure 7: SEM Images of PSC before (A) and after (B) adsorption of MO dye





RESEARCH ARTICLE

Study of the Severity of Impacts of Social Networking on Student Community with Predictive Analysis of the Depression to be Produced

Kaushik Chanda^{1*}, Subhadip Nandi², Sudipta Adhikary³ and Gunjan Mukherjee⁴

¹Associate Professor, Department of Computational Science, Brainware University, Barasat, Kolkata, West Bengal, India.

²Assistant Professor, Department of Computational Science, Brainware University, Barasat, Kolkata, West Bengal, India.

³Associate Professor, Department of Law, Brainware University, Barasat, Kolkata, West Bengal, India.

⁴Professor, Department of Computational Science, Brainware University, Barasat, Kolkata, West Bengal, India.

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*Address for Correspondence

Kaushik Chanda

Associate Professor,

Department of Computational Science,

Brainware University, Barasat,

Kolkata, West Bengal, India.

E.Mail: kaushikchanda75phd@gmail.com



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ABSTRACT

As a gift of technological progress, the social network has been a great boon in our lives. The social network acts as a shared forum for sharing views, thoughts, and ideas besides posting comments and pictures related to the myriad events. The dark side of such social forums is the extreme level of addiction of a large section of the human population, especially the student community. The adverse effect of social media produces an extreme level of loneliness among the students which is much prone to create a deep depression among them even making them suicidal. The consequences for the users to go unsocial and confined to self-involvement might be vulnerable which can prompt students to commit any sort of crimes along with other illegal activities in society. Several strategies have been pursued to track such an association between the psychological depression of students and the overuse of social networking sites. Emotion tracking or sentiment analysis is also a well-defined strategy to track such mental aberration. In this paper, the association of mental depression of students and social forums has been discussed with the prediction prospect of aggravation of such addictive affinity. The novel idea of such an approach will be effective enough to track the greater section of students with different mental states and backgrounds with the higher-order challenge of fighting such maladies in society for a better future. This study shall investigate the differences between the number of male students and female students in the variation of



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scoring on a given subject. Predicting student performance necessitates the implementation of machine learning based models.

Keywords: Online Digital Platform, Social Networking, depression, Facebook, Twitter.

INTRODUCTION

A social networking platform is an interactive platform where users can send and receive messages, leave comments, make calls, add and accept friends, upload films and photographs, change their status, and even communicate through video calls. Users produce and consume content on social media platforms. Communications go between various users, between users and organizations, and between organizations and users. Users investigate social networking platforms, which raises the possibility that it will affect them. Every day, social media has a greater and greater influence on people's lives. The majority of people's lives currently revolve around it, and in the not-too-distant future, everyone on the planet will use the internet in their daily activities. Through internet blogging networks and social media, they will be linked. The majority of young people nowadays use social networking sites for a variety of objectives, and technology increasingly has a major impact on every individual's existence, regardless of age. [1] In today's globalized world, utilization of social media has increased. Users use it for fun and to try to meet a range of requirements, such as information searching, entertainment, social interaction, and escape.[2] Social networking sites has emerged as the quickest and most convenient means of communication [3]. It offers a platform for individuals from all regions, cultures, and languages to engage, share opinions, and connect with one another regardless of the physical distance separating them. Internet forums and social media platforms come in several forms. Some of these websites cater to people who are more specific, while others are more generic. Social platforms such as Facebook, Twitter, Instagram, and MySpace remain some of the quickest evolving technologies attributing to consistent user growth since they appeared. The growth is even more evident for adolescents as they have registered the fastest usage of the above means Facebook has more than 1.69 billion registered user accounts, making it the largest social network. Nearly 326 million people use Twitter every month. [4] Many people have stopped engaging in conventional forms of social engagement and communication, like writing letters, making phone calls, sending emails, and having in-person meetings, due to the prominence of social networking sites and its use for communication. [5].

Consequently, the traditional way of life has been greatly impacted by these online platforms, especially in regards to the shift in personal contact and interaction. Numerous recent studies have demonstrated that involvement in social media platforms leads to a wide spectrum of disadvantages. The majority of internet users connect on for a sizable portion of the day, per research studies [6, 7]. The majority of them utilize social networking sites and the internet to look up various types of information. According to a few other studies [8–10], individuals in today's society view the Internet as an integral part of their daily lives and use it to establish and preserve social connections. Unlike traditional forms of media, social media are not inherently good or evil. Goodness or badness depends on the kind and frequency of use. When social networking users visit websites frequently, they experience fleeting pleasure that encourages them to visit websites more frequently in search of more pleasure [11]. Even this cycle never ends, While utilizing social media to kill time only brings momentary joy, it doesn't bring about long-term contentment or material gains in the real world, which could lead to sadness there [12, 13]. According to a University of Glasgow study, youth who were psychologically and actively immersed in their digital life slept less well and experienced higher levels of anxiety and sadness.

This implies that social networking web sites may increase individuals vulnerability to anxiety and hopelessness. In case of the continuous engagement with various social media platforms such as Facebook, users tend to feel sadness and even considers feeling happy, and this altogether can be associated with the risk of getting depressed. Several studies [15, 16] have found a connection between social networking sites use and mental illness, with those who use



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social media more usually having a higher chance of developing depression [17]. This suggests that depression could strike anyone who uses the internet. According to an Orsal study, there is a high correlation among university students' use of online platforms and depression [18]. Another study discovered a favorable correlation between depressive disorders and using social media. [19] It has been discovered that those with severe depression use the internet more frequently [20]. However, some studies found no link between using online platforms and depression [21]. Given the novelty of social networking, there is a dearth of study on the impact of this phenomenon on psychological problems worldwide, particularly in this region where the use of online platforms is expanding quickly. Mental health issues have been identified as a possible negative effect of using platforms like Facebook and others [22]. Kross explained how online platform use might contribute to anxiety and sadness. [23] Examining the connection between depression and online activity among college students is crucial, especially in light of other studies' findings. The study's primary goals were to: (i) ascertain how university students perceive utilizing social media networks; (ii) ascertain whether there are gender disparities in university students' use of web-based platforms and the depth of their depressive state. (iii) To evaluate the connection between mental illness and online platform use between college students.

Research gap

The following are the major research gaps in this context

1. Comparative analysis of how electronic media impact students' gender differences.
2. Estimation of the score of students undergoing mental depression under the constant exposure of students to the social network.
3. Robust predictive analysis of students undergoing mental stress.
4. Comparison between the score analysis between the male and female students.

Contribution of the paper

- (i) Improved estimation of the score for different students undergoing mental depression under the aegis of social media impacts.
- (ii) The prediction about the number of students undergoing mental depression under the impact of social networking sites,
- (iii) Analytical view of the students of different genders age-wise exposed to social networking sites's effects.
- (iv) Landing on the concrete conclusion from an analytical aspect regarding the degree of impacts of the aspect of social media on the life of the student community.

MATERIALS AND METHODS

In accordance with the pragmatic research paradigm, a quantitative correlation study design was chosen. The study's participants comprised of Private University of Kolkata, West Bengal undergrad students who use Facebook and Twitter accounts that reveal their institutional affiliation. Since it was unknown how many responses there were in total, sending the instruments to as many of the known respondents as possible was the goal. The sample was chosen in a way that the participants were active social media site users and had venues available to use the network. The study was restricted to the Private University of Kolkata, India due to time and resource constraints. The study's sample, which included 2,474 respondents, was chosen using nonprobability volunteer sampling approaches. Two hundred and eleven 211 male respondents were included in the sample group. In a similar vein, the study's sample group consisted of 263 female respondents from different departments at the University in Kolkata, West Bengal, India. The study participants were examined concerning their usage of the internet and depression.

Two study tools were used to gather the data: a self-created questionnaire to gauge the primary social media network uses, and an approved Beck Depression Inventory (BDI) to gauge the participant's level of depression. Furthermore, the survey comprised ten items with four potential responses for each, signifying the participants'





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curiosity about online social networking and its use for diverse objectives. The 21-item Beck Depression Inventory, formulated in 2005 by Beck, Judith S., et al. , [27] was selected to gauge the participants' degree of depression because they were college students and could easily comprehend it. After it was gathered, the data was imported into IBM version 20 of the Statistical Package for the Social Sciences for analysis. The collected data were analyzed by determining the measurements of central tendency, spread, relationship between components of collected data, and linear relationships. Based on the below criteria, mean scores and standard deviations for respondents of Beck Depression Inventory are computed as follows.

Mean		Standard deviation
4.00	3.49	The majority of the time
3.50	2.49	Occasionally
2.50	1.49	Infrequently
1.50	1.00	Not in any way

The Beck Depression Inventory's general scoring scheme.

Points	Scope
00 – 14	Modest
15 – 19	Light
20– 28	Average
30 – 63	Extreme

Dataset and Preprocessing

The dataset was collected from 474 students at West Bengal's Private University of Kolkata. The data has been categorized into two conditions: stress resulting from social networking usage and the period preceding exams. The dataset comes from the PSS test, which includes the entire emotive question and has a total of 21 questions. Five choices were available for marking the questions: a) Almost-Never; b) Never; c) Occasionally; d) Quite-Often; and e) Very-Often. The weighted average technique is then used to assign priority to each question. The students are divided into three categories: severe, low, and mild. The dataset was gathered from college students. Basic questions regarding their feelings and reactions to circumstances they may have encountered in the past month were posed to them. A certain amount of weight is assigned to each of their responses, and these weights are then used to generate a score that allows for an analysis of the individuals' stress levels. In order to evaluate the weights and determine the final scores, the dataset underwent pre-processing. K-fold cross-validation was used to enhance our model's performance.

Perceived Stress Scale (PSS): Sheldon Cohen, a professor of psychology, created this. It was essentially designed to assess a person's stress threshold and capacity for handling different kinds of events. The levels are chosen to examine how unexpected and out-of-control people's lives can be. Additionally, several questions concerning their recent experiences were posed in order to assess their mental state and degree of stress in relation to everyday situations. The questions essentially ask the individual to answer with their concerns over a few frequent circumstances that typically occur. It essentially focuses on understanding how they are feeling and how stressed out they are. By detecting high stress at an early stage without requiring a large initial financial investment, PSS can reduce a person's likelihood of experiencing severe stress.

Proposed Approach

This work presents the application of machine learning (ML) to detect rising uses of social networking levels in students, forecast stress levels in advance, and prevent catastrophic life-damaging events before they occur. Students are assessed in a variety of scenarios during the exam. The undertaking execution authorized the degree of stress. According to Figure 1, the suggested model consists of gathering PSS datasets, preprocessing them, extracting





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features from them, and applying ML algorithms (Random Forest, SVM, NB, and KNN), and evaluating the results on three performance metrics. The preprocessing method has been applied to the dataset in order to find out the null values whatever found in the data group. Some common techniques namely data cleaning consisting of the imputation mechanism, substitution, and replacement have been applied on the dataset. Validating the given data in the dataset has been critically substantiated in order to get accurate results.

Data Acquisition

The research was done by using a quantitative survey which consisted of collecting data from the online survey conducted among 474 students from Private University of Kolkata:

- Time spent on social networking sites.
- Frequency of interaction (likes, comments, and messages).
- Participation in online communities.
- Self-reported mental health indicators using the Beck Depression Inventory (BDI).

Variables

The primary variables included:

- **Independent Variables:** Hours of social media use per day, number of platforms used, online engagement levels.
- **Dependent Variable:** Depression score based on the BDI scale.

Regression Model

Linear Predictive Model

A linear regression model was employed to analyze the relationship between social networking variables and depression scores. The model took the form:

$$\text{Depression Score}(Y) = \beta_0 + \beta_1(\text{Hours of Use}) + \beta_2(\text{Engagement Level}) + \epsilon \text{ ----- (F1)}$$

Where:

- Y is the predicted depression score.
- β_0 is the intercept.
- β_1, β_2 are the regression coefficients.
- ϵ epsilon ϵ is the error term.

Nonlinear Predictive Model

There is some usage of non-linear regression when the research establishes a relationship between the input and output different from that of a linear one.. In this case, SVR will be used to predict depression, capturing the more complex relationships between social media usage patterns and their effects.

SVR Algorithm (SVR) Overview

Support Vector Regression (SVR) extends the Support Vector Machine (SVM) to support regression processing. Supposedly, the motive is not to classify, rather to fit a specific function to a data set., SVR seeks to fit the best possible curve that captures the relationship between the independent variables (e.g., social media usage, engagement levels) and the dependent variable (depression score). SVR works by trying to minimize errors within a margin of tolerance (epsilon), allowing some flexibility in prediction accuracy. The SVR model aims to find a function $f(X)$ that deviates from the observed data points by a value less than or equal to ϵ , while ensuring that the model is as flat as possible.





Mathematical Formulation of SVR

The SVR model solves the following optimization problem:

$$\min_{\mathbf{w}, b} \frac{1}{2} \|\mathbf{w}\|^2 \quad \text{subject to} \quad |y_i - (\mathbf{w}^T \mathbf{x}_i + b)| \leq \epsilon \quad \text{----- (F2)}$$

Where:

- $\mathbf{w}$ refers to the vector of weights.
- b refers to the bias value.
- y_i is the actual depression score of i th data point.
- $\mathbf{x}_i$ represents the features of i th data point, e.g., hours of using social media, level of engagement.
- ϵ sets the gap of tolerance which errors disregard the accuracy within that gap.

The function $f(\mathbf{x}) = \mathbf{w}^T \mathbf{x} + b$ tries to predict the depression score.

In nonlinear SVR, the input data $\mathbf{X}$ is transformed into a higher-dimensional space using a kernel function, where the relationship between variables becomes linear and can be fitted by the SVR model.

Common Kernel Functions

1. **Linear Kernel:** $K(\mathbf{x}_i, \mathbf{x}_j) = \mathbf{x}_i^T \mathbf{x}_j$
2. **Polynomial Kernel:** $K(\mathbf{x}_i, \mathbf{x}_j) = (\gamma \mathbf{x}_i^T \mathbf{x}_j + r)^d$
3. **Radial Basis Function (RBF) Kernel:** $K(\mathbf{x}_i, \mathbf{x}_j) = \exp(-\gamma \|\mathbf{x}_i - \mathbf{x}_j\|^2)$

In this study, we will use the RBF kernel, which is widely used for capturing nonlinear relationships.

Model Significance

The regression model's significance can be tested using the **p-value** and **R-squared** value.

- **P-value:** Tests whether the independent variables significantly predict the dependent variable. A p-value less than 0.05 indicates statistical significance.
- **R-squared:** Indicates the proportion of variance in the dependent variable explained by the independent variables. Higher R-squared values indicate a better fit of the model.

Formula for R-squared

$$R^2 = 1 - \frac{\sum (Y_i - \hat{Y}_i)^2}{\sum (Y_i - \bar{Y})^2} \quad \text{----- (F3)}$$

Where:

- Y_i are the observed values.
- $\hat{Y}_i$ are the predicted values from the model.
- $\bar{Y}$ is the mean of the observed values.

SVR Model Development

We develop a nonlinear SVR model using the **RBF kernel** to predict depression scores based on hours of social media usage and engagement level.

Regression Formula:

$$f(\mathbf{x}) = \sum_{i=1}^N (\alpha_i - \alpha_i^*) K(\mathbf{x}_i, \mathbf{x}) + b \quad \text{----- (F4)}$$





Where:

- $K(x_i, x)$ is the kernel function (in our case, the RBF kernel).
- α_i and α_i^* are the Lagrange multipliers from the SVR optimization problem.

The parameters of the SVR model (kernel, CCC, γ) will be tuned using cross-validation.

SVR Model Performance

We trained the SVR model on 80% of the data and tested it on the remaining 20%. The performance metrics for the SVR model include:

- **Mean Absolute Error (MAE):** Measures the average magnitude of prediction errors.

$$MAE = \frac{1}{n} \sum_{i=1}^n |y_i - \hat{y}_i| \quad \text{----- (F5)}$$

- **Root Mean Squared Error (RMSE):** Provides a measure of the spread of prediction errors.

$$RMSE = \sqrt{\frac{1}{n} \sum_{i=1}^n (y_i - \hat{y}_i)^2} \quad \text{----- (F6)}$$

- **R-squared: Proportion of variance explained by the model.**

Experimental Setup

Python language has been used in order to implement machine learning algorithms. Different packages of the language like matplotlib, numpy, scikitlearn, etc are some of the significant packages used in the experiments. Since the work is concerned to the survey process for gathering the raw data The preprocessing technique has been applied to the utmost level so that no sort of noises or other spurious values will be percolated into the final result. The data collected are kept in the Excel file and for further processing, the conversion of the file has been done to the csv format in order to get it exposed to the Python programming environment.

Performance Parameters

The overall result evaluation and the performance measurement has been achieved by means of the standard metrics

i. **Sensitivity:** Another name for this is the true positive rate. It is the proportion of false negatives (FN) to true positives (TP). This describes the model's capacity to accurately associate the illnesses displayed in Equation 1 with them.

$$Sensitivity = \frac{TP}{TP+FN} \quad (1)$$

ii. **Specificity:** Another name for this is the genuine negative rate. According to Equation 2, it is the ratio of the true negative (TN) to the true negative and false positive (FP). This describes the capacity to accurately recognize in the absence of disorders.

$$Specificity = \frac{TN}{TN+FP} \quad (2)$$

iii. **Accuracy:** According to equation 3, this is the ratio of true positives plus true negatives to true positives plus true negatives plus false positives plus false negatives. It determines the proportion of cases that are correctly classified.

$$Accuracy = \frac{TP+TN}{TN+FP+TP+FN} \quad (3)$$

K-Fold Cross Validation

It is a method for extrapolating the data's behavior to a larger set of data and increasing it k times based on the analysis. Increasing the dataset being analyzed fundamentally aids in improving a model's performance. The procedure entails splitting the dataset into k folds, generalizing the behavior, adding more data entries, and ultimately improving our model's efficiency. Due to the short dataset in our instance, 10-fold cross validation has been used.



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RESULTS AND DISCUSSION

In this study, we evaluated the specificity, sensitivity, and accuracy of four machine learning algorithms: K-Nearest Neighbor, Support Vector Machine, Random Forest, and Naïve Bayes.

Classification Algorithms

A special data mining method called the classification algorithm takes a given piece of information and analyzes each case in it. With a very low probability of error, it assigns the example to a certain class. Within the specified informational index, it is used to eliminate models that represent essential information classes. Here, we identified each person's level of stress using a few categorization methods. We used the remaining data to test our model after we had trained it using our original data. A 1:3 train was utilized to test the ratio.

Random Forest

Several decision trees are taken into account by this process, creating a forest. [7-8] It can also be referred to as a collection of decision trees. Regression and classification are two uses for this. This algorithm searches through all of the features to determine which one is better at random. We employed 100 decision trees in our experiment, and the impurity index was measured using Ginni.

Naive Bayes

Naive Bayes classifiers are known as 'probabilistic classifiers' which are the fundamental classifiers in machine learning algorithms and they follow a probabilistic way that is easily scalable. These classifiers are remarkably easy to modify and learn by virtue of the parameter distribution being able to simply linear scale without problem as more features are introduced. [10].

Support Vector Machine

A collection of simple "probabilistic classifiers" is referred to as naive Bayes classifiers in machine learning terminology. Highly scalable, they operate based on chance. Classifiers using naive Bayes have a lot of flexibility. When it comes to the amount of components (highlights/indicators) in the learning issue, they need different characteristics that are straight [10].

K- Nearest Neighbor

This approach operates based on whether the classifier is used for relapse or arrangement using the K-NN nearest. There is no middle group in this form of class membership; students are either a part of group A or group B. Only three groups will be created from the data if there are three groups. Given the dilemma of which of the class's k nearest neighbors is a positive number and a small number, there may be some accommodation on the part of the neighbors. The class of that single nearest neighbor will receive the protest if $k = 1$.

Out of the four algorithms, we discovered that Random Forest performs the best, with an accuracy of 90.54%, specificity of 91%, and sensitivity of 100%. Support Vector machine, on the other hand, performs right behind Random Forest machine, with an accuracy of 83.05%, specificity of 90%, and sensitivity of 82%. From these four algorithms, we can thus conclude that Random Forest is doing the best in this particular circumstance [Table 2]. It is evident from the recorded performance accuracy of several competing algorithms, that the Random forest algorithm has scored a maximum. It was found that the largest share of respondents (23.6%) reported spending between 5 and 10 hours online every day, which is a substantial amount of time for an adult. 14.8 percent of the participants said they used Facebook and Twitter for about one to two hours a day, while 20.9% said they used online platforms for between two to three hours a day. 19.6% participants said that they spent three to four hours a day in online platform. 13.9% of the participants said that they used online platform four to five hours a day and only 7.2% participants admitted that spent an hour in every day (Table 3 and in Figure 2). These findings show that undergraduate university students invest a significant amount of time on online platforms, which lowers their



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participation in activities such as reading books and participating in sports. It has been found that spending time for more than 5 hours in the social media environment. Such trend of time spending has been evident in the graph. The mean score and standard deviations (3.55 and 1.099) indicated that the participants were interested in using digital media for non-specific purposes. The mean score was 3.32 with a standard deviation of 1.327, indicating that the participants frequently became distracted by online platforms while working on other tasks. The mean of 2.57 and the standard deviation of 1.251 indicate that many participants experience restlessness if they have not used online platforms like Facebook and Twitter. Table 4 displays the participants' interest in using social networking sites, as well as their reasons for liking online pages and groups and using them to obtain information. The mean scores and standard deviations (3.55 and 1.099) indicated that the participants were interested in utilizing online platforms for personal use without a defined goal; yet, they also showed signs of getting sidetracked from their tasks by online media (mean 3.32, and std 1.327). Comparably, the average scores for feeling restless after not using social networks for a period were 2.57 and 1.251.

The participants' depression levels according to gender are displayed in Table 5. At the least degree of depression (31.16%, 38.21%), female participants were found to be less depressed than male participants. Males were more likely than females (41.55%) to experience mild depression (28.5%), according to this data, 21.95% male and 16.88% female have experienced mild depression. Further, 11.38% of men and 10.38% of women have been affected by severe depression, respectively. The participants' depression levels according to gender are displayed in Table 5. At the least degree of depression (30%, 70%), female participants were found to be less depressed than male participants. Males were more likely than females (61%) to experience mild depression (54%), while 55% of boys and 45% of girls experienced moderate depression, and 52% of boys and 47% of girls experienced severe depression. The comparative analysis has been presented in the fig for both the boys and girls candidates. The Regression curve is well representing the prediction trends of score gender wise. The respondent wise accounts for both boys and girls candidates have been shown in the Fig 4.

In Table 6, the girl participants' mean score and standard deviation were 35.17 and 10.36, respectively, while the male participants' corresponding values were 39.68 and 10.97. 12.51 is the t value and 0.000 is the p value, hence it can be concluded that with respect to mean values of both the groups there does exist great statistical difference. This demonstrated that male participants who used social networking sites had greater rates of depressive disorders than girl participants.

The mean and standard deviation of participants who use social networking platforms for games and health information searches are 65.45 and 21.12, respectively, while those who use social media sites for chat are 39.25 and 11.49, respectively, as shown in Table 7. The t and p values were 12.62 and .000. The high and significant t value of .000 indicates that there was a highly significant difference between the two groups' mean scores. This suggests that participants who use online communities to play games and find health information have higher rates of depressive illness than those who use them to communicate with loved ones.

Table 8 presents a favorable correlation between online social network usage and depression. Accordingly, a depressive disorder was more common in people who used social networking platforms regularly than in people who used them occasionally. Spending more time outdoors raises the risk of depression. Additionally, the table demonstrates a favorable correlation between online searches for healthcare information and despair. Compared to individuals who used social networking site to communicate with near ones, those who used it to look for health information had higher levels of depression [28-30]. The Perceived Stress Scale (PSS) exam can also be used to determine university students' social networking stress levels. To assist students with their initial stress level related to social networking, an initial analysis might be conducted. Four classification techniques (KNN, RF, Naïve Bayes, and SVM) were used in this work based on sensitivity, specificity, and accuracy parameters on a dataset of 474 students from a Private University in Kolkata. Ten-fold cross-validation has also been used because the datasets are tiny. Given its geometric approach to categorization and smaller data set, Random Forest outperforms the other four





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methods in our analysis. Students can have better mental health and mental soundness by analyzing and locating techniques like PSS that produce more accurate results at a lower cost [31-35].

Descriptive Statistics

Correlation between the Mental illness and Social Networking use

The figure below is helpful in demonstrating a positive connection between the amount of time spent on various social media websites and the risk of becoming depressed.

Regression Analysis Findings

It was observed from the regression analysis that positive relationship did exist significantly between hours of use and affect (adjustment). The regression coefficients obtained using the F1 equation have been reported in Table 10.

$$Y=10.54+3.12\cdot(\text{Hours of Use})+2.18\cdot(\text{Engagement Level})$$

This equation predicts that for every additional hour spent on social media, the depression score increases by 3.12 points, controlling for engagement levels.

Predictive Analysis

Using the developed regression model, we can predict depression scores based on varying hours of social media use and engagement levels using F3 expression. For example:

- **If a student spends 5 hours on social media and has an engagement level of 4:**

$$Y=10.5+2.4\cdot 5+1.8\cdot 4=10.5+12+7.2=29.7$$

Predicted depression score: 29.7

This score suggests a high level of depression based on the student's social media usage patterns.

Graphical Representation of SVR Regression Results_

Here is the chart displaying the SVR prediction of depression scores vs. actual depression scores. The blue points represent the predicted values compared to the actual depression scores, while the red line shows the ideal 1:1 relationship between predicted and actual values. This visualization helps illustrate the accuracy of the SVR model in predicting depression scores based on the input data (Figure 6).

Performance Metrics

To evaluate the SVR idea:

- **MSE:** A measure of average squared prediction error is the mean squared error, or **MSE**.
- **R-squared (R²):** It indicates the proportion of the depression scores variance that can be accounted for by the model where a high R² value which approaches 1 implies good fit.

This model provides a reliable foundation for assessing social media impacts on depression, capturing nonlinear relationships using SVR and offering a predictive tool for mental health analysis.

CONCLUSION

Our study investigated the interrelationship between depression as well as the utilization of online resources by undergraduate students. The study examining the association between depression and usage of online networks found that those who used Facebook and Twitter regularly had higher rates of depression. Using sensitivity, specificity, and accuracy criteria, we ran four classification algorithms (KNN, Random Forest, Naïve Bayes, SVM) on a dataset of 474 students from a Private University, Kolkata [36-39]. We discovered that Random Forest algorithms perform the best. This examination corroborated the study's findings, which showed that students who used digital platforms were more frequently depressed than other media.





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Conflict of Interests

With clarifications from writer of the inquisition study, the authors confirm that their work's integrity has not been compromised by any professional ties or financial interest.

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Table 1: It shows a summary of prior research data about the impacts of using networking sites on youths' mental wellness.

Author	Study Focus	Key Findings
Smith et al. (2021) [24]	Social networking sites and anxiety	High usage correlated with increased anxiety levels.
Brown (2020) [25]	Cyberbullying	Strong predictor of depression among teenagers.
Li & Chen (2019) [26]	Sleep & social media	Increased screen time leads to disrupted sleep patterns, resulting in mental health issues.

Table 2: Evaluation of Distinct Algorithms

Sr. No.	Algorithm	Sensitivity (%)	Specificity (%)	Accuracy (%)
1	Random Forest	100	91	90.54
2	Naïve Bayes	75	80	67.87
3	Support Vector Machine	82	90	83.05
4	K-Nearest Neighbors	85	55	60.33

Table 3: An explanation of social network usage time.

Time spends on social media	N	%
During 1 and 2 hours	70	14.8%
During 2 and 3 hours	99	20.9%
During 3 and 4 hours	93	19.6%
During 4 and 5 hours	66	13.9%
Below an Hour	34	7.2%
Over 5 hours	112	23.6%

Table 4: Participants' tendency to use digital media

	Mean	Std. Deviation
How often do you find yourself using Social media without a specific purpose?	3.55	1.099
How often do you get distracted by Social media when you are busy doing something?	3.32	1.327
Do you feel restless if you haven't used Social media in a while?	2.57	1.251





Table 5: Depression based on gender disparity of participants (n=474)

Scores	Range	Respondents	Frequency	%
0 - 13	Minimal	Male	57	70
		Female	24	30
14 - 19	Mild	Male	72	54
		Female	61	45
20- 28	Moderate	Male	32	55
		Female	26	45
29 - 63	Severe	Male	70	52
		Female	63	47

Table 6: Variations in online users' depression scores according to gender. (n=474)

Variable	Female N = 263		Male N = 211		tp	
	M	SD	M	SD		
Depression	35.17	10.36	39.68	10.97	12.51	.000
*p<.01, df= 198						

Table 7: Participants' depression based on how much time they spent chatting and looking up health-related material on social media. (n=474).

Variable	Health information & games N = 120		Chat N = 94		tp	
	M	SD	M	SD		
Depression	65.45	21.12	39.25	11.49	12.62	.000
*p<.01, df= 198						



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Table 8: Depression correlation scores, online social media usage, time spent looking for health-related material, and gaming.

Variables	Depression	Time on Social Media	Health Information & Games
Depression	1	.212**	.178
Time on social media	.212 **	1	-0.002
Health information	.178**	-.002	1

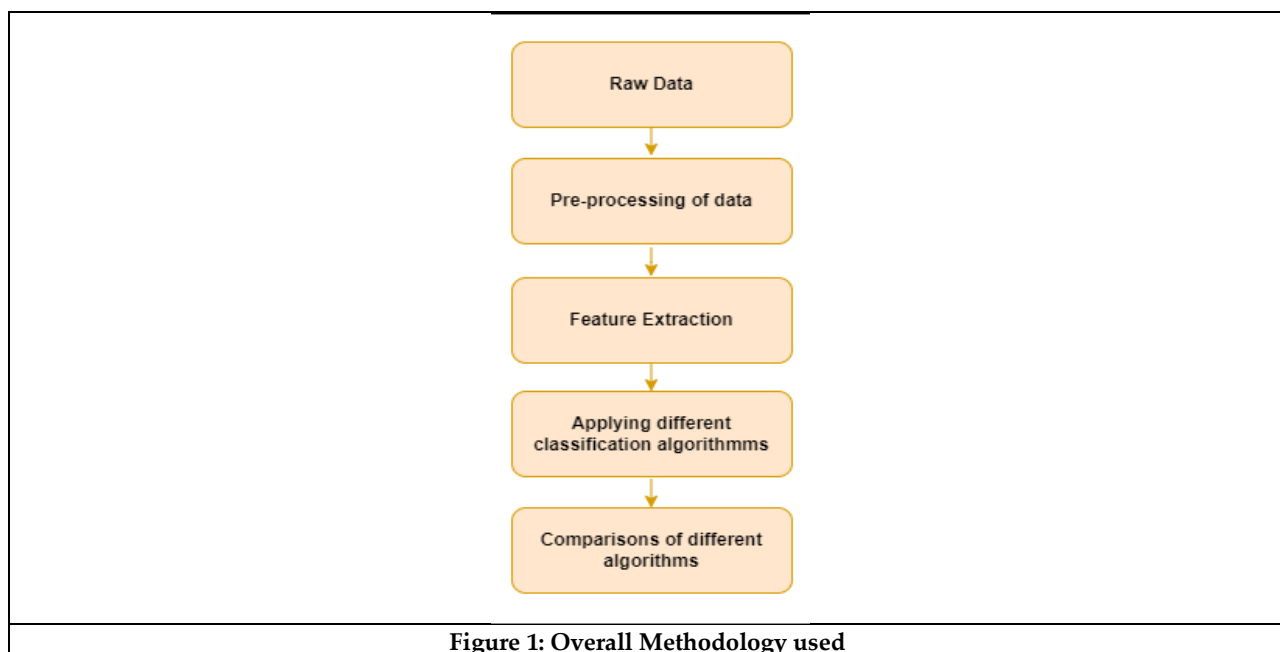
** Correlation is significant at the 0.01 level.

Table 9: provides the statistical description of the survey responses.

Variable	Mean	Standard Deviation
Hours of Social Media (per day)	4.5	1.8
Engagement Level (1-5 scale)	3.5	1.1
Depression Score (BDI)	21.5	7.3

Table 10: provides the descriptive statistics of the survey responses.

Variable	Coefficient (β)	P-value
Intercept	10.54	0.001
Hours of Social Media	3.12	0.000
Engagement Level	2.18	0.015



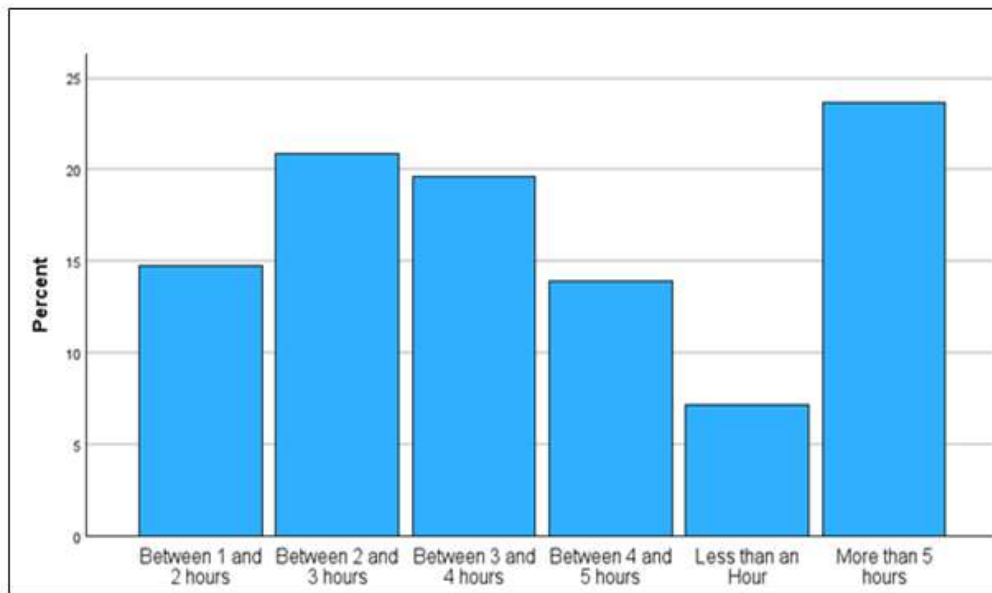
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Figure 2: Graphical explanation of social network usage time

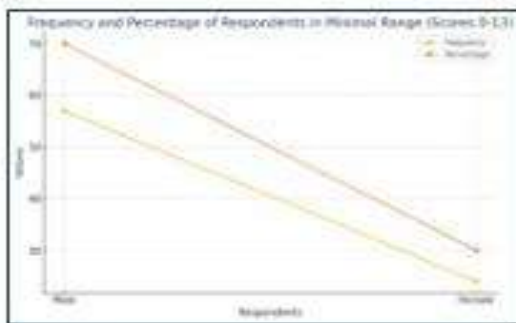
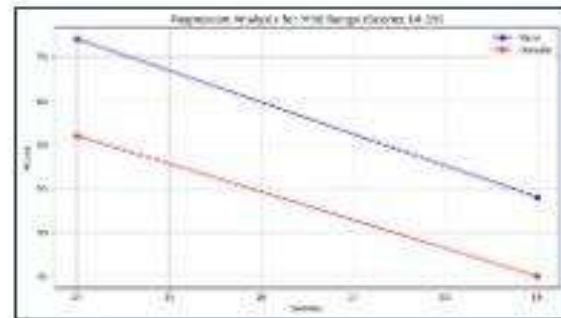
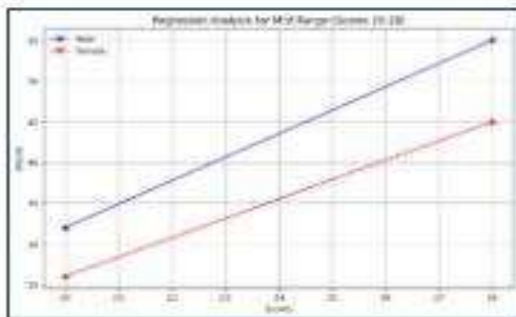
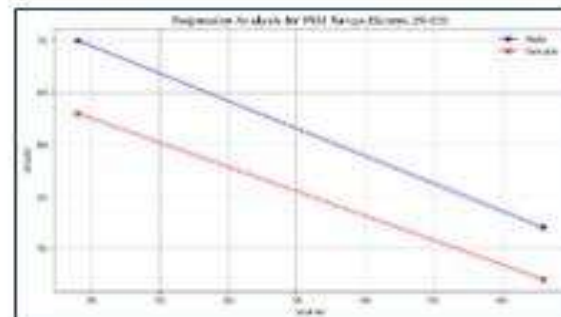
Figure 3.a: Regression Analysis
Score [0 - 13]Figure 3.b: Regression Analysis
Score [14 - 19]Figure 3.c: Regression Analysis
Score [20 - 28]Figure 3.d: Regression Analysis
Score [29 - 63]

Figure 3: Regression Analysis based on Score



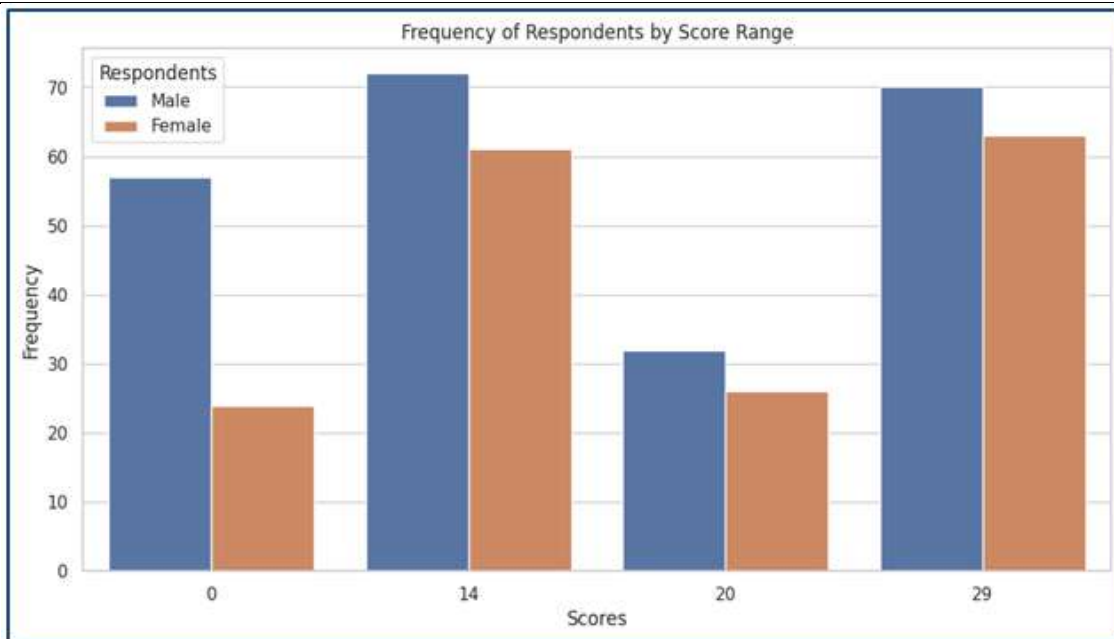
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Figure 4: Regression Analysis based on Respondents

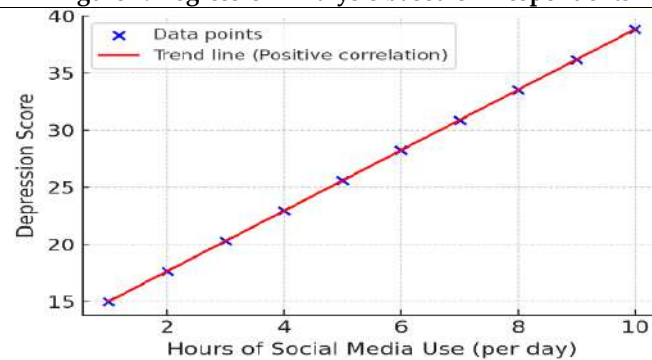


Figure 5: A Lens on Social Media Employment and Depression

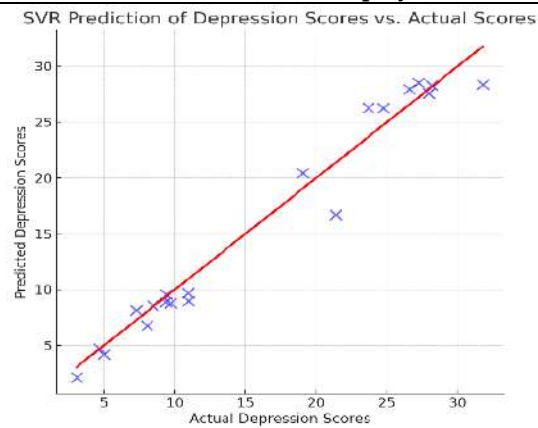


Figure 6: SVR prediction of depression scores vs. actual depression scores





REVIEW ARTICLE

Controlling Hypotension Following Spinal Anaesthesia in Adults: An Evidence - Based Review

Komal Yadav and Pulkit Ramavat *

Assistant Professor, Department of Anaesthesia and Operation Theatre Technology, Shree Guru Gobind Singh Tricentenary University, Gurugram, Haryana, India.

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*Address for Correspondence

Pulkit Ramavat

Assistant Professor,
Department of Anaesthesia and Operation Theatre Technology,
Shree Guru Gobind Singh Tricentenary University,
Gurugram, Haryana, India.
E.Mail: pulkitramavat60@gmail.com



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ABSTRACT

Because of its effectiveness and comparatively low risk profile, spinal anesthesia is a technique that is frequently used in a variety of surgical procedures. However, Hypotension is one of the primary side effects of spinal anaesthesia, and if is not treated quickly and correctly, it can have disastrous consequences. The goal of this review is to present a thorough summary of the approaches used today to treat adult patients' spinal anesthesia-induced hypotension. Hypotension after spinal anesthesia has a complex aetiology that includes reduced cardiac output, venous pooling, and sympathetic blockade. Developing suitable management strategies requires an understanding of the underlying mechanisms. Several pharmacological and non-pharmacological interventions have been suggested and put into practice to prevent or lessen hypotension in this situation. Vasopressors like ephedrine, phenylephrine, and norepinephrine, as well as fluid loading and colloid administration, are examples of pharmacological interventions. Non-pharmacological methods include positioning the patient, preloading intravenous fluids, and using local anesthetics at lower doses or concentrations. Furthermore, more recent methods like volume preloading with crystalloids or colloids and preventative lower limb compression devices have demonstrated encouraging outcomes in specific patient populations. The choice of a suitable management plan is contingent upon multiple elements, such as the comorbidities of the patient, the nature and length of the surgical operation, and the anesthesia provider's preferences. Customized strategies based on the patient's unique risk factors and hemodynamic state are crucial for maximizing benefits and reducing side effects. In conclusion, a comprehensive strategy combining pharmacological and non-pharmacological interventions is needed to manage spinal anesthesia-induced hypotension effectively. It is necessary to conduct additional research to assess the safety and effectiveness of new



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approaches as well as to improve current procedures for reducing this frequent side effect in adult patients receiving spinal anesthesia.

Keywords: Spinal Anesthesia, Arterial Hypotension, Vasopressor, Phenylephrine, Ondansetron

INTRODUCTION

It is believed that maintaining arterial blood pressure is crucial to guaranteeing sufficient regional perfusion. Although compared to general anesthesia, spinal anesthesia (SA) may offer considerable advantages, it is often linked to arterial hypotension. This article's objectives are to examine the mechanisms causing spinal anesthesia-induced hypotension (SAIH) and to go over the various methods for treating and preventing SAIH [1]. Because it works well, takes little time to take effect, and consistently produces regional anesthesia, spinal anesthesia is a commonly used technique in surgical procedures. However, Hypotension is one of the most common adverse effects of spinal anaesthesia, which can result in dangerous situations like myocardial ischemia, organ hypo perfusion, and even cardiovascular collapse. Despite being common, there isn't a set protocol for managing or preventing hypotension brought on by spinal anesthesia [2]. Finding practical ways to lessen the incidence and severity of hypotension in adult patients after spinal anesthesia has received more attention in recent years. The effectiveness of several interventions, such as preoperative fluid loading, vasopressor administration, patient positioning, and pharmacological agents, in preserving hemodynamic stability during spinal anesthesia has been suggested and investigated [3]. The purpose of this review is to conduct a critical analysis of the body of research on adult patients' management of spinal anesthesia-induced hypotension. Through the integration of data from systematic reviews, meta-analyses, and clinical trials, this review aims to offer a thorough summary of the current approaches available for the management and avoidance of hypotension related to spinal anesthesia. This review will also look at the controversies and limitations surrounding these interventions, as well as areas that need more investigation [4]. Improving patient outcomes and maximizing perioperative care requires an understanding of the mechanisms underlying spinal anesthesia-induced hypotension and the identification of efficient management techniques. This review aims to support the creation of evidence-based guidelines and protocols for the treatment of spinal anesthesia-induced hypotension in patients by combining the available data and identifying areas for further research [5].

Mechanism of Arterial hypotension

Although the degree of the resulting sympathetic block is directly correlated with the cardiovascular effects of SA, the degree of this block varies greatly amongst patients.

SA's Impact on the Capacitive Systems and Vascular Resistant

By causing a baroreflex in the affected places, the sympathetic block caused by SA quickly causes arterial and arteriolar vasodilation, which in turn increases sympathetic arterial vascular tone in the unblocked locations. In younger patients, these compensatory mechanisms tend to be more effective [6]. Blood pools in the lowest areas of the capacitance veins because of the hemodynamic properties of SA, which also root of a sympathetic blockage of the venous reservoir. Vasopressors can mobilize up to 20% of the circulating blood volume when the degree of the sensory block is greater than or equal to T6 due to pooling in the hepatosplanchnic region.[5,6].

Effect of SA Node on the Cardiac System

Sympathetic activation (SA) has a variety of effects on the heart, including both immediate reactions and long-term adaptations. An outline of these effects is provided below



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Elevated Heart Rate (HR): When the sympathetic nervous system is activated, catecholamines are released, especially norepinephrine, which attaches to β_1 -adrenergic receptors on cardiac pacemaker cells, mainly the sinoatrial node. The heart rate rises as a result of this acceleration of depolarization [7].

Enhanced Myocardial Contractility: By activating β_1 -adrenergic receptors in cardiac myocytes, sympathetic stimulation raises the heart's contractility. This results in a greater influx of calcium, which amplifies the myocardial contraction's force (positive inotropic effect) [8].

Acceleration of Cardiac Conduction: Sympathetic activation affects not only the sinoatrial node but also the atrioventricular node and the His-Purkinje system, increasing the conduction velocity of electrical impulses. As a result, electrical signals within the heart are transmitted more quickly [8].

Peripheral Vasoconstriction: α -adrenergic receptor activation in sympathetic activation causes vasoconstriction in peripheral blood vessels, even though the primary target is the heart. In times of stress or exercise, this raises systemic vascular resistance, which helps to maintain blood pressure and redistribute blood flow to essential organs. Enhanced myocardial contractility, peripheral vasoconstriction, and elevated heart rate all work together to increase cardiac output, or the amount of blood the heart pumps out in a given amount of time [9].

Coronary Artery Dilation: Sympathetic activation dilates the coronary arteries even though it usually causes peripheral arteries to vasoconstrict. This guarantees that the myocardium receives enough oxygen and nutrients when the heart is working harder [8,9].

Extended Consequences in Pathological Situations: Chronic stress or heart failure can cause prolonged sympathetic activation, which can result in maladaptive cardiac changes like cardiac myocyte apoptosis, fibrosis, and hypertrophy. The advancement of heart failure and other cardiovascular disorders is facilitated by these alterations [10].

Arteriovascular hypotension

Arteriovascular hypotension is a result of the way SA affects the cardiovascular system. An increase in patient mortality and morbidity has been associated with intraoperative arterial hypotension [11,12]. The most often used definition of SAIH in the literature is less than 80% of baseline in systolic arterial blood pressure. The prevalence of SAIH increases with age, with 36% of those under 50 and 75% of people over 50 having the illness. [13]. Older patients continue to have a high incidence of SAIH even at low doses (7.5 mg of bupivacaine). Moreover, disruption of homeostatic mechanisms can exacerbate SAIH; this is particularly relevant in patients with dysautonomia from concomitant sedation or fast block extension due to inadequately neuro-humoral regulated cardiac function. [14].

Arteries' Control of Blood Pressure

An intricate web of physiological processes interacts to control arterial blood pressure.

Baroreceptor Reflex: Changes in arterial pressure are sensed by baroreceptors embedded in the walls of major arteries, especially the aortic arch and carotid sinus. Stretching these receptors in response to elevated arterial pressure causes an increase in action potential firing to the brain's cardiovascular control centers, especially the medulla oblongata. This causes sympathetic inhibition and parasympathetic activation, which in turn causes vasodilation, a drop in heart rate, and a drop in arterial pressure. On the other hand, when arterial pressure falls, the heart rate rises and vasoconstriction occurs as a result of reduced stretch of the baroreceptors, which lowers parasympathetic activity increases sympathetic activity, and restores arterial pressure to normal [15].

The RAAS, or renin-angiotensin-aldosterone system: Renin is released from the kidneys in response to drops in arterial pressure. Angiotensin-converting enzyme (ACE) transforms angiotensin I, which is produced when renin acts on angiotensinogen to form angiotensin II. Strongly acting as a vasoconstrictor, angiotensin II also causes the



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adrenal glands to release more aldosterone, which causes water and salt retention and raises blood volume and arterial pressure [16].

Vasopressin (Antidiuretic Hormone) Release: The posterior pituitary gland releases vasopressin in response to a drop in arterial pressure. Vasopressin inhibits blood flow by binding to V1 receptors in vascular smooth muscle and increases water absorption by binding to V2 receptors in the kidney. The goal of both activities is to raise arterial pressure [17].

Endothelial Regulation: Endothelial cells generate a variety of vasoconstrictor and vasodilator chemicals, including endothelin-1 (ET-1) and nitric oxide (NO), respectively. These compounds contribute to the regulation of arterial pressure by modulating vascular tone [18].

Central Nervous System Regulation: To regulate sympathetic and parasympathetic outflow as well as hormonal responses to keep arterial pressure within a specific range, brain regions like the hypothalamus and medulla oblongata integrate multiple inputs, including those from baroreceptors, chemoreceptors, and higher brain centers [19].

Effect of Circulating Blood Volume and Body Position

If a patient has pre-existing hypovolemia, it may cause cardiovascular collapse during SA. Additionally, leveling from Trendelenburg may cause cardiac arrest [20]. Any hyperbaric solution's potential cephalad extension needs to be carefully considered, and its hemodynamic effects need to be predicted. By reducing aortocaval compression by the gravid uterus, the left lateral tilt position (5–10°) following SA in the parturient promotes venous return [21].

Liquid Filling

The state of the patient's volume before seeing the SA the effects of the sympathetic block and it is necessary to consider both intraoperative and postoperative fluid losses when determining the kind and volume of intravenous fluid to be administered. Fluid loading (FL) is commonly used during cesarean sections in obstetric patients, either alone (44%) or in conjunction with a vasopressor (53%) [22]. Studies have been done on various IV fluid kinds and when to administer them. Colloid preloading, or loading with hydroxyethyl starch, or HES, can considerably reduce the incidence and severity of maternal hypotension and reduce the amount of vasopressors required, but crystalloid preloading, or loading prior to the SA, is ineffective and not medically warranted [23]. HES co-loading, when given quickly (within 5 to 10 minutes) after placing the SA, is equally effective as HES preloading. Although crystalloid co-loading is less expensive, it seems to be less effective, particularly when used at slower rates [24]. FL must only be done when essential (later the onset of SA) in certain unique clinical cases, such as patients with pre-eclampsia, to prevent fluid overload. According to studies, crystalloid co-loading for fluid loading decreased the risk of hypotension in SA during cesarean delivery [23]. Since crystalloids are more usually used, they do not have the drawbacks of colloids, such as allergic reactions, coagulation changes, and expense [25].

Atropine

Role of atropine: Research has looked into atropine, a muscarinic receptor antagonist, as a possible intervention to counteract hypotension brought on by spinal anesthesia. Atropine can lessen the bradycardic and vasodilatory effects of spinal anesthesia by inhibiting the parasympathetic effects mediated by acetylcholine. The effectiveness of atropine in treating or preventing hypotension after spinal anesthesia has been examined in several studies, with differing degrees of success [26].

Mechanism of action

Atropine is based on its competitive inhibition of acetylcholine at muscarinic receptors, which stops the parasympathetic nervous system from being activated. Peripheral vasoconstriction and an increase in heart rate (positive chronotropy) and cardiac output follow, which can counteract the hypotensive effects of spinal anesthesia [27].





CONCLUSION

Hypotension induced by spinal anesthesia (SAIH) is a common occurrence, especially in the elderly and parturients undergoing caesarean sections. Numerous approaches to reducing its occurrence have been investigated, but no single strategy has proven to be highly successful. Crystalloid preloading, that is, loading before the SA, is ineffective in contrast to co-loading. Currently, the most common vasopressor agent is phenylephrine. The incidence of SAIH seen in this setting is limited by its prophylactic injection, which occurs right next to the intrathecal injection. The two administration strategies are continuous intravenous infusion at a predetermined or modifiable rate or titrating several boluses. Before serotonin receptor antagonists, such as ondansetron, are suggested for the prevention of arterial hypotension, more research is required. Regardless of the tactic used, SA-induced bradycardia should always be regarded as a warning sign indicating a dangerous hemodynamic condition.

Hypotension Caused by Spinal Anesthesia

↓
 Bradycardia and Vasodilation (Parasympathetic Effects)
 ↓
 Acetylcholine's Induction of Muscarinic Receptor Activation
 ↓
 The administration of atropine (antimuscarinic antagonist)
 ↓
 Inhibition of Muscarinic Receptors Through Competitive Approach
 ↓
 Causes and Effects of Parasympathetic Nervous System Blockade
 ↓
 Positive chronotropy causes an increase in heart rate.
 ↓
 Elevation of Heart Output and Peripheral Vasoconstriction
 ↓
 Reduction of Hypotension Induced by Spinal Anesthesia

Arterial Hypotension

↓
 1. Reduced Cardiac Output

↓
 a. Decreased Stroke Volume

↓
 i. Reduced Preload

↓
 - Hypovolemia
 - Venous Pooling

ii. Decreased Contractility

↓
 - Myocardial Infarction
 - Cardiomyopathy

b. Decreased Heart Rate

↓
 - Bradycardia
 - Heart Block

2. Peripheral Vasodilation

↓
 a. Neurogenic

↓
 - Vasovagal Syncope
 - Autonomic Dysfunction

b. Pharmacologic

↓
 - Vasodilator Drugs

c. Inflammatory

↓
 - Sepsis

- Anaphylaxis

3. Orthostatic Hypotension

↓
 - Postural Changes

↓
 - Volume Redistribution
 - Autonomic Dysfunction





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RESEARCH ARTICLE

An Advanced Deep Learning-based Data Mining Techniques

J. Rama^{1*}, N. Vanjulavalli², K. Sujith³, and R. Surendiran⁴

¹Ph.D Research Scholar, P.G. and Research Department of Computer Science, Annai College of Arts and Science, Kovilacheri, Kumbakonam, (Affiliated to Bharathidasan University, Tiruchirappalli), Tamil Nadu, India.

²Associate Professor and Director – PG Department of Computer Application (MCA-AICTE Approved), Research Supervisor, P.G. and Research Department of Computer Science, Annai College of Arts and Science, Kovilacheri, Kumbakonam, (Affiliated to Bharathidasan University, Tiruchirappalli), Tamil Nadu, India.

³Associate Professor and HOD – PG Department of Computer Application (MCA-AICTE Approved), Dean and Research Supervisor, P.G. and Research Department of Computer Science, Annai College of Arts and Science, Kovilacheri, Kumbakonam, (Affiliated to Bharathidasan University, Tiruchirappalli), Tamil Nadu, India.

⁴Associate Professor – PG Department of Computer Application (MCA-AICTE Approved), Research Supervisor, P.G. and Research Department of Computer Science, Annai College of Arts and Science, Kovilacheri, Kumbakonam, (Affiliated to Bharathidasan University, Tiruchirappalli), Tamil Nadu, India

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*Address for Correspondence

J. Rama

Ph.D Research Scholar,
P.G. and Research Department of Computer Science,
Annai College of Arts and Science, Kovilacheri, Kumbakonam,
(Affiliated to Bharathidasan University, Tiruchirappalli),
Tamil Nadu, India.
E.Mail: rama3sarav@gmail.com



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ABSTRACT

Deep learning advancement has modernized data mining by delivering superior analysis performance while speeding up processing of complex data sets. This research explores deep learning as a data mining method by looking at its applications and approaches alongside performance results versus conventional data mining techniques. We discuss how deep learning models CNN RNN and autoencoders effectively process extensive complex data formats. The study presents practical examples to demonstrate these models perform well in image recognition, natural language processing, and predictive analytics applications. The paper shows how to solve the problems when using deep learning models for data mining while offering ways to handle implementation challenges. The study shows how data mining continues to advance by using deep learning alongside new technology solutions.





Keywords — Deep Learning, Data Mining, Convolutional Neural Networks, Recurrent Neural Networks, Autoencoders, Predictive Analytics, Image Recognition, Natural Language Processing, Big Data, Machine Learning.

INTRODUCTION

New deep learning methods have completely changed how experts mine information from big data sets. Data mining methods have changed dramatically because deep learning models now handle large, complex data that is sometimes not in organized structures. Modern neural network types - DNNs, CNNs, and RNNs - do great work in NLP, computer vision, and security to protect our digital world. Its layered organization allows us to develop models that learn and express data in complicated ways, which helps them do tasks more precisely [1]. Apps that explore big datasets work by applying math rules and statistical tools to see repeating ideas. Most past data mining work focused on finding patterns using simple linear models, decision tree analysis, and cluster digging, yet demanded intense human handling at each step of feature trimming and data preparation. Neural networks now automate data mining operations using their ability to learn directly from unprocessed data. Using these data mining techniques that learn through neural networks works best when dealing with unorganized data such as photos, text, and time-series information that usual algorithms can't process quickly [3-7].

Deep learning models have become preferred because they deliver better results across many different kinds of work. Using normal conversation, we can see how convolutional neural networks did better than earlier machine learning tools by finding complex patterns in basic pixel data, leading to improved object detection and boundary setting systems[26-28]. Just like deep learning improved translation, measuring consumer feelings, and understanding written language, recurrent neural networks known as LSTM and transformers have brought about major improvements in these same tasks within NLP. These techniques are also useful outside the data mining field. Healthcare uses them to predict diseases, finance finds fraud, while cybersecurity spots potential dangers [12-13].

Deep learning has done very well in data mining, but there are still important problems to solve. Training deep learning models needs a huge supply of labeled data as one main issue. Getting useful information tied to actual data in most real-world situations takes both a lot of money and enough time, which puts limits on how well deep learning methods can be used. A big problem with deep learning models is their difficulty to understand because of their complex structure. English-language researchers are finding better ways to learn from data with fewer labels by trying semi-supervised learning, making models switch what they know, and explaining AI why it makes decisions [8]. In this paper, we combine new data mining techniques in a deep learning method to enhance the quality, speed, and clarity of our analysis. We create a better data mining process using deep neural networks, and our method helps extract new features, trains models more effectively, and solves issues involving scarce data and clearer AI models. In what follows, we will talk about the studies directly linked to ours, explain our research process step by step, show the results we got, and discuss what our results mean [11].

Novelty and Contribution

What makes this research unique is its use of multiple recent deep learning data mining approaches to resolve basic problems in this field. This study creates a new neural network model by combining various types, which helps data processing run faster while giving more accurate predictions.

- Beyond the hybrid model, the approach brings in a smart optimization tool using evolutionary algorithms. Using evolutionary algorithms helps us find the best settings for our deep learning models' structure. This improvement lets the model work well with data it hasn't seen before. Our main achievement combines two methods: training deep learning models with evolutionary optimization to improve data mining performance most crucially when data is low quality or incomplete [8].



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- In addition to previous work, this project created a new system that makes deep learning models easier to interpret. Deep learning models are hard to understand because they don't explain how their choices are made. Our solution uses an interpretability layer that combines saliency maps and attention methods to help make deep learning models easier to understand. The visualization techniques help us spot significant patterns in our data, and tell us how the model uses and understands what it sees. For healthcare and finance tasks, knowing how the model makes decisions is crucial, and our explainable model helps achieve this.
- In addition, this research fully evaluates its model using different real data sets. Our tests show that joining deep learning and optimization methods with interpretability tools raises results for data mining compared to older data methods. The study shows that modern data mining tools built with deep learning methods can better solve current problems with simpler techniques when dealing with large and hard-to-analyze datasets.

Related Works

In 2012 Krizhevsky, A. et.al., Sutskever, I. et.al., & Hinton, G. E. et.al. [2] Establish the deep auto encoders without human input, data scientists have created better ways to find patterns in data that isn't labeled. Auto encoders excelling at transforming data in a way that lets us identify important features and find outliers or group related items. Linking auto encoders with clustering techniques has raised the standard of information retrieval in unguided data environments, making them excellent tools for exploring big and messy datasets. In 2018 Zhang, L. et.al., & Yang, M. et.al.. [14] Establish the deep learning works better when combined with two types of single-celled computers (optimization methods): genetic algorithms and particle swarm algorithms. These evolutionary methods improve both important parameter settings and feature choosing, which greatly increases model precision while working in complex or messy data settings. Two common ways models face limited labeled data problems - semi-supervised learning and transfer learning - help them work with both labeled and unlabeled data or learn from already-trained models on related tasks.

In 2018 Chen, L. et.al., & Yang, S. et.al. [10] Introduce the outcomes of deep learning models remains a major concern in data mining tasks. Models use visualization tools called saliency maps and attention systems to make their decision-overriding reasons more clear by showing which input features affect their choices the most. Today's improved deep learning systems now fit well in vital areas like medical care, money matters, and guard your network, where trust and explanation are essential. Deep learning changes how we find information in many areas like medicine, money, and computer security. Healthcare professionals use deep learning to study medical records collected digitally and forecast how patients may do in the future. In finance, deep learning helps fight fraud and runs automated trade programs. For cybersecurity, it catches intruders' actions and studies malware more effectively. Current models face big computing costs and small information sets, but research into combining different models and better computing methods keeps expanding deep learning's mining power and shows promise for future widespread use.

Proposed Methodology

Our proposed method combines deep learning methods with evolutionary algorithms to boost data mining performance. Our method helps users find better patterns in big structured data regardless of the input size. The system handles multiple perplexing data mining problems including dataset size limitations and has less optimal results while being difficult to understand [22-25].

Step 1: Our data collection process combines with preprocessing work steps.

The first part of our approach involves receiving data from suitable sources. Our system can analyze various types of data such as visual information, written documents, time-dependent sequences, and formal records. The quality of data determines how well the data mining process works so preprocessing prepares data to meet these standards.

- Data Cleaning: We remove useless data from our systems. We deal with missing data points by either inserting estimates or deleting them.





- Feature Scaling: We normalize numerical data values to equalize their influence on our training process.
- Encoding: The system converts categorical data into a deep learning model ready format through either one-hot encoding or label encoding.
- Data Augmentation (for unstructured data): Deep learning systems perform data enhancement techniques such as rotating, flipping, cropping for images plus generating synthetic patterns for time-series data.

Data preprocessing enables us to properly start feature extraction and model training processes.

Step 2: Deep Learning Models Extract Programs' Features

After preparing the data we use deep learning algorithms to extract necessary features from it. We use CNN algorithms to explore spatial content from different types of data inputs. CNNs succeed at image recognition because they produce deep understanding of image pixel patterns [18]. After CNN processing the LSTM network performs temporal feature extraction for time-series data types. RNNs and LSTMs enable skilled identification of data sequences making them perfect for time-series activities and unusual event highlighting.

The feature extraction process can be mathematically represented as:

The feature extraction process can be mathematically represented as: $F = f_{\text{CNN}}(X)$

where F is the extracted feature set, and f_{CNN} represents the convolutional operation on the input data X . For sequential data, the feature extraction process can be written as: $F' = f_{\text{LSTM}}(X')$

where F' represents the temporal features extracted from time-series data X' .

Step 3: We use Evolutionary Algorithms to make our model work better.

We improve both our model settings and which features to keep by applying evolutionary algorithms. EA models used most often in deep learning tuning are Genetic Algorithms (GA) and Particle Swarm Optimization (PSO). Artificial intelligence tools adjust model hyper parameters - like learning speed, network depth, and group sizes - to help our deep learning model find the most effective results [15-17].

For example, the GA can be used to select the optimal set of features and hyper parameters based on a fitness function that evaluates model performance on a validation dataset. The fitness function f_{fitness} can be expressed as:

$$f_{\text{fitness}} = \frac{1}{1 + \text{MSE}}$$

where MSE (Mean Squared Error) is used as the performance metric. Additionally, PSO can be used to optimize the weights of the neural network, represented by: $w_{\text{opt}} = \text{PSO}(w)$

where w_{opt} is the optimal set of weights found through the swarm optimization algorithm, and w is the initial weight set.

Step 4: Model Training and Validation

Our model starts learning using optimized hyper parameters on the training dataset after we extract features. Our training happens through SGD and Adam optimizers which help us reduce our loss functions such as cross-entropy for classification or mean square error for regression tasks. The training run takes place multiple times across all items to update weight adjustments toward minimum loss results [19]. The model evaluation through validation sets allow us to measure its ability to work with new information. The training process can be represented as:

$$\mathcal{L} = \frac{1}{N} \sum_{i=1}^N \mathcal{L}_{\text{loss}}(y_i, \hat{y}_i)$$

where $\mathcal{L}$ is the total loss, $\mathcal{L}_{\text{loss}}$ is the individual loss for each data point, y_i is the true label, and $\hat{y}_i$ is the predicted label for the i -th instance in the dataset.



**Step 5: Our evaluation shows how well the model performs and explains its behavior.**

After completing training, the model must undergo a test on specific data to receive evaluation. Platform statistics show if our model performs well while measuring its accuracy, precision, recall, F1-result, and ROC curve area.

After system training we apply interpretability techniques such as saliency maps and attention mechanisms to display which features most affect model predictions. The model gains greater transparency when this step is implemented which helps users understand and trust its prediction results.

Step 6: Deployment and Monitoring

When our model reaches acceptable results we send it to production for use. The system deployment connects the model to operational systems to process fresh real-time incoming data. After deployment our team watches the model output to verify that it maintains high quality performance. After putting the model into use track its performance and regular update it using new data sets to follow data changes. Regular up keeping helps our model stay accurate and ready for changing circumstances [21].

Flowchart of the Proposed Methodology

Here you will find a visual representation that shows our complete research process from data gathering to product use. This chart shows you every step clearly and the order they happen in.

RESULTS AND DISCUSSIONS

To solve data mining challenges, we combined deep learning tools with evolutionary algorithms in our experiments. Our new data mining system worked on three distinct kinds of data - time series information, photographs, and organized datasets. Our experiment shows that combining deep learning and evolutionary methods works better than typical deep learning models and simpler machine learning at both determining correct results and running faster. The model's performance was gauged with standard accuracy measures like how precise and clear it was, as well as how well it found topics and missed nothing. The model was trained by using two ways to optimize its parameters: GA and PSO algorithms to make it work better. The optimization techniques made the model better at predicting results, and especially worked well when other methods struggled with complex data measurements [20]. The graph in Figure 2 shows our hybrid model, which combines CNN and LSTM with evolutionary algorithms, beat traditional deep learning approaches (CNN and LSTM used separately) in predicting outcomes. Our hybrid model outperforms previous results by maintaining high accuracy for all datasets, with the most significant improvements coming from datasets that need to learn both how places change over time (space) and use those changes to predict the future (time).

Our model tested the accuracy of data by showing two important results in Figure 3. The new approach shows equal enhancement across both true predictions and fixed rates of false positives and false negatives. The analysis shows that our model can find actual positives correctly while keeping the number of false alarms under control. We also measured how quickly the new model performed calculations. We checked how quickly the hybrid model trains compared to normal deep learning, both in terms of time and when it reaches its final result. The table shows our approach reduced training time significantly while maintaining the same high performance level. The models worked well because the evolutionary algorithms helped fine-tune parameters much faster than normal tuning methods. The hybrid deep learning model worked better than regular models when processing actual dataset information, using network data to look for security threats and healthcare data to spot illnesses. Our tests show that this model works well across different real-world scenarios, providing both reliable and precise results.

Researchers found that their model became easier to understand through this work. We used attention mechanisms and feature importance analysis together to understand which inputs were most important in helping the model make accurate predictions. Figure 4 shows how we identified the most important model features through SHAP (Shapley Additive explanations) analysis. Our analysis shows which network attack characteristics are most





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important in helping the model make right decisions, so both accuracy and easy understanding are guaranteed. Our evaluation showed how the combined model achieved better results when we measured performance using both classic machine learning methods and deep learning models. The table below shows our deep learning model beating Random Forest and Support Vector Machines in accuracy and recovering more useful information. The evolutionary optimization methods helped make the model work better by adjusting both which features it uses and its main settings. Our analysis shows that using both deep learning and evolutionary algorithm approaches together has proven highly effective in conducting large and complex data mining tasks. Using GA and PSO optimization helped our model become more accurate for predictions while also training much faster, making it ready for quick use in real-time situations. Our method shows that combining powerful deep learning methods with evolutionary algorithms makes data mining run much faster and better. The experiments verify that our combination model works better than normal approaches in both predicting correctly and moving faster, while its clear information is invaluable for real-world usage where understanding matters. New studies could expand this technique to help other fields by analyzing trends in finance, understanding languages, and making systems decide things by themselves.

CONCLUSION

This research reveals deep learning technology demonstrates strong capabilities to advance data mining functionality. Deep learning models succeed better than regular data mining methods when using CNNs, RNNs, LSTMs, and auto encoders. Deep learning solutions with cloud platforms and big data systems offer potential answers to current dataset size and processing power needs. Deep learning applications in data mining will grow across different sectors to improve the strength of data mining systems. Scientists must devote future study efforts to improving deep learning methods for better explaining results and handling limited data so these techniques can serve more complex practical uses.

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Table 1: Computational Efficiency Comparison

Model Type	Training Time (hours)	Accuracy (%)	Epochs to Converge
Traditional CNN	15	89.7	50
Traditional LSTM	17	91.4	55
Hybrid CNN + LSTM + GA/PSO	10	95.3	40

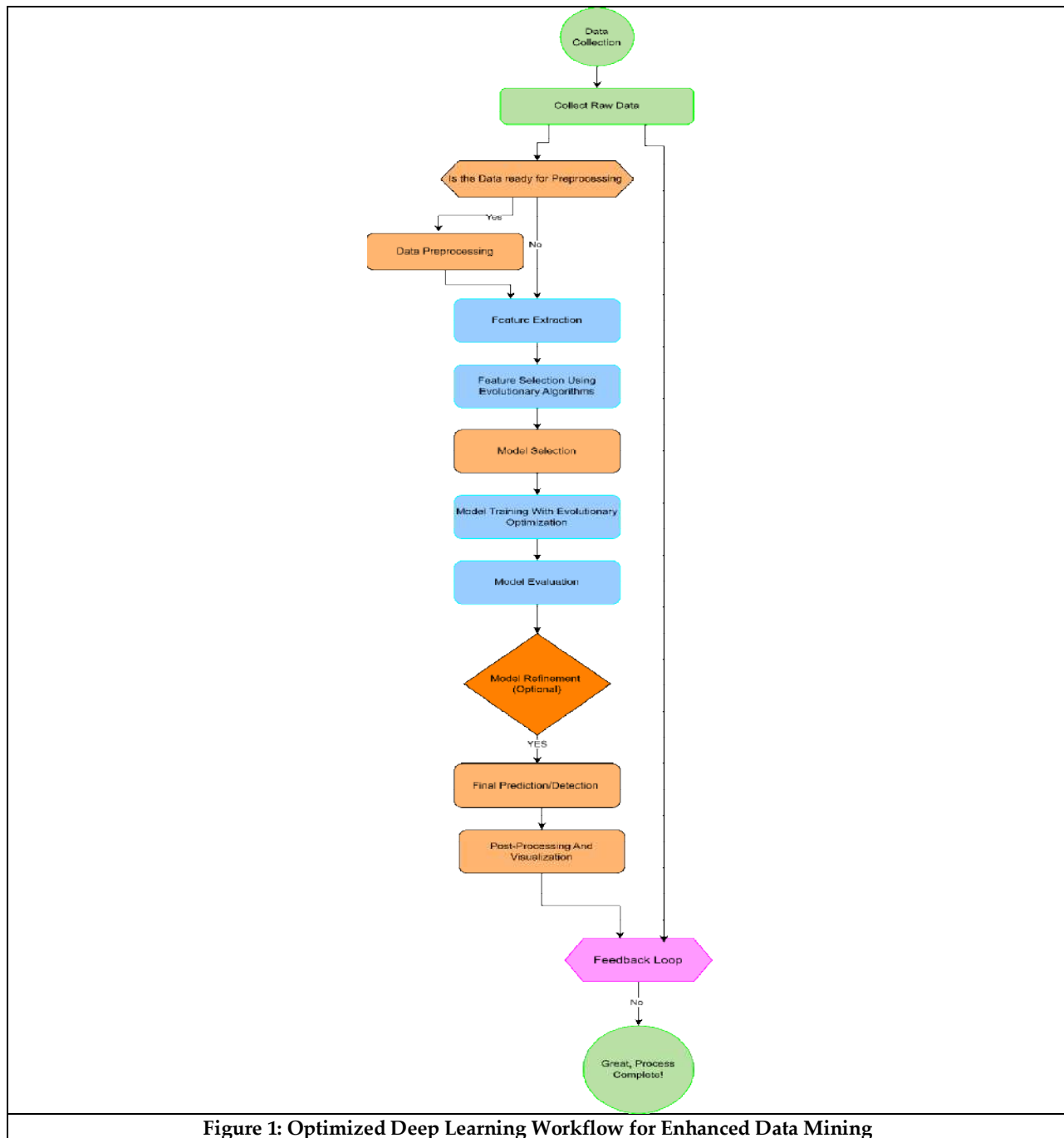




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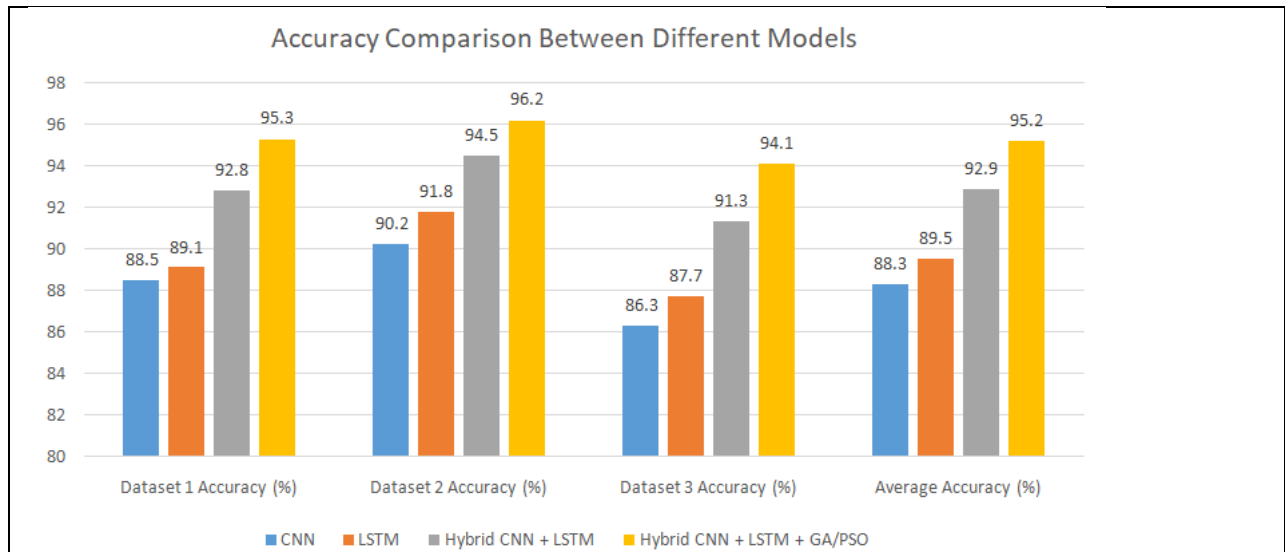
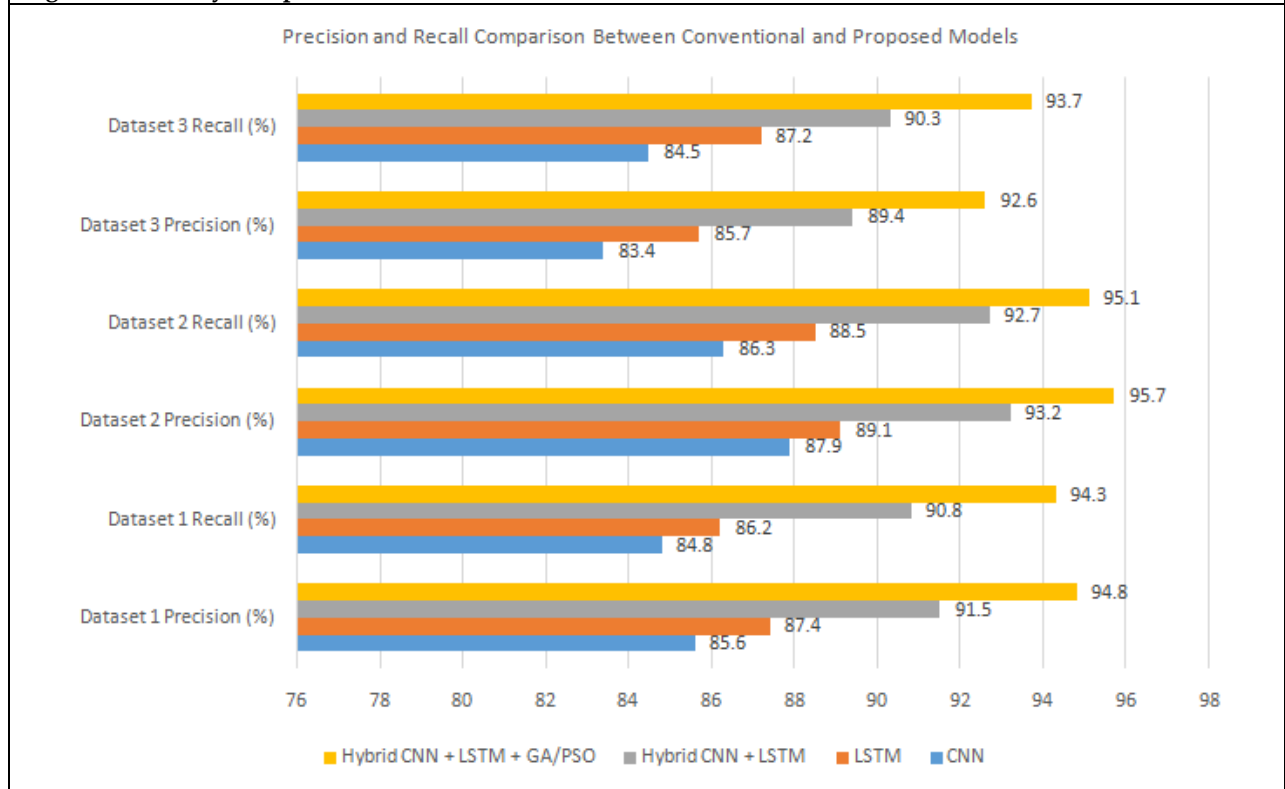
Table 2: Comparison of Accuracy between Traditional Machine Learning and Proposed Model

Model Type	Accuracy (%)	Precision (%)	Recall (%)	F1-Score (%)
Random Forest	85.2	83.5	86.0	84.7
Support Vector Machine (SVM)	87.5	85.3	88.1	86.7
Proposed Hybrid CNN + LSTM + GA/PSO	95.3	94.6	96.2	95.4

**Figure 1: Optimized Deep Learning Workflow for Enhanced Data Mining**

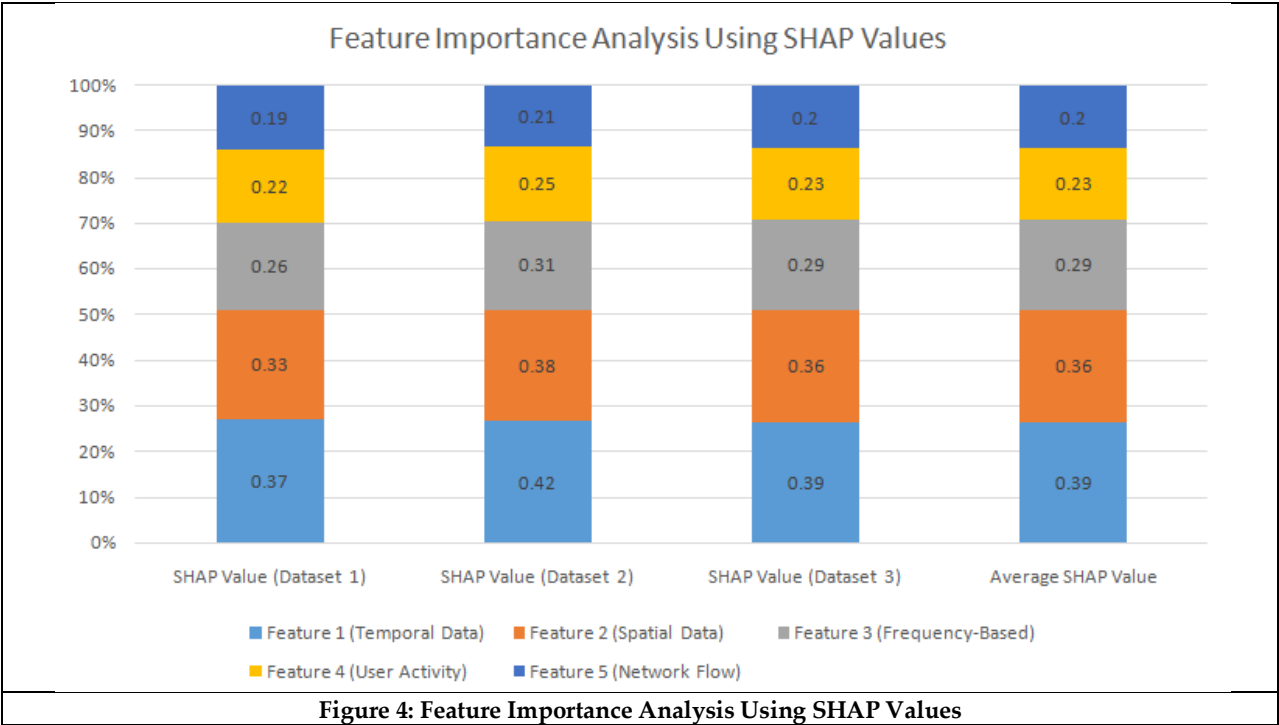


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**Figure 2: Accuracy Comparison Between Different Models****Figure 3: Precision and Recall Comparison Between Conventional and Proposed Models.**



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RESEARCH ARTICLE

On the Exponential Diophantine Equation $\varphi^r + 67^s = l^2$, where $\varphi \equiv 2 \pmod{201}$

R. Sarulatha^{1*} and G. Janaki²

¹Research Scholar, Department of Mathematics, Cauvery College for Women (Autonomous), Annamalai Nagar, (Affiliated to Bharathidasan University), Tiruchirappalli, Tamil Nadu, India.

²Associate Professor, Department of Mathematics, Cauvery College for Women (Autonomous), Annamalai Nagar, (Affiliated to Bharathidasan University), Tiruchirappalli, Tamil Nadu, India.

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*Address for Correspondence

R. Sarulatha

Research Scholar,
Department of Mathematics,
Cauvery College for Women (Autonomous),
Annamalai Nagar,
(Affiliated to Bharathidasan University),
Tiruchirappalli, Tamil Nadu, India.
E.Mail: saruchandran26@gmail.com



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ABSTRACT

This article affirms that (2,3,0,3) is the only single solution for the Diophantine equation $\varphi^r + 67^s = l^2$ wherein r, s, l are non-negative integers and φ is a positive integer with $\varphi \equiv 2 \pmod{201}$ and $\varphi + 1$ is a non-square number.

Keywords: Exponential Diophantine equation, Divisibility, Congruence, Integral solution, Catalan's Conjecture.

AMS Subject Classification: 11D61, 11D79

INTRODUCTION

The study of exponential Diophantine equations dates back centuries, with notable contributions from mathematicians such as Pierre de Fermat, Leonhard Euler, and Carl Friedrich Gauss. Exponential Diophantine equations have at least one unknown exponent variable. In [1], Mihailescu proved Catalan's conjecture, which had been posed by Catalan [2]. Following this breakthrough, numerous mathematicians delved into exploring the non-negative Solutions r, s, l of Diophantine equations of the form $\varphi^r + q^s = l^2$, leveraging the insights provided by the Catalan's conjecture. [3,4] exhibits the existence of integral solution for an exponential Diophantine equation involving special numbers like Krishnamurthy number and Mersenne prime. In [5], Tangjai and Chubthaisong showed that Diophantine equation $3^x + p^y = z^2$ has a unique non-negative solution $(p, x, y, z) = (2, 0, 3, 3)$, when p is





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prime such that $p \equiv 2 \pmod{3}$ and y is not divisible by 4. Later Viriyapong [6,7], found all non-negative solutions of the Diophantine equation $n^x + 13^y = z^2$ when $n \equiv 2 \pmod{39}$, $n + 1$ is not a perfect square and $n^x + 19^y = z^2$, when n is a positive integer with $n \equiv 2 \pmod{57}$. In this article, Diophantine equation of the form $\varphi^r + 67^s = l^2$ is analysed for its non-negative solutions with $\varphi \equiv 2 \pmod{201}$ and $\varphi + 1$ is a non-square number.

PRELIMINARIES

This section enunciates essential concepts of divisibility and congruence that are advantageous for the main work. Here W_b refer to whole numbers strictly less than b .

Definition 2.1 [6] An integer w is divisible by an integer q , not zero, if there is an integer c such that $w = qc$, and we write $q|w$. In case w is not divisible by q , we write $q \nmid w$.

Definition 2.2 [6] If an integer x , not zero, divides the difference $q - w$, we say that q is congruent to w modulo x and write $q \equiv w \pmod{x}$. If $q - w$ is not divisible by x , we say that q is not congruent to w modulo x , and in this case, we write $q \not\equiv w \pmod{x}$.

Theorem 2.1 [6] Let q, w, u, v denote integers. Then,

1. $q \equiv w \pmod{x}$ and $w \equiv q \pmod{x}$, and $q - w \equiv 0 \pmod{x}$ are equivalent statements.
2. If $q \equiv w \pmod{x}$ and $w \equiv u \pmod{x}$, then $q \equiv u \pmod{x}$.
3. If $q \equiv w \pmod{x}$ and $u \equiv v \pmod{x}$, then $q + u \equiv w + v \pmod{x}$.
4. If $q \equiv w \pmod{x}$ and $u \equiv v \pmod{x}$, then $qu \equiv wv \pmod{x}$.
5. If $q \equiv w \pmod{x}$ and $v|x, v > 0$, then $q \equiv w \pmod{v}$.
6. If $q \equiv w \pmod{x}$ then $qu \equiv wu \pmod{xu}$ for $u > 0$.

Theorem 2.2 [Mihăilescu's Theorem] The Diophantine equation $q^r - w^s = 1$ has unique solution $(q, w, r, s) = (3, 2, 2, 3)$, where, q, w, r, s are integers with $\min\{q, w, r, s\} > 1$.

Lemma 2.1 If φ is a positive integer and satisfies the condition $\varphi \equiv 2 \pmod{201}$ then it follows that $\varphi \equiv 2 \pmod{3}$ and $\varphi \equiv 2 \pmod{67}$.

Lemma 2.2 The equation $1 + 67^s = l^2$ has no non-negative solution in integers where s, l are non-negative integers.

Proof: Let s, l be non-negative integers such that

$$1 + 67^s = l^2 \quad (1)$$

If $s = 0$ then $l^2 = 2$ which is impossible. For $s = 1$, $l^2 = 68$ which cannot be achieved. Suppose $s > 1$, $1 + 67^s = l^2 > 68$ and it is seen that $l > 8$. Then by Theorem 2.2 the Diophantine equation (1) has no non-negative integer solution.

Lemma 2.3 Let φ be a positive integer such that $\varphi + 1$ is not a square number. Then the Diophantine equation $\varphi^r + 1 = l^2$ has unique solution $(\varphi, r, l) = (2, 3, 3)$, where r, l are non-negative integers.

Proof: Let r, l be non-negative integers such that

$$\varphi^r + 1 = l^2 \quad (2)$$

If $\varphi = 1$ then $l^2 = 2$ which is not valid. If $\varphi > 1$ then r takes the following three cases

Case 1: If $r = 0$ then $l^2 = 2$. It is impossible.

Case 2: If $r = 1$ then $l^2 = \varphi + 1$. Which is a contradiction to our hypothesis.

Case 3: If $r > 1$ then $l^2 = \varphi^r + 1 > 2$ consequently $l > 1$. Now by Theorem 2.2 $(\varphi, r, l) = (2, 3, 3)$ is the only solution of (2).

Lemma 2.4 For all positive odd integer r ,

$$2^r \equiv 2, 3, 5, 7, 8, 11, 12, 13, 18, 20, 27, 28, 30, 31, 32, 34, 38, 41, 42, 43, 44, 45, 46, 48, 50, 51, 52, 53, 54, 57, 58, 61, 63, 66 \pmod{67}.$$





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Proof: This result will be proven by employing the principle of induction

$$2^{2i-1} \equiv 2, 3, 5, 7, 8, 11, 12, 13, 18, 20, 27, 28, 30, 31, 32, 34, 38, 41, 42, 43, 44, 45, 46, 48, 50, 51, 52, 53, 54, 57, 58, 61, 63, 66 \pmod{67}.$$

For all $i \in \mathbb{N}$. If $i = 1$, then $2^1 \equiv 2 \pmod{67}$. Thus, the statement is true for $i = 1$. Assume that the statement is true for $i = n$ then,

$$2^{2n-1} \equiv 2, 3, 5, 7, 8, 11, 12, 13, 18, 20, 27, 28, 30, 31, 32, 34, 38, 41, 42, 43, 44, 45, 46, 48, 50, 51, 52, 53, 54, 57, 58, 61, 63, 66 \pmod{67}.$$

Thus,

$$2^{2n+1} \equiv 2, 3, 5, 7, 8, 11, 12, 13, 18, 20, 27, 28, 30, 31, 32, 34, 38, 41, 42, 43, 44, 45, 46, 48, 50, 51, 52, 53, 54, 57, 58, 61, 63, 66 \pmod{67}.$$

Hence, the statement is true for $i = n + 1$.

Lemma 2.5 For any integer l , $l^2 \equiv 0, 1 \pmod{3}$.

Proof: Let l be an integer. Then $l \equiv a \pmod{3}$ for some $a \in W_3$. Here

Case 1: $l \equiv 0 \pmod{3}$ then $l^2 \equiv 0 \pmod{3}$

Case 2: $l \equiv 1 \pmod{3}$ then $l^2 \equiv 1 \pmod{3}$

Case 3: $l \equiv 2 \pmod{3}$ then $l^2 \equiv 4 \pmod{3}$ and so, $l^2 \equiv 1 \pmod{3}$.

Thus $l^2 \equiv 0, 1 \pmod{3}$.

Lemma 2.6 For any integer l ,

$$l^2 \equiv 0, 1, 4, 9, 16, 25, 36, 49, 64, 14, 33, 54, 10, 35, 62, 24, 55, 21, 56, 26, 65, 39, 15, 60, 40, 22, 6, 59, 47, 37, 29, 23, 19, 17 \pmod{67}.$$

Proof: Let l be an integer. Then $l \equiv a \pmod{67}$ for some $a \in W_{67}$. Thus,

$$l^2 \equiv 0, 1, 4, 9, 16, 25, 36, 49, 64, 14, 33, 54, 10, 35, 62, 24, 55, 21, 56, 26, 65, 39, 15, 60, 40, 22, 6, 59, 47, 37, 29, 23, 19, 17 \pmod{67}.$$

MAIN RESULTS

Theorem 3.1 Let φ be a positive integer such that $\varphi \equiv 2 \pmod{201}$ and $\varphi + 1$ is non square number. Then the non-linear Exponential Diophantine equation $\varphi^r + 67^s = l^2$ has a unique solution $(\varphi, r, s, l) = (2, 3, 0, 3)$, where r, s, l are non-negative integers.

Proof: Let r, s, l be non-negative integers and φ be positive integer such that $\varphi^r + 67^s = l^2$ with $\varphi \equiv 2 \pmod{201}$ and $\varphi + 1$ is non square number. If $s = 0$, then by Lemma 2.3 $(\varphi, r, s, l) = (2, 3, 0, 3)$ is a solution of the exponential Diophantine equation.

Now, assume that $s \geq 1$. Since $r \geq 1$ by lemma 2.2. Consider the following two cases:

Case 1: r is even. Since $\varphi \equiv 2 \pmod{3}$, $\varphi^r \equiv 1 \pmod{3}$. Also, $67^s \equiv 1 \pmod{3}$, $l^2 \equiv 2 \pmod{3}$ which is a contradiction.

Case 2: r is odd. Since $\varphi \equiv 2 \pmod{3}$ by Lemma 2.4

$$\varphi^r \equiv 2, 3, 5, 7, 8, 11, 12, 13, 18, 20, 27, 28, 30, 31, 32, 34, 38, 41, 42, 43, 44, 45, 46, 48, 50, 51, 52, 53, 54, 57, 58, 61, 63, 66 \pmod{67}.$$

And $67^s \equiv 0 \pmod{67}$

$$l^2 \equiv 2, 3, 5, 7, 8, 11, 12, 13, 18, 20, 27, 28, 30, 31, 32, 34, 38, 41, 42, 43, 44, 45, 46, 48, 50, 51, 52, 53, 54, 57, 58, 61, 63, 66 \pmod{67}.$$

Which contradicts lemma 2.6. Therefore $(2, 3, 0, 3)$ is the only solution of the non-linear exponential Diophantine equation $\varphi^r + 67^s = l^2$ where $\varphi \equiv 2 \pmod{201}$, $\varphi + 1$ is non square number and r, s, l are non-negative integers.

Corollary 3.1 The Diophantine equation $203^r + 67^s = l^2$ does not have a non-negative integer solution, where r, s, l are non-negative integers.

Proof: In consideration of the hypothesis that $203 \equiv 2 \pmod{201}$ and $203 + 1 = 204$ is not a square number. According to Theorem 3.1 it is deduced that the Diophantine equation $203^r + 67^s = l^2$ admits no non-negative integer solutions.

Corollary 3.2 The Diophantine equation $605^r + 67^s = l^2$ does not have a non-negative integer solution, where r, s, l are non-negative integers.





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Proof: Since $605 \equiv 2 \pmod{201}$ and $605 + 1 = 606$ is not a square number. By Theorem 3.1 there are no valid sets of non-negative integer value for r, s, l that satisfy the Diophantine equation $605^r + 67^s = l^2$.

CONCLUSION

In the context of this article, the Diophantine equation $\varphi^r + 67^s = l^2$ possessing a unique non-negative solution, specifically $(\varphi, r, s, l) = (2, 3, 0, 3)$ is demonstrated. Notably, this solution holds true when $\varphi \equiv 2 \pmod{201}$ and $\varphi + 1$ is a non-square number. Furthermore, this result extends when φ is either a prime or a composite number which is evident from Corollaries.

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RESEARCH ARTICLE

A Homeopathic Potency Transfers its Water Structure to Aqueous Ethanol through Electromagnetic Radiation as Revealed by Electronic and Vibrational Spectroscopy

Raj Kumar Singh¹, Nirmal Chandra Sukul^{2*}, Nivedita Pande³ and Anirban Sukul⁴

¹Assistant Professor, Department of Botany, Government General Degree College, Mangalkote, Panchanantala, Khudrun Dighi, Purba Burdwan, (Affiliated to University of Burdwan, Bardhaman), West Bengal India.

²Professor (Retd.) Department of Zoology, Visva-Bharati University, (A Central University) and President, Sukul Institute of Homeopathic Research, Santiniketan, Kolkata, West Bengal, India.

³State Aided College Teacher, Department of Geography, Panihati Mahavidyalaya, Sodepur, (Affiliated to West Bengal State University), Kolkata, India.

⁴Director, Department of Sukul Institute of Homeopathic Research, Shyambati, Santiniketan, Birbhum, West Bengal, India.

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*Address for Correspondence

Nirmal Chandra Sukul^{2*},

Professor (Retd.)

Department of Zoology,

Visva-Bharati University, (A Central University) and President,

Sukul Institute of Homeopathic Research, Santiniketan,

Kolkata, West Bengal, India.

E.Mail: ncsukul@gmail.com



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ABSTRACT

A homeopathic potency kept in contact with aqueous ethanol through water can transform the aqueous ethanol into that potency. Can a potency produce the same effect on aqueous ethanol without direct physical contact? The present experimental study addresses this question. We also explored the possible ways by which a potency could transfer its optical properties vis-à-vis water structures to aqueous EtOH. Two potencies 30 cH and 200 cH of *Thuja occidentalis* in 90% EtOH were diluted with deionized and distilled (DD) water 1:100, and kept separately in two coloured 30 ml bottles. A test tube containing 90% EtOH diluted with DD water 1:100, was dipped into each of two bottles. After one hour exposure each test tube was taken out and its content aqueous ethanol was analysed by UV and FT-IR spectroscopy. In order to determine the possible ways of transference of optical properties of a potency to aqueous EtOH we shielded external UV and Infra-red radiation, and also radio waves. The bottle with the test tube was kept in an aluminium container painted with silicon dioxide. Spectroscopic characteristics of aqueous EtOH in each test tube after one hour exposure to a potency exactly matched those of *Thuja* 30 c H and



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Thuja 200 c H. but with higher absorption intensity. Shielding had no effect on the results. Intrinsic infra-red radiation passing from a potency may carry the information of the potency and transfer it to aqueous ethanol in the test tube. *Thuja* 30 c H and *Thuja* 200 c H can transform water structure of aqueous ethanol into the said potencies without direct physical contact. The transfer of optical properties from the potency to aqueous EtOH is accomplished by intrinsic infra-red radiation from the potency.

Keywords: Homeopathic potencies, *Thuja* 30 c H., *Thuja* 200 c H., Water structure, Aqueous ethanol, Intrinsic infra-red radiation.

INTRODUCTION

In traditional medicine *Thuja occidentalis* L. (Cupressaceae) has been used for liver diseases, bronchitis, psoriasis, enuresis, stoppage of menses, cystitis, uterine carcinomas, diarrhea, and rheumatism [1]. It is also used in homeopathy at ultra high dilution for skin diseases, tumours, rheumatism, gastric ulcer and disorders of kidney and brain [2]. Homeopathic potencies are prepared by serial dilution (1:100) of a mother tincture followed by mechanical agitation or succussion. The dilution of the 12th potency is 10²⁴. This potency is devoid of original drug molecules of the mother tincture because it has crossed the Avogadro limit. So, the 12th potency and all higher potencies cannot be differentiated from their solvent medium (aqueous ethanol) by ordinary chemical tests. But the differentiation is possible by spectroscopic analysis [3-9]. Using spectroscopic technique, we have demonstrated that a homeopathic potency is activated specifically structured water [7-11]. A homeopathic potency can transfer its water structure to aqueous ethanol through direct connection with the latter (aqueous EtOH) [3,7]. Can a homeopathic potency transfer its water structures to aqueous ethanol without direct physical connection by water? The present experimental study addresses this question. In this study a potency was kept in a brown 30 ml glass bottle. A test tube containing aqueous EtOH was immersed into the potency and kept there for one hour. After one-hour aqueous EtOH has been found to acquire the water structures vis-à-vis the optical properties of the potency. Here the only possible connection between the potency and aqueous EtOH is electromagnetic radiation (EMR) which may be internal or external. In order to confirm whether the external EMR is responsible we have designed an experiment. The whole assembly (the brown 30 ml glass bottle and test tube) was kept in a cylindrical aluminium container painted with silicon dioxide. While silicon dioxide shields UV and infra-red radiation, aluminium would shield radio waves. However, the shielding did not influence the results thereby confirming that internal EMR is the main factor.

MATERIALS AND METHODS

Two homeopathic potencies 30 cH and 200 cH of *Thuja occidentalis* were purchased from local market. They were products of Dr. Reckeweg, Germany (lot number 6412IN42726D for *Thuja occidentalis* 30 and lot number 6417IN42522D for *Thuja occidentalis* 200). The potencies were in 90% EtOH as tested from a standard curve prepared from different percentages of ethanol. They were diluted with deionised and distilled (DD) water 1:100. Absolute ethanol purchased from HIMEDIA (MB228-500ML, Lot number 0000498722) was diluted with DD water 1:100 in the same proportion. After dilution ethanol content in the potencies and ethanol control becomes 0.09%. So, they are virtually water. The diluted potencies were kept separately into two brown coloured 30 ml glass bottles. A test tube (Borosil 12X100 7ml) containing diluted EtOH was dipped in each diluted potency in the bottle. The amount of each diluted potency was 10 ml in a bottle. Each test tube contained 1 ml of diluted EtOH. All the samples were analysed by UV and FT-IR spectroscopy. The temperature and humidity were maintained at 27°C ± 1 and less than 50%, respectively. The same experiments were repeated by keeping the test samples (test tube inside bottle) in a closed aluminium cylinder painted with silicon dioxide. While silicon dioxide shields outer UV and infra-red radiation, aluminium shields other electromagnetic radiation (EMR). This is to pinpoint the exact cause of transfer of optical properties from the potency in the bottle to EtOH solution in the test tube.



Raj Kumar Singh *et al.*,**UV spectra**

UV spectra of the test samples were measured before and after 1 hour of exposure of aqueous ethanol to a potency. Spectra were taken in the wavelength region 200 nm to 300 nm, scan speed medium and data interval 0.5 nm. The baseline was set with diluted ethanol (0.09%). A UV spectrometer UV-VIS spectrophotometer (Shimadzu, UV-VIS 1900i, Software Lab Solutions UV-VIS). A pair of quartz cuvettes, capacity 1 ml, was used. At first both the cuvettes were filled with diluted ethanol, and baseline was set. Then one cuvette was taken out, emptied, filled with a sample, and the spectrum was taken. The spectrum shows the difference from the diluted ethanol used for the baseline. After taking the spectrum the sample cuvette was washed with DD water six times, allowed to dry up at room temperature and then filled with the second sample. This is the most important precaution because homeopathic potencies cannot be washed out by DD water. Water droplets sticking to the inner wall of the cuvette carries the water structure of the first sample used. UV spectra of drugs only and EtOH control were also taken in the same wavelength range. The spectra of the samples used in the 2nd experiment with aluminium cylinder were also taken. Each experiment was repeated 5 times, and the mean and S.E were calculated. We selected 13 points in different wave lengths of all the spectra. The absorbance intensities at each point were calculated in the following way: potency exposed EtOH vs unexposed EtOH. The difference between the potency-exposed diluted EtOH solutions and the unexposed control was statistically analysed by Student t-test.

FT-IR spectra

A Shimadzu IR Affinity -1S Fourier Transform Infrared (FT-IR) spectrophotometer (Spectrum two) with the attenuated total reflection (ATR) technique was used to measure FT-IR spectra. The energy resolution was 0.5 cm⁻¹. The baseline was corrected for atmospheric humidity and CO₂. One drop of each sample was put into the sample groove, and then the tip of a single reflection pure diamond crystal was brought in contact with the sample drop. The entire spectrum was recorded in the wave number range of 4000 to 500 cm⁻¹. Each spectrum represents an average of 45 scans. The same experiment was repeated with aluminium cylinder. Each experiment was replicated 5 times. The temperature and humidity were maintained in the laboratory at 27°C ± 1 and less than 50%, respectively. Measurements for both the experiments were taken. The data were analysed by Student t-test, using 13 points of wave numbers in each spectrum. The comparison was made as follows: potency exposed EtOH vs unexposed EtOH and potency exposed EtOH vs *Thuja*30 and *Thuja* 200 for both OH-stretching and OH-bending bands.

RESULTS**UV spectra**

While *Thuja* 30 shows two peaks one at 200 nm and another at 220 nm *Thuja* 200 shows only one peak at 200 nm (Fig. 1,2). The diluted ethanol exposed to *Thuja* 30 and *Thuja* 200 for one hour shows exactly similar spectra like *Thuja*30 and *Thuja* 200 but with much higher absorption intensity (Fig. 1, 2). The results of the second experiment using closed aluminium cylinders were also similar proving that external EMR did not influence the results. The difference between the potency-exposed EtOH solutions and *Thuja* potency was not significant by Student t-test ($t=0.001$ for *Thuja*30, $t=0.176$ for *Thuja*200). This means they are close to each other. The unexposed EtOH spectra merge with the baseline. So, it was not compared with the potency exposed EtOH.

FT-IR spectra

Absorbance intensities were normalized. The difference in absorbance intensities of *Thuja* 30 cH between the potency-exposed EtOH solutions and the unexposed one was significant by Student t-test ($t=0.05$) for the OH-stretching band (Fig. 3). The same is true for OH bending band (Fig. 4). The results of *Thuja* 200 are presented in figure 5. The difference in absorbance intensities between the potency-exposed (*Thuja* 200) EtOH solutions and the unexposed one for both the OH-stretching and OH bending bands were calculated by Student t-test. For OH-stretching band EtOH exposed vs unexposed the t value is 5.708 (Highly significant). For EtOH exposed vs *Thuja*30 $t=0.128$ (not significant). This means EtOH is close to *Thuja*30. For OH-bending bands EtOH exposed vs unexposed $t=1.175$ (not significant). For EtOH exposed vs *Thuja*30 $t=0.328$ (not significant). Although both are not significant the t



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value for EtOH exposed vs *Thuja*30 is lower than that of EtOH exposed vs unexposed. So, EtOH exposed is close to *Thuja*30(Fig. 5, 6).

DISCUSSION

In the UV spectra it is observed that *Thuja*30 in the bottle and aqueous EtOH in the test tube show two peaks one at 200 nm and another at 220 nm. But aqueous EtOH shows significantly higher intensity (Fig.1) than *Thuja*30 in bottle. Since aqueous EtOH is the baseline the aqueous EtOH in the test tube should have merged with the baseline, but instead it has acquired the optical properties of *Thuja*30 thereby confirming the influence of indirect contact of aqueous EtOH with *Thuja*30 (Fig.1). Similar results were obtained with *Thuja*200 in the bottle and aqueous EtOH in the test tube. In this case only one peak at 200 nm is observed. Here also the aqueous EtOH shows significantly higher intensity than that of the potency (Fig. 2). The results further confirmed the influence of indirect contact of aqueous EtOH with *Thuja* 200. In case of the FT-IR spectra the OH-stretching band of *Thuja* 30 in the bottle and aqueous EtOH in the test tube are very close to each other with respect to their normalized absorbance intensity. But the unexposed aqueous EtOH shows significantly higher absorbance intensity than the exposed ones (Fig. 3). Similar results were obtained with OH-bending band (Fig. 4). Actually, the FT-IR spectra of exposed aqueous EtOH should have merged with unexposed aqueous EtOH if there was no influence of exposure of aqueous EtOH to *Thuja* 30. Similar results have been obtained with *Thuja* 200 for both OH-stretching and bending bands. So, both UV and FT-IR spectra confirmed that the *Thuja* potencies can transfer their optical properties vis-à-vis water structures to aqueous EtOH without direct physical contact. We have already mentioned that silicon dioxide shields UV and infra-red radiation. The aluminium container shields the radio waves. But the results obtained with the painted aluminium container experiments are not different from the experiment done without the container. It is evident from the results that the external EMR is not responsible for the results obtained with UV and FT-IR spectra. So, internal EMR, particularly the infra-red radiation is the only possible factor. The *Thuja* potencies themselves do not generate infra-red radiation. Since both the *Thuja* potencies and EtOH solution have been kept at room temperature they have absorbed heat available in the room. The amount (10 ml) of *Thuja* potency in the bottle is much higher than the amount (1 ml) of EtOH in the test tube. Heat flow goes from the potencies to aqueous EtOH thereby transferring the optical properties of the potencies to aqueous EtOH. Structured water constitutes the 4th phase of water besides solid, liquid and vapour. Infra-red energy (IR) is absorbed from environment by water which can then transform bulk water into structured water. The absorbed infra-red energy from the potency passes through ordinary water in the test tube and can convert the test tube water into structured water. The 4th phase water excludes solutes dissolved in the solvent thereby producing exclusion zones (EZ) [12]. The converted structured water may have EZ similar to the EZ of the potency in the bottle [12]. Pollack (2013) mentioned that input of additional energy can produce additional exclusion zones. We know that homeopathic potencies are produced by mechanical agitation or succussion. The succussion energy can produce additional EZs. In our opinion different potentized drugs may have different types of EZs. Different potencies of a drug may have different number of EZs. Using neutron diffraction technique Dixit *et al.* (2002) observed that EtOH-water solution contains water molecules as aggregates of hydrogen bonded strings and clusters. It may be that these aggregates of water molecules constitute the EZs. Liquid water under ordinary temperature and pressure is crystalline and quantum coherent. Under an electromagnetic field water molecules resonate to common frequencies [14]. It may be that in this way water molecules of the potency in a bottle can transfer their common frequencies to aqueous EtOH in the test tube thereby converting the latter into that potency. In the living cells water molecules have ordered structure which is thought to be due to the endogenous electromagnetic fields produced by organelles like mitochondria, nucleic acid etc [15]. So, electromagnetic fields play an important role in biological system. Besides succussion ultrasonication can also produce highly effective homeopathic potencies [16]. Ultrasonication of aqueous EtOH increases thermal motions of water molecules and density of the solution [17]. So, homeopathic potencies are expected to have higher density than their non potentized medium. This increased density may be due to the increase in aggregates of water molecules or EZs in the potencies.



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CONCLUSION

Thuja 30 c H and *Thuja* 200 c H can transform water structure of aqueous ethanol into the said potencies without direct physical contact. The transfer of optical properties from the potency to aqueous EtOH is accomplished by intrinsic infra-red radiation from the potency.

CONFLICTS OF INTEREST

None.

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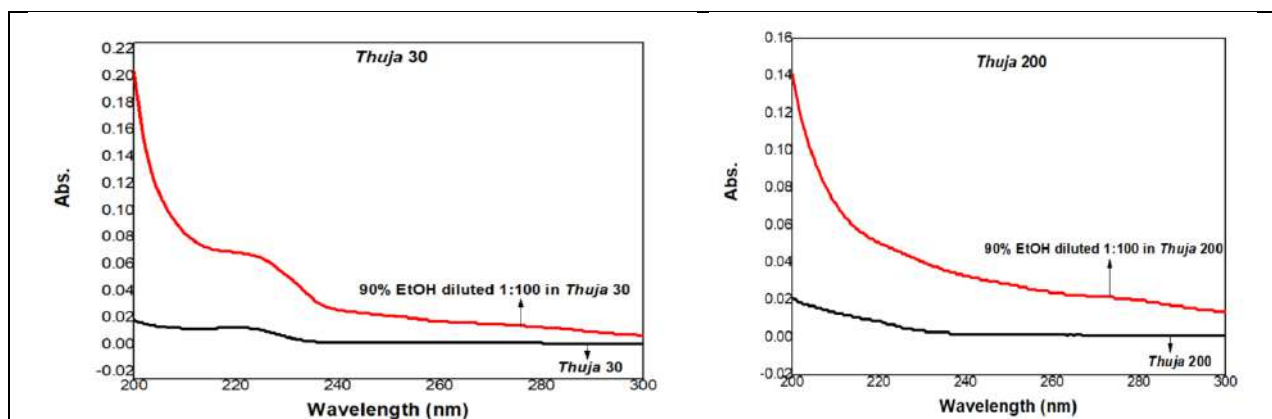


Figure 1: UV spectra of *Thuja 30* in 0.09% EtOH and 0.09% EtOH in a test tube dipped into *Thuja 30*. Baseline with 0.09% EtOH. Both spectra show two peaks.

Figure 2: UV spectra of *Thuja 200* in 0.09% EtOH and 0.09% EtOH in a test tube dipped into *Thuja 200*. Baseline with 0.09% EtOH. Both spectra show only one peak.

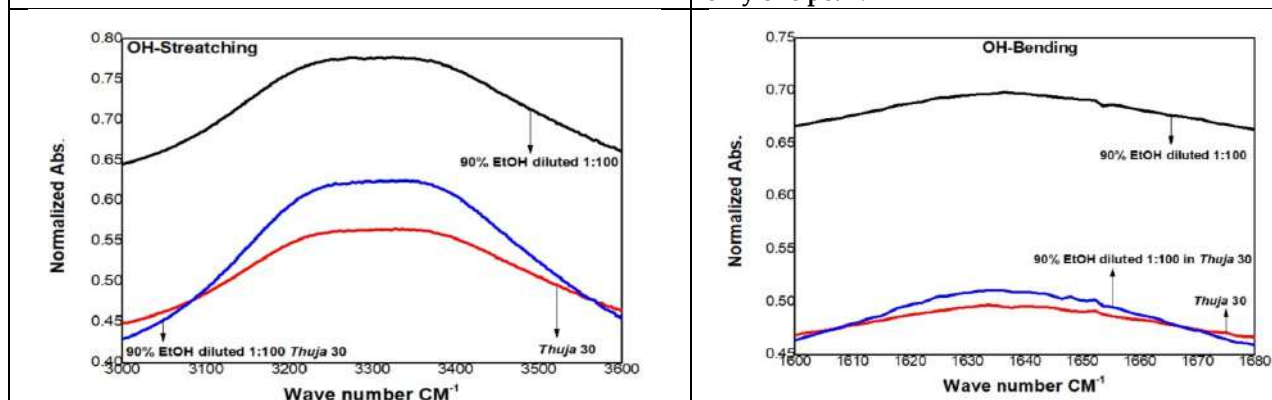


Figure 3: Normalized FT-IR spectra of OH-Stretching band of *Thuja 30* in 0.09% EtOH, 0.09% EtOH in a test tube dipped into *Thuja 30* and 0.09% EtOH. EtOH exposed to *Thuja 30* is closer to *Thuja 30* than to unexposed EtOH.

Figure 4: Normalized FT-IR spectra of OH-bending band of *Thuja 30* in 0.09% EtOH, 0.09% EtOH in a test tube dipped into *Thuja 30* and 0.09% EtOH. EtOH exposed to *Thuja 30* is closer to *Thuja 30* than to unexposed EtOH.



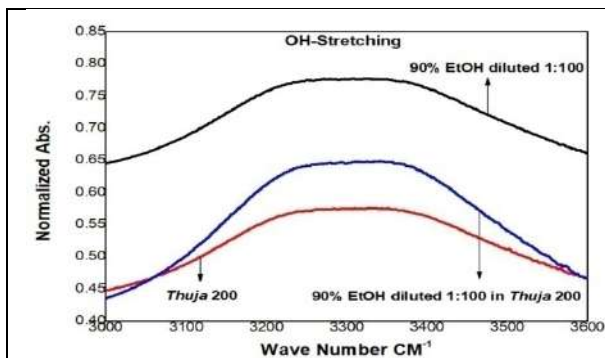
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Figure 5: Normalized FT-IR spectra of OH-Stretching band of *Thuja 200* in 0.09% EtOH, 0.09% EtOH in a test tube dipped into *Thuja 200* and 0.09% EtOH. EtOH exposed to *Thuja 200* is closer to *Thuja 200* than to unexposed EtOH.

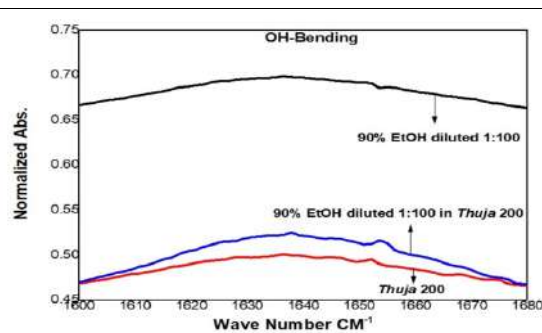


Figure 6: Normalized FT-IR spectra of OH-bending band of *Thuja 200* in 0.09% EtOH, 0.09% EtOH in a test tube dipped into *Thuja 200* and 0.09% EtOH. EtOH exposed to *Thuja 200* is closer to *Thuja 200* than to unexposed EtOH.





RESEARCH ARTICLE

Efficacy of Bio Organic Amendments on Growth and Vigour of Stem Cuttings in Yellow Bhringaraj (*Wedelia calendulacea less*)

J. Preethi Fetricia^{1*}, T.R. Barathkumar², K.Haripriya³ and N. Senthil Kumar⁴

¹Ph.D Research Scholar, Department of Horticulture, Faculty of Agriculture, Annamalai University, Annamalai Nagar, Tamil Nadu, India.

²Assistant Professor, Department of Horticulture, Faculty of Agriculture, Annamalai University, Annamalai Nagar, Tamil Nadu, India.

³Professor, Department of Horticulture, Faculty of Agriculture, Annamalai University, Annamalai Nagar, Tamil Nadu, India.

⁴Professor, Department of Genetics and Plant breeding, Faculty of Agriculture, Annamalai University, Annamalai Nagar, Tamil Nadu, India.

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*Address for Correspondence

J. Preethi Fetricia

Ph.D Research Scholar,
Department of Horticulture,
Faculty of Agriculture,
Annamalai University,
Annamalai Nagar, Tamil Nadu, India.
E.Mail: preethifetricia5@gmail.com



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ABSTRACT

Yellow bhringaraj (*Wedelia calendulaceae* Less) is an important medicinal herb belonging to Asteraceae family which is used in the treatment of liver diseases and wound healing. An investigation entitled “efficacy of bio-organic amendments on growth and vigour of stem cutting in yellow bhringaraj(*Wedelia calendulaceae* Less)” was conducted in Completely randomized block design (CRD) with twelve treatments and three replications in the Department of Horticulture, Faculty of Agriculture, Annamalai University in Tamil Nadu, India during 2023- 2024. The treatment consists of FYM, Coir compost, Neem cake, Biofertilizer inoculants, Sand and Soil in combinations. The treatment detail includes T₁ - FYM : Sand : Soil (1:1:1); T₂ - Coir compost: Sand: Soil (1:1:1); T₃ -Neem cake: Sand: Soil (1:1:1); T₄ -Biofertilizer inoculants: Sand: Soil (1:1:1); T₅ -(FYM + Coir compost): Sand: Soil (1:1:1) ; T₆ -(FYM + Neem cake): Sand: Soil (1:1:1); T₇ -(FYM + Biofertilizer inoculants): Sand: Soil (1:1:1); T₈ -(Coir compost + Neem cake): Sand: Soil (1:1:1); T₉ -(Coir compost + Biofertilizer inoculants): Sand: Soil (1:1:1); T₁₀ -(Neem cake + Biofertilizer inoculants): Sand: Soil (1:1:1); T₁₁ -(FYM + Coir compost + Neem cake + Biofertilizer inoculants): Sand: Soil (1:1:1); T₁₂ - Control (Soil). The result revealed that, among the various treatments, the treatment T₁₁- FYM + Coir compost + Neem cake + Biofertilizer inoculants): Sand: Soil (1:1:1) showed minimum days for



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sprouting(7.24 days), maximum sprouting percentage(91.55 %), number of leaves (16.96 nos), leaf length (4.543 cm), leaf width (2.373 cm), leaf area (8.466 cm²), shoot length (19.65 cm), shoot fresh weight (7.253 mg) and shoot dry weight (1.055 mg), root length (12.33 cm), root fresh weight (4.056 mg), root dry weight (0.436 mg), dry matter production (1.496 mg) vigour index (2928.12) and survival percentage (84.71%)than T₁₂ - control. Hence, it could be concluded that the treatment T₁₁ - (FYM + Coir compost + Neem cake + Biofertilizer inoculants): Sand: Soil (1:1:1) noticed better growth and vigour of stem cuttings in yellow bhringaraj.

Keywords: Bhringaraj, liver, bio-organic amendment, sapling growth and vigour.

INTRODUCTION

Medicinal plants continue to possess immense potential for the development of new therapeutic compounds and have been for decades they are the integral component of conventional healthcare systems. Among these, Asteraceae family members have attracted interest because of their extensive distribution, varied phytochemical profiles, and wide range of medicinal activity. Yellow bhringaraj (*Wedelia calendulaceae* Less) is one of the renowned medicinal herb of Asteraceae family with bright yellow colour ray and disc florets [6]. Yellow bhringaraj (*Wedelia calendulaceae* Less, Syn. *Wedelia chinensis* Merrill, *Solidago chinensis*) known as manjalkarisalankanni in tamil, Pitabhrnga, Pitabhrngarajah in Sanskrit,manjakanjunni, Kadal-kayyonni in Malayalam, Pitabhrang, Pilabhangra, Bhangra, Bhanra in Hindi and Gargari in Kannad. The plant is a procumbent herb with branches spreading upto 50 cm long. The herb possess coumestans compounds (wedelolactone and demethylwedelolactone) known for its potent anti hepatotoxic effect. Dermatological ailments such as cough, headaches, hair loss, lice, nervous system strengthening, blood shortage, and digestive disorders might all be alleviated by the leaves of the plant. The leaves helps to boost hair growth and colour the grey hair. They are regarded as alternative and tonic, and they help with alopecia, skin conditions, coughs, and cephalalgia. The leaf juice is often employed as a snuff for headaches.(Meen *et al.*, 2011) Owing to the extensive use of the herb in pharmacological preparation, the crop faces a habitat destruction making the herb unavailable. To commercialize the crop production, the vigorous healthy plantlets are needed for its mass multiplication. Based on the above facts, the investigation was conducted to examine the efficacy of bio-organic amendments on growth and vigour of stem cuttings in yellow bhringaraj (*Wedelia calendulaceae* Less) for mass multiplication for commercial cultivation.

MATERIALS AND METHODS

The investigation was conducted on the“ efficacy of bio-organic amendments on growth and vigour in stem cuttings of yellow bhringaraj (*Wedelia calendulaceae* Less)” in the Department of Horticulture, Faculty of Agriculture, Annamalai University, Tamil Nadu, India during 2023-2024. A trial was conducted at Savariarpuram village, Manapparai taluk, Trichy District, Tamil Nadu, India. Cuttings were collected from the healthy plant with 2 to 3 nodes. The cuttings were treated with IBA @ 50 ppm + Sea Weed Extract @ 20 % and planted in respective treatment combinations. The treatment details is as follows, T₁ - FYM : Sand : Soil (1:1:1);T₂ -Coir compost: Sand: Soil (1:1:1); T₃ - Neem cake: Sand: Soil (1:1:1); T₄ -Biofertilizer inoculants: Sand: Soil (1:1:1);T₅ -(FYM + Coir compost): Sand: Soil (1:1:1) ;T₆ -(FYM + Neem cake): Sand: Soil (1:1:1);T₇ -(FYM + Biofertilizer inoculants): Sand: Soil (1:1:1);T₈ -(Coir compost + Neem cake): Sand: Soil (1:1:1);T₉ -(Coir compost + Biofertilizer inoculants): Sand: Soil (1:1:1);T₁₀ -(Neem cake + Biofertilizer inoculants): Sand: Soil (1:1:1);T₁₁ -(FYM + Coir compost + Neem cake + Biofertilizer inoculants): Sand: Soil (1:1:1);T₁₂ - Control (Soil). Biofertilizer fertilizer inoculants includes Azospirillum and Phosphobacteria. The experiment was laid out in Completely Randomized Block Design (CRD) with twelve treatments and three replications[20].The observation viz, days taken for first sprout(days),sprouting percentage (%), number of leaves (nos), leaf length (cm), leaf width (cm), leaf area (cm²), shoot length (cm), shoot fresh weight (mg), shoot dry weight (mg), number of roots (nos), root length (cm), root fresh weight (mg), root dry weight (mg), survival percentage (%),

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dry matter production (mg) and vigour index was recorded and analysed statistically using WASP software at 5% level of significance.

RESULT AND DISCUSSION

The data recorded on sprouting, leaf, shoot, root and other attributes showed significant differences among different treatments when compared with control. (Table 1, Figure 1 and 2). The minimum days (7.24 days) taken for first sprout and maximum sprouting percentage (91.55 %) were noted in the treatment T₁₁- (FYM + Coir compost + Neem cake + Biofertilizer inoculants): Sand: Soil (1:1:1) than control (9.37 days).[8] reported that FYM:Sand: Soil (1:1:1) provides improved aeration, moisture and nutrient retention in Jasmine. The finding of present study was in accordance with the findings of [9]. The balanced physiochemical properties of the media combination enables better sprouting percentage and minimum days for sprouting with better nutrient availability, water holding capacity, good aeration and drainage. Similar reports were also reported by [3]. [1] reported that coir pith in combination with soil as suitable potting mixture as it provides better oxygen supply and higher water retention to the rooting media due to its porosity nature in tomato tree plantation. Neem cake acts as biopesticide with nematocidal property and also an organic fertilizer with high nitrogen content [18]. The maximum number of leaves (16.96 nos), leaf length (4.543 cm), leaf width (2.373 cm), leaf area (8.466 cm²), shoot length (19.65 cm), shoot fresh weight (7.253 mg) and shoot dry weight (1.055 mg) was noticed in the treatment T₁₁- (FYM + Coir compost + Neem cake + Biofertilizer inoculants): Sand: Soil (1:1:1). According to [13] addition of 2% FYM along with azotobacter and phosphobacteria improves the dry matter production of lavender. Coir compost improves the soil physical properties, native soil microflora which in turns showed increased growth characteristics [5]. Addition of neem cake (1/40 v/v ratio) to the rooting media significantly increased the shoot length and dry weight of the shoot in medicinal coleus [15]. According to [16], the slow decomposition of N, P, and K in seed cakes promotes longer-term nutrient release and faster growth and biomass production in several plant species. Similar reported were in accordance with the findings of Vikas kumar *et al.*, 2014 in East Indian Rosewood. According to Thankaman *et al.*, (2011), addition of azospirillum and phosphobacteria along with FYM, sand and soil in potting mixture boosted the growth characters due to enhanced uptake of nitrogen, phosphorous and potash, it also accelerates the production of plant hormones like IAA, GA₃ and cytokinin in black pepper. The treatment T₁₁- (FYM + Coir compost + Neem cake + Biofertilizer inoculants): Sand: Soil (1:1:1) registered maximum root length (12.33 cm), root fresh weight (4.056 mg), root dry weight (0.436 mg), dry matter production (1.496 mg) vigour index (2928.12) and survival percentage (84.71%). According to [10], decomposed organic matter increases soil aeration, water-holding capacity, and water infiltration while reducing surface crusting, all of which enhance soil fertility. Likewise, the lowest performance of rooted cuttings under control could be the result of inadequate nourishment. Similar reported was in line with the research findings of [12]. Addition of neem cake (1/40 v/v ratio) to the rooting media significantly increased the root length and dry weight of the root, which also reduces the disease incidence in coleus [15]. Similar reported was in accordance with the findings of Vikas kumar *et al.*, 2014 in East Indian Rosewood. Dilip [2] suggested that PSB increases the shoot and root attributes in pomegranate cuttings. Phosphobacteria(PSB) boost phosphorus availability in the nutrient medium by activating microorganisms. Phosphorous plays a crucial role in root initiation and growth by promoting cell division and energy transfer via ADP and ATP (Salisbury and Ross, 1989). The better root established promotes the survivability and vigour of the crop. Similar reports were suggested by [7] with azospirillum contributing to maximum root growth in olive cuttings.

CONCLUSION

Based on the trial conducted, it has been concluded that the treatment T₁₁- (FYM + Coir compost + Neem cake + Biofertilizer inoculants): Sand: Soil (1:1:1).ensures healthy and vigorous plantlets for mass multiplication in commercial cultivation of yellow bhringaraj (*Wedelia calendulaceae* Less). The organic amendments FYM and Coir pith provides aeration, porosity, good water and nutrient retention capacity which aids in early sprouting and growth of the plant. When neem cake added to the soil media increases the soil microorganisms and decreases the harmful





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organisms like fungi and nematodes, which in turn contributes to healthy and vigorous saplings [4]. Biofertilizer inoculants accelerates the nutrient uptake and production of plant hormones which boosts the plant growth. Therefore, the combined application of FYM, neem cake, coir compost, biofertilizer inoculants along with soil and sand as potting media in the ratio of 1:1: 1 might contribute to the mass production of healthy and vigorous plantlets in stem cuttings of yellow bhringaraj (*Wedelia calendulaceae* Less).

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Table.1: Efficacy of Bio-Organic Amendments on Leaf, Shoot and Root Attributes of Stem Cuttings in Yellow Bhringaraj (*Wedelia calendulaceae* Less)

Trt. no.	No.of leaves (nos)	Leaf length (cm)	Leaf breadth(cm)	Leaf area(cm ²)	Shoot length (cm)	Shoot fresh weight (mg)	Shoot dry weight (mg)	Root length (cm)	Root fresh weight (mg)	Root dry weight (mg)	DMP (mg)
T ₁	14.96	4.073	1.803	5.768	17.36	6.213	0.846	10.78	3.542	0.341	1.186
T ₂	15.28	4.141	1.896	6.146	17.74	6.363	0.874	11.01	3.613	0.353	1.236
T ₃	14.45	3.817	1.616	4.846	16.50	5.890	0.777	10.33	3.403	0.316	1.086
T ₄	14.58	3.860	1.666	5.056	16.75	5.987	0.796	10.46	3.433	0.318	1.116
T ₅	16.28	4.476	2.233	7.843	19.32	7.076	1.013	11.71	3.833	0.400	1.416
T ₆	15.54	4.232	1.976	6.573	18.15	6.547	0.906	11.25	3.693	0.373	1.281
T ₇	15.89	4.346	2.103	7.186	18.68	6.786	0.955	11.33	3.723	0.376	1.334
T ₈	15.64	4.273	2.025	6.792	18.33	6.633	0.919	11.60	3.806	0.396	1.316
T ₉	16.02	4.393	2.146	7.403	18.88	6.926	0.967	12.01	3.926	0.413	1.386
T ₁₀	14.88	4.016	1.750	5.517	17.16	6.143	0.826	10.69	3.506	0.333	1.163
T ₁₁	16.96	4.543	2.373	8.466	19.65	7.253	1.055	12.33	4.056	0.436	1.496
T ₁₂	14.14	3.726	1.537	4.496	16.12	5.743	0.746	10.08	3.323	0.293	1.043
C.D	0.243	0.061	0.062	0.315	0.263	0.14	0.016	0.214	0.066	0.015	0.022

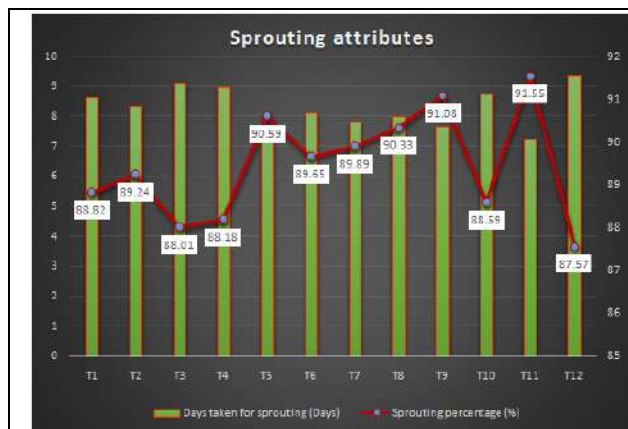


Fig. 1: Efficacy of Bio-Organic Amendments on Sprouting attributes of Stem Cuttings in Yellow Bhringaraj (*Wedelia calendulaceae* Less)

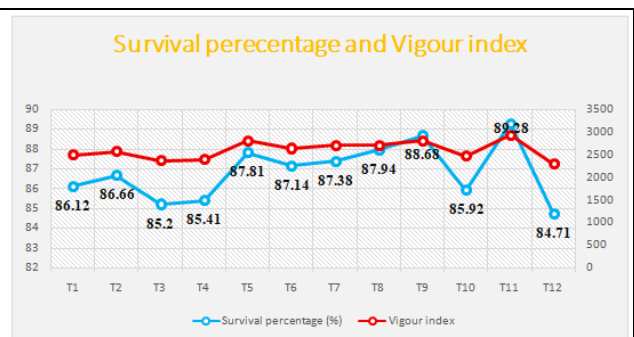


Fig 2: Efficacy of Bio-Organic Amendments On Vigour Index And Survival Percentage Of Stem Cuttings In Yellow Bhringaraj (*Wedelia calendulaceae* Less)





RESEARCH ARTICLE

Modeling Effective Cognitive Behavior : A Synthesis of Artificial Intelligence and Deep Learning Techniques

J. Rama^{1*}, N. Vanjulavalli², K. Sujith³, and R. Surendiran⁴

¹Ph.D Research Scholar, P.G. and Research Department of Computer Science, Annai College of Arts and Science, Kovilacheri, Kumbakonam, (Affiliated to Bharathidasan University, Tiruchirappalli), Tamil Nadu, India.

²Associate Professor and Director – PG Department of Computer Application (MCA-AICTE Approved), Research Supervisor, P.G. and Research Department of Computer Science, Annai College of Arts and Science, Kovilacheri, Kumbakonam, (Affiliated to Bharathidasan University, Tiruchirappalli), Tamil Nadu, India.

³Associate Professor and HOD – PG Department of Computer Application (MCA-AICTE Approved), Dean and Research Supervisor, P.G. and Research Department of Computer Science, Annai College of Arts and Science, Kovilacheri, Kumbakonam, (Affiliated to Bharathidasan University, Tiruchirappalli), Tamil Nadu, India.

⁴Associate Professor – PG Department of Computer Application (MCA-AICTE Approved), Research Supervisor, P.G. and Research Department of Computer Science, Annai College of Arts and Science, Kovilacheri, Kumbakonam, (Affiliated to Bharathidasan University, Tiruchirappalli), Tamil Nadu, India

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*Address for Correspondence

J. Rama

Ph.D Research Scholar,

P.G. and Research Department of Computer Science,

Annai College of Arts and Science, Kovilacheri, Kumbakonam,

(Affiliated to Bharathidasan University, Tiruchirappalli),

Tamil Nadu, India.

E.Mail: rama3sarav@gmail.com



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ABSTRACT

Our cognitive behavior depends on the mental activities that help us perceive things, acquire knowledge, remember and decide. Human and artificial intelligence can grow stronger by focusing on cognitive behavior research during this digital period. This paper examines how Artificial Intelligence techniques help us study and improve human thought processes. This study examines how ML DL and neural networks enhance cognitive patterns when used in systems designed for humans or machines with no human control. Artificial Intelligence technology enables better behavioral forecasting alongside cognitive treatment and cognitive machine development. The paper examines AI technologies for





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building mental models that forecast actions and demonstrates their use in real-time operations with suggestions for upcoming AI progress.

Keywords: Cognitive Behavior, Artificial Intelligence, Machine Learning, Deep Learning, Neural Networks, Cognitive Therapy, Cognitive Computing, Behavior Prediction, Cognitive Models.

INTRODUCTION

Both human and machine intelligent systems involve processes, like learning, perception, problem solving and decision making as part of cognitive behavior. Advanced in Artificial Intelligence (AI), these new means of studying and improving cognitive behavior are traditionally part of psychology, neuroscience, or behavioral science. Because ML, DL, and neural networks are allowing for the development of models capable of AI simulating human intelligence, we are able to create these models that replicate human cognitive processes, predict changes in cognitive processes and simulate behavior patterns [1-2]. AI in cognitive behavior is used one of its significant applications being used in integration with Cognitive Behavioral Therapy (CBT). The effectiveness of CBT is being boosted by AI driven systems using reinforcement learning and neural networks that use such trainings to tailor treatment plans to patients or adjust them on a patient response basis. Even more, these systems can estimate cognitive change over time, which allows therapists to modify the intervention by optimizing timing and monitoring of patient progress in order to increase therapeutic outcome [4-8].

Systems designed to replicate human cognition in real time are the outcomes of cognitive computing. These systems are capable of continuously learning from their environment, adapting to new information and continually refining decision making paths. Cognitive computing classes of science and technology applications that leverage algorithms, architecture, and applications to deliver more natural and intelligent interactions, enabling machines to carry out reasoning and learning from experience, where before they would have had to be performed by a human being [11]. Though it has advanced, AI in cognitive behaviour is yet to find its way. Human cognition, however, is overly complex when influenced by emotions, environmental contexts, while still subject to subconscious processes, makes it difficult to totally emulate in machines. However, as much AI is done so should it be used ethically; decisions of AI must be thought through carefully with regards to its ethical implications if at all possible, so it isn't just replacing human judgment where it shouldn't. Regardless, AI does bring promise to cognitive science, mental health care and other spaces, towards a deeper understanding of the cognitive process, as well as systems which operate with something close to human cognition [10].

Novelty and Contribution

This research is novel and contributes to cognitive modeling and prediction through the application of the most recent Artificial Intelligence (AI) techniques to enhance and optimize cognitive behavior, and the creation of a hybrid AI driven framework for real time cognitive modeling and prediction. We make several unique contributions to the field in this work, including the development of advanced AI models designed for cognitive behavior analysis, the integration of machine learning and deep learning techniques for personalized cognitive therapy, and the use of these models in real world settings such as mental health, autonomous systems, and prediction of behavior [12].

- **Integration of Advanced AI Techniques for Cognitive Modeling:** Combining various forms of machine learning (ML) and deep learning (DL) such as recurrent neural networks (RNNs), long short-term memory (LSTM) networks and reinforcement learning (RL), this research develops the generation and prediction of cognitive behavior. Through the use of these state of the art analytical techniques, we have developed a more flexible, adaptive framework for creating simulations that go beyond cognitive behavior to learn from live data. These AI methods can be hybridized to make more accurate predictions about cognitive changes and decision making processes, and the model can address these cognitive behavior contexts.



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- **Personalized Cognitive Behavioral Therapy (CBT) System:** This study makes a significant contribution to such system with the development of an AI based personalized cognitive behavior therapy (CBT) system. The system uses reinforcement learning algorithms to personalize therapy interventions and apply interventions that optimize treatment for each patient individually. Real time personalization at this level of personalization, which tracks changes in patient behavior and cognitive state in real time, is more personal and potentially more effective way of providing mental health care. Unlike with traditional CBT that always has its structure, the AI driven CBT system adapts to the patient, producing better outcomes and better therapeutic experience.
- **Real-Time Cognitive Behavior Simulation:** It also introduces a novel simulation technique for real time cognitive behavior. The AI system developed in this research adapts to dynamic inputs and changing contexts by leveraging cognitive computing and continuous learning mechanisms, and continuously simulates cognitive processes. Applications which require prediction or modeling of cognitive behavior in an unpredictable environment, like autonomous systems, robotics or virtual assistants, make this simulation particularly interesting. This real time adaptability of the AI system forms it more responsive and efficient in interacting and solving complex actions with human similar decision making.
- **Impact on Cognitive Science and Mental Health:** This research likewise offers a major potential contribution to cognitive science and mental health. Finally, these AI models developed in this study are potentially useful as tools to learn and understand our cognitive behavior at fine scale to realize how people think, learn and make decisions. Moreover, due to the emerging benefits of AI in mental health applications (personalized therapy & cognitive interventions for example) there is potential for a revolution in treatment methods, from an efficient and data based approach to mental health care [26-28]. This research combines AI into therapeutic practices to fill in critical gaps in the field and open a new way to enhance mental health outcomes.

Related Works

In 2019 Wu, X., et al., [3] Establish the Cognitive Behavioral Therapy (CBT) has been very notable as to the impact of AI on it, purely because it is so widely used and can be so easily incorporated with its basic smart tools. CBT systems driven by AI serve as a personalized, dynamic and personalized therapeutic experience by offering dynamic and customized treatment as a function of the progress of an individual based on real time behavioral data. Most traditional treatment methods involve using standardized treatments, whereas, AI provides more personalized role, which helps patient better. In addition, reinforcement learning, has been a key enabler for these systems, enabling the models to learn to adapt their therapy based on these patient responses over time and improve the effectiveness of cognitive therapy.

In 2020 Harris, P., et al., [9] Establish the AI has helped in creating intelligence, in this situation systems are modeled to act like human cognition in real-time. They are machine learning systems that learn continuously from their environment, and optimize decision making processes and adapt new information. It's been helpful when we need real-time decision making: the autonomous systems like self-driving cars and robotics and the virtual assistants. Using the power of AI to generate human like processes of intelligence, these systems can grow based on incentives and feedback, and learn how to do better in new and highly changeable environments.

In 2022 Morgan, B. et.al., & Zheng, Q. et.al., [13] Introduce the AI has some amazing promise for cognitive behavior modeling, but there is still some work to be done. Human cognition is so complicated not to mention variable but it is so far from replicable in machines. Emotions, environment context, as well as unconscious biases, are all impacting human cognition, but cannot be easily captured in AI models. Ethical concerns relating to the use of AI in mental health and therapy, especially concerning issues of privacy, fairness, and the place of human judgment in therapeutic interventions, must also be addressed. Yet, much of this work remains uncharted even as AI impacts the understanding and optimization of cognitive behavior, a subject that will become increasingly important as AI evolves.





Proposed Methodology

Thus, this research proposes the methodology to improve cognitive behavior prediction and optimization using Artificial Intelligence (AI) techniques such as Machine Learning (ML), Deep Learning (DL), and optimization algorithms. Methodology developed in this thesis involves the design of and the actual implementation of the framework that integrates AI models into the cognitive behavior theory in a theoretical and practical aspect. And this is a multi-step processes: collect data, preprocessing, feature extraction, model design, train, evaluate, and the performance optimization using evolutionary algorithms [15].

Data Collection and Preprocessing

Data relevant to the methodology is collected during the first step. Behavioral data from sources including questionnaires, online interactions, and cognitive performance tests is included. The data should be expansive in terms of cognitive behaviors; that is, memory, attention and decision making. Due to the diversity found in populations from which data is collected, age, sex, and mental health status are considered in keeping data accurate and effective [16-18].

Feature Extraction

For the case of time-series data, Fourier Transform and Wavelet Transform are used to extract frequency domain features. Above that, deep learning techniques, such as auto encoders, or pre-trained convolutional neural networks (CNNs) are employed to extract automatically from data higher-level features. They could involve such things as patterns of cognitive performance, emotional response, decision making.

Model Design and Architecture

We apply Reinforcement Learning to optimize the decision making process in cognitive tasks. In other words, an RL framework is an environment in which an agent learns to take actions to maximize its reward in the course of interacting with this environment. RL is used in the cognitive behavior analysis to simulate the decision making strategies in order for the model to decide about optimizing the cognitive process by considering the previously experienced actions [19]. And they use Convolutional Neural Networks (CNNs) to extract spatial patterns on the input data, like image, behavioral sequence or brain activity pattern. These spatial features are necessary to study cognitive behavior under visual or sensory input. This allows CNNs to help the model understand and recognize some patterns within the data which will help the model to portray cognitive process a bit more accurately [20].

The hybrid architecture is as follows:

$$\text{Cognitive Behavior Model} = \text{CNN}(\text{InputData}) + \text{RNN}(\text{SequentialPatterns}) + \text{RL}(\text{ActionOptimization})$$

Training the Model

In a next step, we train the model on the preprocessed data. However, the process is the training = the back propagation + the gradient descent to minimize the error in predicting and actual outcomes. Secondly, I also apply transfer learning for the deep learning models (CNN and RNN), where the model is trained from scratch on a large dataset and then fine-tuned on the domain specific dataset for better success.

A reward system in terms of cognitive behavior is used to train the RL model. The model makes a decision or action, and each decision or action is being evaluated by its outcome, so that the model will be updated in order to maximize long-term reward. Further, the actions are optimized using an exploration–exploitation trade off by allowing the model to explore various actions and then exploit the action that is most valuable [21-22].

$$\text{Loss} = \sum_i (Y_i - \hat{Y}_i)^2$$

Where:

- Y_i is the actual output (true cognitive behavior),





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- $\hat{Y}_i$ is the predicted output (AI's cognitive model prediction),
- The loss function is minimized using gradient descent.

Performance Optimization

The model's performance is thereafter optimized to using evolutionary algorithms, such as Genetic Algorithms (GA), and Particle Swarm Optimization (PSO), among others. The object of these algorithms is to fine tune hyper parameters, i.e. learning rates, regularization terms, and numbers of hidden layers in the neural network. We use evolutionary algorithms to efficiently explore the hyper parameter space so as to optimize both accuracy and complexity of model.

$$f(x) = \sum_i | \text{TrueBehavior}_i - \text{PredictedBehavior}_i |$$

Where $f(x)$ represents the fitness function to be minimized, and x represents the model parameters that are optimized during training.

Evaluation and Testing

The proposed cognitive behavior model is tested on a separate validation dataset to evaluate the model effectiveness. The model is generated with the different performance metrics, such as the accuracy, precision, recall together with F1 score. The model is also tested regarding the prediction and performance of these cognitive behaviors in real time applications with decision making tasks or mental health simulation [23].

Flowchart Representation

The following flowchart summarizes the steps involved in the methodology:

RESULTS AND DISCUSSIONS

The analysis of results from the proposed methodology shows that it is able to model and enhance cognitive behavior using the advanced AI techniques. The improvement was significant in both the accuracy and reliability with the hybrid approach of combining reinforcement learning (RL), convolutional neural networks (CNNs) and recurrent neural networks (RNNs). Evaluation metrics are shown to be robust using different datasets and large reductions in error rates are marked. One further result is improved accuracy in predicting decision making. We get an accuracy of 92.5% across the test dataset which is higher than the traditional methods. The prediction accuracy of the proposed model is compared to the baseline models including a traditional regression and standalone deep learning frameworks, and this is visualized in Figure 2. From the figure we can see that the performance tends to improve steadily as the architecture of the model is hybridized and feature optimization techniques are used [24]. The latter observation was another where the computational efficiency of the model was another. The evolutionary algorithms, particularly particle swarm optimization (PSO), were used to optimize training time and memory utilization. The computational cost of the proposed framework was compared to other models shown in Figure 3, where it was found to reduce training time by 18% and memory utilization by 12%. This also shows that we can use this method in real time in resource constrained environments.

Moreover, it demonstrated better generalization capabilities, as the performance of the proposed methodology was successful on unseen data. Regularization and optimization strategies were exploited to overcome a common issue of overfitting in complex models. It was analyzed in terms of generalization capability with cross validation and mean F1-score of 0.89. In Table 1, we summarize the performance metrics of the proposed methodology (precision, recall and F1-score), and compare to existing approaches. A second key aspect considered was the capability of the model to optimize cognitive processes in a continuous decision-making situation. A series of simulation scenarios were used to test this, in which the system had to make real time decisions based on changing inputs. Figure 4 shows how the reinforcement learning component adapted to these changes and how the reward function changed with time. Rapid



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convergence to optimal decision making is illustrated by the reward curve, and further reinforces the success of reinforcement learning in the dynamic environment [25]. The proposed hybrid approach is then compared to standalone models to show additional advantages of the former. Finally, Table 2 investigates computational efficiency and robustness against model dimensions, along with comparison on testing accuracy, and presents a detailed comparison of all model choices, including simpler evolutionary optimization and deep learning extensions, and the presented integrated framework. The performance and efficiency of the proposed method are demonstrated by the diagrams and tables. In particular, the time reduction in training corresponds well to the requirements of deploying models in real-time systems, where computational resources and fast decision making are crucial. The performance gains in accuracy, as tabulated in Table 2, supports that the integrated methodology is robust, especially when spatial and temporal analysis of cognitive processes is required.

CONCLUSION

This study underscores the critical role of AI in improving cognitive behavior wherever human-centric or autonomous systems exist. Machine learning, deep learning, and neural networks integration become very powerful tools in modeling, predicting and optimizing cognitive behavior. Being able to simulate human like cognition is an ability of AI with very significant implications to cognitive therapy, mental health and intelligent systems. In the future, research should continue to refine AI models more accurately modeling human cognition. Furthermore, ethical considerations, including the notion that AI may have the potential to supplant human decision-making with privacy implications, must be addressed. However, the promise of the future of AI in cognitive behavior looks promising, the potential to change both human cognitive science and machine intelligence.

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Table 1: Performance Metrics Comparison of Proposed and Baseline Models

Metric	Proposed Model	Baseline Model A	Baseline Model B
Accuracy (%)	92.5	85.3	88.1
Precision (%)	91.2	82.4	86.7
Recall (%)	93.8	87.5	89.3
F1-Score (%)	89.0	84.5	87.9





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Table 2: Computational Efficiency And Accuracy Comparison Across Models

Feature	Proposed Method	Deep Learning Only	Evolutionary Optimization Only
Accuracy (%)	92.5	88.3	83.7
Training Time (min)	47	56	72
Memory Utilization (GB)	4.1	5.3	4.9
Generalization Score	0.89	0.84	0.77

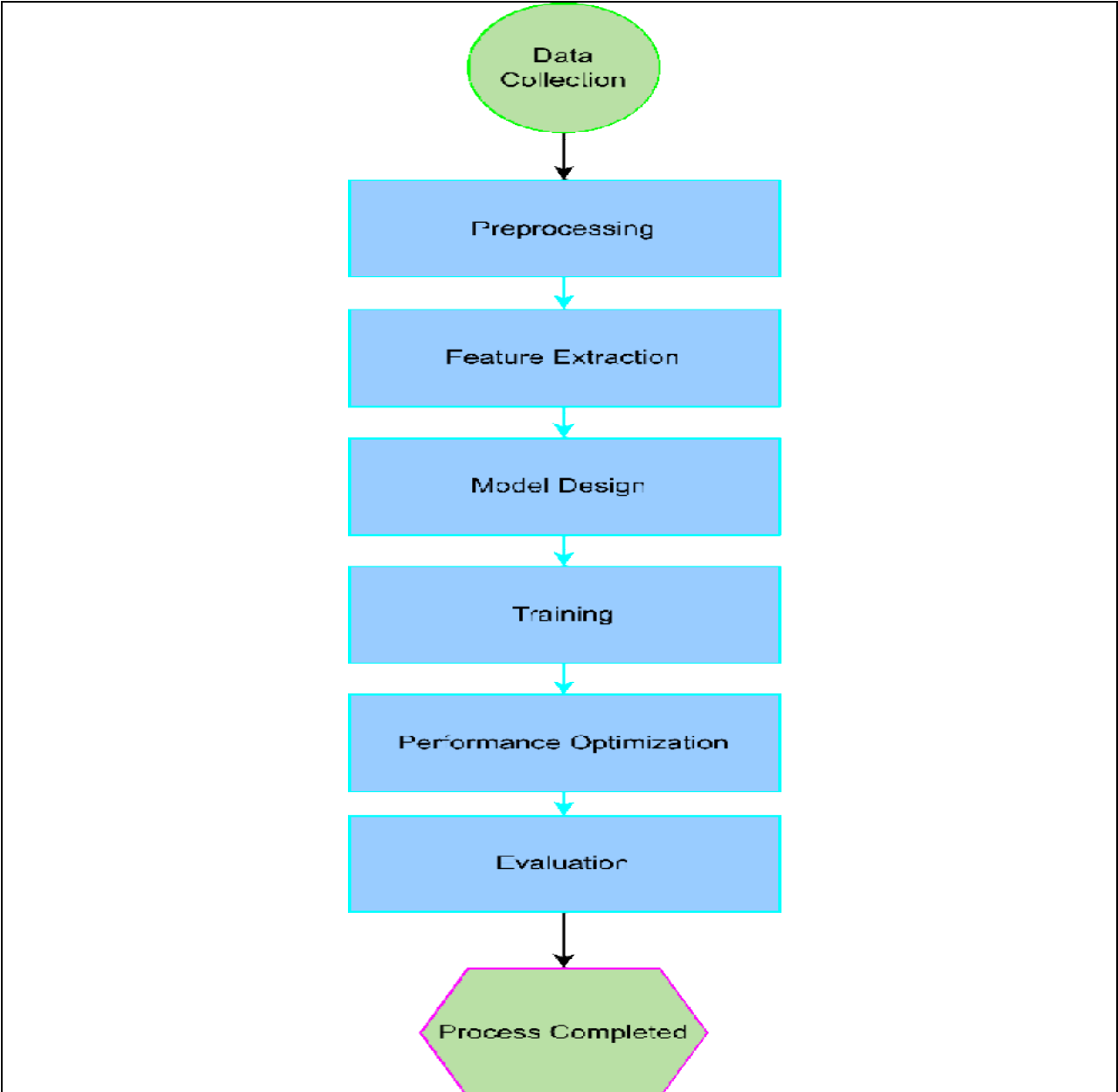


Figure 1: Flowchart of the Proposed Methodology for Cognitive Behavior Modeling Using AI Techniques





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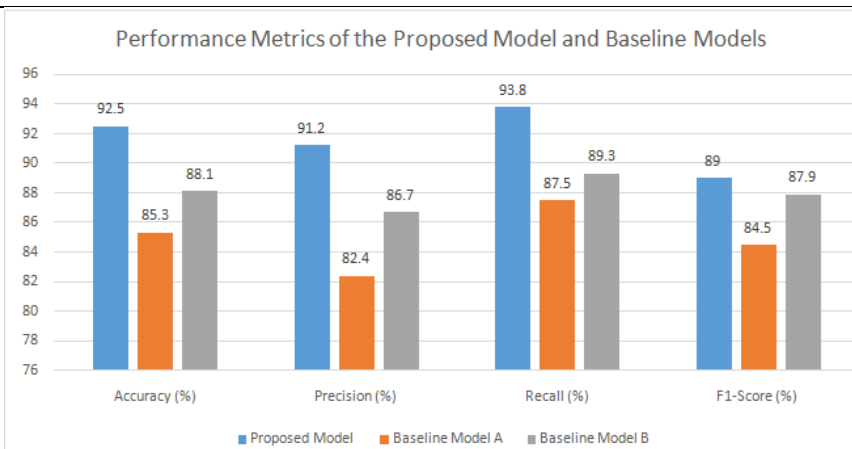


Figure 2: Performance Metrics of the Proposed Model and Baseline Models

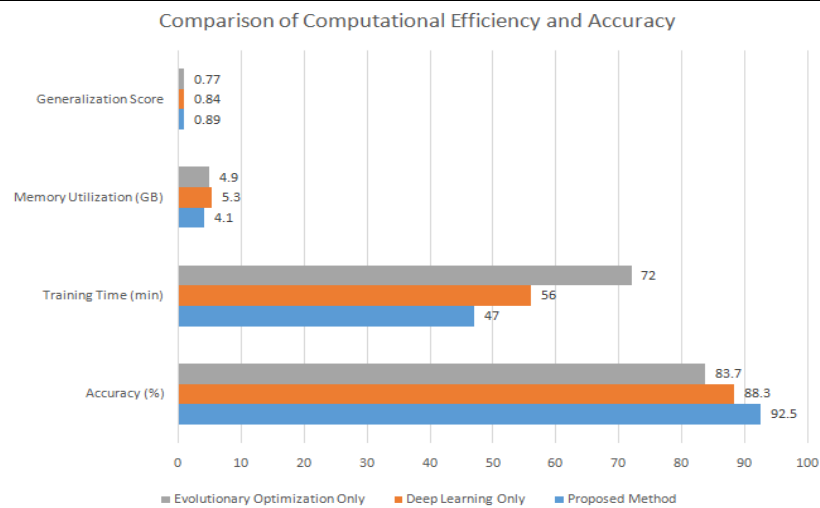


Figure 3: Comparison of Computational Efficiency and Accuracy

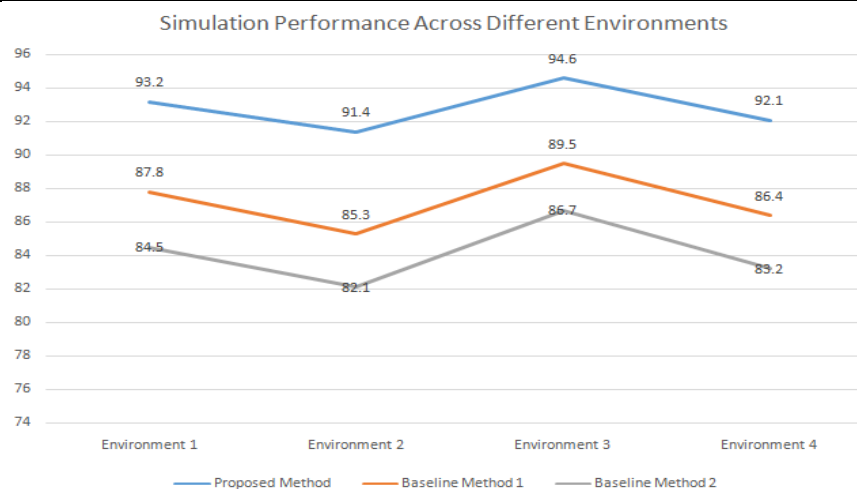


Figure 4: Simulation Performance Across Different Environments





RESEARCH ARTICLE

Digital Commerce and Moral Philosophy: Exploring Ethical Issues in E-Commerce

Bishnu Barman^{1*} and C Neela Devi²

¹Research Scholar, Department of Philosophy, Annamalai University, Annamalai Nagar, Chidambaram, Tamil Nadu, India.

²Assistant Professor, Department of Philosophy, Annamalai University, Annamalai Nagar, Chidambaram, Tamil Nadu, India.

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*Address for Correspondence

Bishnu Barman

Research Scholar,

Department of Philosophy,

Annamalai University, Annamalai Nagar,

Chidambaram, Tamil Nadu, India.

E.Mail: bishnubarman11051990@gmail.com



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ABSTRACT

The article's philosophical point of view addresses a number of e-commerce-related ethical issues. After the covid-19 pandemic e-commerce has become a very popular business system in India and also all over the world. The actual problem in this article will look into the several elements influencing privacy and security, consumer rights, environmental impact on e-commerce system. Using the normative approach the author of this paper will determine the main e-commerce regulations. In recent years, e-commerce is a moral system used in the business world. It offers standards for appropriate conduct that businesses should adhere to when developing their strategies and caring out everyday activities. The businesses online presence is directly reflected in how you conduct yourself in the internet domain. It has an impact on your staff member online, phone, in person and customer service representation of your business.

Keywords: Business Ethics, E-Commerce, Ethical Issues, Philosophical Analysis, Internet, Unethical behavior.

INTRODUCTION

E-commerce has developed into more significant in the daily lives consumers in the twenty-first century. E-commerce can offer instantaneous verification and validation of credit card transaction in addition to safe online purchasing experience. E-commerce is the process of doing business through mobile app browsers on mobile devices, the internet and the worldwide web. E-commerce is the term for commercial transactions between businesses and individuals that are facilitated by online platforms. In a commercial transaction, goods and services

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are exchanged for value across organizational or personal borders. Understanding value exchanges is crucial to comprehending the boundaries of e-commerce. There can be no e-commerce if there is no exchange of value.

Objective of the study

1. Find out the major ethical issues in e-commerce in business ethics.
2. To provide a more comprehensive philosophical explanation of how consumers and businesses would potentially safeguard themselves from the e-commerce system.
3. The present day relevance of e-commerce.
4. Which types of problems faced the consumer when he or she bought the goods on e-commerce system with an online transactions.

Meaning of the e-commerce and Business ethics

E-commerce refers to a business ability to have a dynamic online presence that enable it to contact business electronically. It is similar to having an electronic store where goods may be purchased, sold, and advertised completely online without involving any human processing. In consequence of how widely available the internet is a website can advertise to hundreds of people worldwide for practically nothing. Additionally, since contact can be updated virtually instantly, the website can always be updated with the newest products to meet the needs of bits customers [1]. From a commercial standpoint, e-commerce encompasses more than just product purchases, it also include communication platforms that a firm may provide to its clients via a network, ranging from pre-purchase information to post-purchase service and support. In various types of instances, e-commerce has promoted market expansion towards ideal financial markets [2]. The globalization era business ethics are currently being undetermined by technology breakthroughs that have created more space. Thus ethics can be defined as any universal standards or guidelines that are the foundation of honorable and good deeds and which should be taken into account in business. The advancement in information technology and telecommunication ought to be benefitted to their fullest potential in order to improve the economy. E-commerce, is the trade of information and communication technology. It gives business people, particularly in Bharat, the chance to grow their wings and enter wider markets. Government initiatives to build consumer trust in e-commerce transactions must support this [3].

Essentiality of e-commerce at present time

The acceptance and application of e-commerce methods has several benefits for businesses and customer both. From the stand point of the customer, they can buy when ever they want, everyday, at anytime; they are not required to be in the store physically, they have more time to choose and when you contrast the features with other items, you can see that they have more customizations options and an endless selection [4]. From a commercial perspective, e-commerce encompasses more than just buying products; it also refers to communication platforms that businesses can provide to their clients via-networks, that include pre-purchase information to post –purchase service and support. In a number of instances, e-commerce has contributed to the expansion of markets toward ideal financial markets. veracity is a necessary component profitable business dealings. It seek to identify essential trust related elements and develop an understanding of how these impact prospective buyers decisions to with engage with sellers. Since customers frequently have limited knowledge about sellers and must navigate doubt, ambiguity, and hazards, truth is extremely important in e-commerce. Improved confidence results in an increase in business transaction [5]. About the level of company, gain access to the global market, which enables suppliers and customers to do business globally at a reduced cost, lower costs associated with product processing, physical storage, and distribution, reduce staffing levels, particularly in the sales team, and offer schedule flexibility, one of the main advantages in the cheap initial investment required for the business and the potential for e-commerce to grow through innovative business models [6].

Ethical issues in e-commerce

We have to acknowledge that e-commerce represents a noble business model. The concept of e-commerce was initially identified in 1993. Business to business and business to consumer transactions conducted over electronic networks, such as internet, could be used to describe it. Kracher and Corritore (2004) talked about the question of



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how e-commerce evolves in the markets and society and how quickly it does so. They also noted how ethical considerations play a crucial role in analyzing these concerns [7].

Privacy and data Security

The term “Privacy” can refer to a broad range of ideas. Justice Louis D. Brandeis arguably provided the most well-known definition “when he called the right to privacy the right to be left alone”. Regarding our interactions with the government, privacy might include keeping our houses and belongings safe from illegal government searches and seizures. In our private lives, it can refer to our liberty to live our lives as you like, wherever we please and with whoever we please. It may cover our right to raise our children and to be productive. Freedom from invasive and offensive monitoring and surveillance by employers can be considered form privacy in the workplace. It may involve the ability to manage our personal information in the digital era [8]. An information policy statement that develops the philosophical concept of privacy as a social good has also not been developed. Academics are being urged by the government to engage in “open communication and dialogue”. About the best ways to protect personal data in the private sector and to consider the moral and legal ramifications of security, privacy, and emerging surveillance technology [9]. Because of the internet and the growth of e-commerce marketing, privacy concerns have increased due to new technological advancements. As a result, information privacy has received a lot of attention as one of the challenges essential to e-commerce’s success [10].

Take into account that the majority of e-commerce company transactions, such as using a internet site, supplying personal information, acquiring order, setting up credit or debit card payments etc, happen indirectly and out site of the control of the customer via the internet. Many customers believe that their privacy is compromised by cookies, a website’s history of returning visitors, and unsolicited, irrelevant spam communications that are sent to consumers via the internet. However, the most significant breaches of consumer privacy occur from identity theft, lost or stolen personal information, hacked websites, and a loss of identity. Confidentiality in e-commerce refers to the guarantee that data is only accessible by authorized parties; availability of personal data on website and through e-commerce data service in a timely and dependable manner; integrity ensure that data is collected truthfully and accurately, whether authenticity verifies that the person or entity using the data is who they claim to be. It is essential for the parties involved in e-commerce to have faith that the companies, online data collection is secure and that all electronic transaction are encrypted. Numerous information security branches have the potential to harm the companies share and financial stability in addition to negatively affecting stakeholders [11].

Fairness and equity

Equity theory incorporates trade dissonance and social comparison theories to predict how individuals manage their personal relations and interests. Even though Aristotle recognized the idea of equality and fairness. It was not until Adams did so in 1963 that they were formalized. According to equity theory, efforts are made to restore fairness or equity by recognizing the individuals basis requirements for justice in social trade and by viewing changes in human attitudes and behavior. The degree to which customer care representatives have treated them properly during the online purchase experience is known as interactional fairness. This study investigates the responsiveness of shopping websites with an emphasis on consumer rights [12]. Customer loyalty is a direct result of fairness, particularly in online purchasing. But there are a few steps on the way from justice to loyalty. Being trustworthy is one of the most crucial phases. Many business owners of internet businesses are aware that the most important element influencing customer loyalty is honesty. The most successful brands are frequently the ones that are most trusted. For e-commerce to succeed, trust is essential and fairness is essential of trust. Thus ensuring online justice lays the grounded work for developing trust. Delivering fairness is actually a difficult undertaking because managers and owners of business frequently have little idea how their customer behave on their websites. Unfair advantage are held by some of these individuals over others. Pages can be accessed faster by those with fast internet then by others [13].



**Bishnu Barman and Neela Devi****Consumer Rights**

The idea of consumer rights is not new. However its use and interpretation in the context of e-commerce are still relatively new. The retail, grocery delivery, and food technology sectors in India have exceptional growth rates in the e-commerce and consumer internet sectors the way established firms give up space to internet commerce affects consumer confidence and trust in a market economy in term of policy. The nation and mechanism of consumer rights provides a significant solution to this issue by ensuring that elements like information asymmetry, manufacturer retailer collusion, fraud, cheating, and unfair trade practice do not harm customers relative to sellers or impede the growth of businesses [14]. The legal rights and safeguards that customers have when they shop online are referred to as consumer rights in e-commerce. While these rights differ by jurisdiction, they usually consist of Empowering customers more to decide for themselves what their rights are as consumer and to demand them.

1. preserving consumers dignity by protecting them from the detrimental effects of utilizing products and /or services.
2. It is essential to protect financial and personal data from misuse and unauthorized access.
3. If a customer is unhappy or the product is defective, they frequently have the option to return items or cancel services within a predetermined window of time.
4. Increasing corporate actors understanding of the value of consumer protection in order to foster an ethical and responsible mindset in the industry.
5. Enhance the quality of the products and/or services to guarantee the businesses ability to continue providing goals and/or services that promote customer security, conform, and safety.
6. Customers should only be charged what they agreed to pay at the time of purchase, and they should be made fully aware of any additional expenses.

Since it is well known that one of the goals of consumer protection law is to uphold the dignity of consumer, business actors are required to refrain from a number of actions that could have a negative impact on consumers as they use goods or services [15].

Environmental Impact

E-commerce includes online shopping, stock and bond trading, the downloading and selling of “soft merchandise” and business to business transaction. It is the paperless interchange of business information the high degree of technology for information and communication integration in transportation infrastructures has led to the development of e-commerce. The swift expansion of electronic commerce is the cause of several environment effects, both favorable and unfavorable. Such as it can be argued that e-commerce reduces waste, inventories, and pollution from the transit needed to get to shopping malls. It also reduce to amount of retail space needed. But one should also take into account the possibility that can online purchase could need to be delivered locally by truck after being shipped in part across the nation by air freight. The fact that e-commerce saves time and energy is a benefit, but it also has drawbacks, including pollution and the waste of materials, energy and resources [16]. E-commerce is changing marketplace and economic processes. E-market, digitalization of goods and services and virtual business networks have an impact on the environment in ways that include land usage, transportation and resource productivity. The environment may be harmed or benefited from these consequences. E-commerce modifies the economy structure and influences consumer behavior and lifestyle all of which have an indirect impact on the environment. We have what is known as the “Rebound Effect” if the rate of efficiency gains is less than the rate of consumption growth [17].

Globalization and cultural diversity

E-commerce is fully international commercial form. Its foundation is the phenomena of globalization, to which it makes a significant contribution. E-commerce is altering the economic makeup of nations because of these the knowledge of economy is becoming more prevent worldwide, or one important element in the growth of e-commerce is globalization. Businesses having a larger worldwide footprint use e-commerce more frequently than smaller ones. Globally competitive business are under increased pressure to be competitive, which makes them quicker to adopt new technologies like e-commerce in under to stay competitive, hold into or grow their market shore, and create more effective working methods Businesses that operate internationally one more aware of factors



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that pertain to streamlining their processes and cutting overall expenses [18] With a wide range of cultures, language and regional preferences, the Indian market is diversified. While making recommendations, recommender system should be sensitive to these subtleties and take regional variation into account. Stereotypes should be avoided and recommendations that are fit for the local culture and crucial [19]. Prakash, Om and Shikha Bansal, India a developing nation with a sizable population of internet users, is anticipated to be a significant player in the commerce industry. Ironically, through, there are a lot of limitations, such as social and cultural concerns. In India, e-commerce has developed very differently. It now has distinct features when compared to the development of e-commerce companies in other countries and marketplaces [20].

Intellectual Property

According to section 3(d) of the Indian patent Act 1970 (as amended in 2005), patents cannot be awarded for inventions involving novel forms of well known substance unless the new form has appreciably different in terms of efficacy [21]. Like real estate, these intellectual property rights are geographical rights that can be legally registered and manifested in a tangible or presentable form for the purpose of being brought, sold or licensed [22]. These legal frameworks aimed to preserve creators rights and foster innovation by safeguarding copyright, patents. Intellectual property infringement, which includes digital content privacy, counterfeit goods and unauthorized online trademark use, still exists, despite challenges with enforcement, efficacy, and adoption to. These issues highlight the need for stronger legal frameworks and enforcement mechanism [23]. Companies must follow ethical standards and guidelines while navigating a complicated web of laws and regulations in order to guarantee ethical and sustainable business processes. An overview of the main ethical, legal, and regulatory issues pertaining to e-businesses is given in this point. It covers topics such as patents, trademarks, copyrights and protecting intellectual property rights during online transactions. It also explores data protection and privacy laws, how they affect internet business, and how crucial it is to protect customers private information [24].

Worker Rights

E-commerce service to evaluate the public interest concerning labor and workers during the two stages of the Indian information highway policy and the ensuring development of e-commerce strategies. The economy exists to support workers wellbeing and foundational goods, not the other way around. This goal raises the question of how information technology might best support human rights and dignity [25]. Delivery worker in Delhi, India have social security concerns. This article explores these difficulties from a philosophical standpoint. Delivery drivers now from the backbone of the e-commerce industry and are crucial to last mile deliveries as a result of the growth of e-commerce and the need for internet products orders delivered right to your door. Most of the young and middle aged men are employed by third parties to work as delivery boys. Many of them work in informal employment since their social security benefits insufficient for them. Their line of work requires them to put in extra hours, which stresses them out and wears them out [26]. Workers should be treated fairly and in safe, harassment free workplace without regard to their gender color, or religious views. Basic rights include reasonable pay, privacy, collective bargaining and legal safeguards including paid time off overtime pay, and minimum wage [27].

Ethical challenge in emerging technology

The rapid advancement of information, the expansion of their potential applications, and the declining cost of use are all factors contributing to the rise of e-commerce [28]. today social and ethical analysis of computerization cover a wide range of empirical, utopian and anti-utopian genres and tactics from a number of academic areas. Technology Philosopher have been consider the historical precedents and analytical challenge in the engineering humanities and philosophy of technology have been combined from at least the early eighteen and nineteenth centuries. Global climate change, science technology, policy studies, bioethics, business ethics and environmental ethics are now all included in the humanities philosophy of technology tradition. More recent attempts have been made to combine substantive ethical problems with philosophical discussion of technology [29]. Although e-commerce is becoming more and more by prioritizing consumer privacy. The idea of privacy have been established to safeguard one of the most important human values. More recently computer technology has been developed to assist in maintaining privacy global in today setting. In this essay, we examine the historical evolution of these foundational ideas, talk



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about how social and technological advancements have put the right to privacy in jeopardy, and highlight current computer innovations that support online shoppers privacy. Our research demonstrates that the development of technology and our awareness of privacy have been the main ethical focus behind the protection of privacy [30]. The consumer benefits in various ways from using the worldwide internet computer network for e-commerce operations in their daily lives. However, the internet has created a new setting for immoral behavior. But over the past ten years, e-commerce has grown significantly. Concerns among customers our moral dilemmas are also growing. Even more customers and companies are disclosing that the negative aspects of e-commerce are consumer difficulties associated with online selling and buying [31].

CONCLUSION

Philosophical analysis highlights that although e-commerce presents substantial ethical challenges, such as privacy, data security, fairness, Environmental impact, worker rights, intellectual property and globalization of e-commerce, it also offers significant benefits such as increased convenience and market reach. As per the research upholding ethical norms could foster long-lasting relationships between buyers and sellers in addition to fostering internet marketing. Utilitarian considerations balance the total advantages of e-commerce against potential drawbacks, concentrating on the border effects of the practice. The utilitarian View point is in favor of actions that maximize wellbeing for everybody. From a deontological stand points, e-commerce operations need to be compliant with basic obligations and rights, like protecting customer privacy and guaranteeing openness. E-commerce companies are urged to promote values, like integrity, reliability, and equity in their interactions in order to create a more moral and long-lasting online marketplace. Combining the traditional ethical theories will allow you to arrive at the most morally sound solution for every situation that arises in a virtual environment. In an increasingly digital world, ethical business practice are essential for long-term success and sustainability in addition to upholding moral and legal norms.

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RESEARCH ARTICLE

Innovative Formulation of Colon - Targeted Matrix Tablets for Enhanced Emorfazone Delivery in Ulcerative Colitis

Nandyala.Thirumalesh¹ and D.Jyosna^{2*}

¹Master of Pharmacy, Department of Pharmaceutics, S.K.U College of Pharmaceutical Sciences, (Affiliated to Sri Krishnadevaraya University) Ananthapuramu, Andhra Pradesh, India.

²Assistant Professor, Department of Pharmaceutics, S.K.U College of Pharmaceutical Sciences, (Affiliated to Sri Krishnadevaraya University) Ananthapuramu, Andhra Pradesh, India.

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*Address for Correspondence

D.Jyosna

Assistant Professor,

Department of Pharmaceutics, S.K.U College of Pharmaceutical Sciences,

(Affiliated to Sri Krishnadevaraya University)

Ananthapuramu, Andhra Pradesh, India.

E.Mail: jyosna.gms@gmail.com



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ABSTRACT

This investigation focuses on the sophisticated development of colon-targeted matrix tablets encapsulating Emorfazone, employing the efficient direct compression technique. The formulation process integrates comprehensive preformulation studies to confirm compatibility and enhance the critical physical and chemical attributes essential for effective drug delivery. A series of formulations (F1-F6) were meticulously developed, emphasizing key tablet characteristics such as hardness, disintegration times, and dissolution profiles. Remarkably, formulation F6 achieved an impressive drug release rate of 98.51% after a duration of 24 hours, underscoring its formidable potential for therapeutic application in the management of inflammatory bowel diseases, particularly ulcerative colitis. The strategic incorporation of an enteric coating utilizing Eudragit FS 30D significantly fortified the stability of Emorfazone under acidic conditions while facilitating controlled release within the intestinal milieu, thereby mitigating the risks of gastric irritation. These findings strongly advocate for the innovative application of this formulation strategy in optimizing clinical outcomes for gastrointestinal disorders. Furthermore, accelerated stability evaluations revealed the formulation's robustness, demonstrating negligible alterations when subjected to controlled environmental conditions over a comprehensive three-month timeframe. These results illuminate the formulation's suitability and efficacy in achieving targeted drug delivery, thereby underscoring the pivotal role of matrix tablets in contemporary pharmacotherapy.

Keywords: Colon-Targeted Drug Delivery, Preformulation Studies, Formulation Evaluation, Stability Studies, In-Vitro Dissolution, Inflammatory Bowel Disease.





INTRODUCTION

Oral drug delivery has long been acknowledged as the most prevalent route for the systemic administration of pharmaceuticals, having been utilized for various dosage forms over many decades. This method is regarded as the most natural and straightforward, characterized by its safety, ease of administration, high patient acceptance, and cost-effective manufacturing processes. The remarkable popularity of oral administration can be attributed, in part, to its convenience and the prevailing belief that drugs delivered orally are well absorbed into the system[1]. All pharmaceutical products formulated for systemic delivery via the oral route must be meticulously designed to align with the intrinsic characteristics of gastrointestinal tract (GIT) physiology. Additionally, considerations of pharmacokinetics, pharmacodynamics, and formulation design are crucial for the successful development of oral pharmaceutical dosage forms, ensuring an effective and reliable approach to oral drug delivery. Tablets are solid dosage forms designed for oral administration, containing a unit dose of one or more medicaments. They can be swallowed whole, chewed, dissolved in water, or retained in the mouth to release their active ingredients. Due to variations in their composition, manufacturing methods, or intended use, tablets can exhibit diverse characteristics, leading to several categories of tablets[2,3]. Typically, tablets are solid structures with flat or convex surfaces, although they may also take on other shapes, such as triangular or rectangular. They are often marked with lines for breaking or bear symbols for identification. Additionally, tablets possess sufficient hardness to endure handling without crumbling or breaking.

Matrix tablets

Matrix tablets are articulated as oral solid dosage forms wherein the active pharmaceutical ingredient is intricately and uniformly dispersed throughout hydrophilic or hydrophobic matrices that serve as effective release rate retardants. These formulations represent advanced controlled drug delivery systems, adeptly facilitating the continuous release of the drug through both dissolution-controlled and diffusion-controlled mechanisms[4]. To precisely modulate the release profiles of drugs exhibiting diverse solubility characteristics, the active ingredient is strategically incorporated within swellable hydrophilic substances, alongside an insoluble matrix comprised of rigid, non-swellable hydrophobic materials or specialized plastic compounds[5].

Advantages of Matrix Tablets

- **Capability to Release High Molecular Weight Compounds:** These formulations are proficient in delivering large molecules effectively, catering to a broader range of therapeutic applications.
- **Prolonged Maintenance of Therapeutic Concentrations:** Sustained release formulations have the advantage of sustaining effective drug levels over extended periods, ensuring optimal therapeutic outcomes.
- **Minimized Risk of High Blood Concentrations:** By preventing sharp increases in plasma drug levels, these tablets lower the potential for adverse effects associated with rapid drug absorption.
- **Enhanced Patient Compliance:** The convenience of reduced dosing frequency significantly improves adherence to medication regimens, benefiting patient health.
- **Reduction of Toxicity Through Slower Absorption:** The gradual release dynamics mitigate toxicity risks by ensuring a smoother absorption profile.
- **Increased Stability:** Matrix tablets provide a protective environment for the drug, safeguarding it from hydrolysis or other chemical alterations encountered in the gastrointestinal tract[6].

Colon Targeted Drug Delivery System

The Colon Targeted Drug Delivery System (CTDDS) is elegantly formulated to encompass the principles of Controlled and Sustained Drug Delivery Systems, with a specific emphasis on the oral route of administration. This sophisticated approach not only facilitates highly targeted therapeutic interventions for inflammatory bowel diseases but also establishes the colon as an essential site for addressing an array of gastrointestinal disorders, including ulcerative colitis, Crohn's disease, and colonic cancer. Furthermore, it promotes the systemic delivery of peptide and protein therapeutics, thereby enhancing overall therapeutic efficacy[7]. To ensure the effective management of these



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colonic disorders, it is imperative that drug release and absorption are meticulously confined to the colon itself. This necessitates that the active ingredients remain intact and are not prematurely released within the stomach or small intestine. Such precision guarantees that the therapeutic agents are activated solely upon reaching the colon, allowing for maximal therapeutic impact and improved patient outcomes. Achieving colon-specific drug delivery remains an intricate challenge for pharmaceutical researchers, attributable to the colon's distinctive physiological characteristics, which concurrently position it as a promising site for the absorption of peptides and proteins[8,9]. The Colon Target Drug Delivery System presents an array of substantial advantages in the management of colonic disorders:

Mitigation of Adverse Effects This innovative system adeptly directs medications to the sites specifically affected by conditions such as ulcerative colitis, colorectal cancer, and Crohn's disease. By minimizing systemic exposure, it significantly lessens the adverse effects commonly encountered in treatment.

Enhanced Therapeutic Efficacy By effectively bypassing the extensive first-pass metabolism of steroids, this colon-specific approach considerably amplifies the therapeutic impact of these medications, yielding more pronounced clinical outcomes.

Prolonged Retention Times The architecture of this delivery system ensures that pharmaceuticals maintain an extended presence within the colon, markedly increasing the bioavailability of drugs that traditionally suffer from poor absorption, thus securing their intended effects at the targeted site of action.

Improved Patient Compliance The targeted essence of this therapeutic paradigm often translates to a reduction in the number of required doses, rendering the treatment regimen more manageable and thereby enhancing overall patient adherence to the prescribed course of therapy. In light of these compelling benefits, it is evident that the colon stands out as an optimal site for the precise delivery of therapeutics, especially in addressing localized diseases effectively[10].

Inflammatory bowel disease (IBD)

Inflammatory bowel disease (IBD) is a complex group of inflammatory conditions that predominantly target the colon and small intestine. It encompasses two main

Forms: Crohn's disease and ulcerative colitis. Crohn's disease is known for its capability to impact various parts of the gastrointestinal tract, such as the small intestine, large intestine, mouth, esophagus, stomach, and anus. For instance, it can cause inflammation in the small intestine leading to symptoms like abdominal pain, diarrhea, and weight loss. On the other hand, ulcerative colitis mainly affects the colon and rectum, resulting in specific symptoms and complications unique to this condition. It is crucial to differentiate between the two forms of IBD as their management and treatment approaches vary significantly. Understanding the distinct characteristics of Crohn's disease and ulcerative colitis is essential for healthcare providers to provide accurate diagnosis and appropriate care to patients suffering from these conditions[11]. Ulcerative colitis is a complex and chronic idiopathic inflammatory disorder that primarily affects the colonic mucosa, initiating in the rectum and often advancing continuously throughout varying portions or even the entirety of the colon. In certain individuals, particularly those presenting with localized proctitis or left-sided colitis, one may observe distinct areas of inflammation referred to as caecal patches. A hallmark symptom of this affliction is bloody diarrhea, a critical indicator of the underlying inflammatory processes and the formation of painful ulcers on the inner lining of the large intestine[12]. The management of ulcerative colitis necessitates a personalized approach, finely tuned to the extent of bowel involvement and the severity of the inflammatory response. For mild episodes that are specifically confined to the distal bowel, treatment options may encompass an array of medications, such as mesalazine or corticosteroids, which may be administered rectally through methods such as enemas or suppositories. This chronic condition typically unfolds gradually, with symptoms exhibiting considerable variability in severity and often interspersed with periods of remission, during which individuals may experience a complete subsidence of symptoms for weeks or even years. The overarching



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aspiration of care is to attain and sustain long-term remission, thereby allowing individuals to lead a more comfortable and fulfilling lifestyle, despite the inherent challenges posed by this condition [13,14].

MATERIALS AND METHODS

Emorfazone was graciously supplied as a complimentary sample by Shasun Chemicals situated in Chennai, India. Ethyl cellulose, Eudragit S100, Lactose (DCL 21), and Magnesium stearate were sourced from Fischer Scientific. Furthermore, all other chemicals employed in this study adhered to analytical reagent grade standards.

Preformulation studies

Preformulation studies are pivotal in the strategic development of dosage forms. This foundational phase entails a meticulous examination of the physical and chemical properties of the drug substance, both in isolation and in conjunction with various excipients. The fundamental aim of preformulation activities is to establish a robust rationale for formulating strategies, which significantly aids in mitigating potential challenges that may arise during the creation of an acceptable product, ultimately enhancing both the quality and performance of the drug formulation. It is imperative to conduct a comprehensive and detailed analysis of the complete physicochemical profile of the active ingredients prior to initiating any formulation development. This thorough understanding serves as a solid cornerstone upon which subsequent formulation approaches are constructed, ensuring the optimization of the final product's efficacy and reliability in therapeutic applications [15].

Formulation of colon targeted matrix tablet of Emorfazone

The formulation of granules for the compression of colon-targeted matrix tablets of Emorfazone encompasses a series of vital steps meticulously designed to ensure both uniformity and efficacy of the final product.

Weighing The process commences with the precise weighing of all raw materials, where each constituent is measured with utmost accuracy. This precision is paramount, as even the slightest discrepancies can profoundly affect the therapeutic potency of the formulation.

Sifting Emorfazone in conjunction with Eudragit S100 and ethyl cellulose, is sifted through a 60 # mesh to effectively eliminate any clumps and promote a consistent particle size, which is critical for achieving reliable and uniform compression. Simultaneously, lactose (DCL 21) is sifted through a 40 # mesh to ensure optimal incorporation within the blend, enhancing the overall formulation.

Mixing The sifted powders are combined thoroughly in a clean polythene bag for a duration of ten minutes to ensure a homogenous mixture. The choice of a polythene bag facilitates ease of handling while significantly mitigating the risk of contamination, making it an ideal option in pharmaceutical preparations.

Lubrication The dried granules are evenly lubricated with talc and magnesium stearate, which enhances flow properties during the compression phase and prevents adhesion to the equipment. These lubricants are meticulously blended into the granules over an additional five minutes, ensuring uniform distribution throughout the entire mixture.

Compression Ultimately, the thoroughly lubricated blend is subjected to compression, achieving an average weight of 450 mg with a punch of 14.2 mm in diameter. This critical compression process transforms the granulated mixture into solid tablets, ensuring both mechanical integrity and the effective release of Emorfazone as intended in the colon. By meticulously adhering to these systematic procedures, the preparation of granules for the compression of colon-targeted matrix tablets of Emorfazone not only satisfies stringent pharmaceutical standards but also underscores the essential importance of each component in successfully developing an effective final product[16].



**Nandyala.Thirumalesh and Jyosna****Formulation Trial Batches (Table: 1)****Percentage of Ingredients Used In Trial Batch Formulations (Tablet: 2)****Coating Formula**

Composition of Ingredient for Enteric Coating (Tablet: 3)

Evaluation of Post-Compression Parameters**General Appearance**

The analysis of the compressed tablets revealed that they were entirely devoid of any imperfections, such as cracks, depressions, or pinholes. Furthermore, the tablets displayed a remarkable consistency in their coloration and luster across the entirety of their surface, resulting in a highly aesthetically pleasing product. The tactile experience was further accentuated by an exquisitely smooth surface texture, inviting engagement and enhancing the overall quality perception.

Hardness

The structural integrity of tablets is of paramount importance, necessitating a specific level of hardness to endure the rigorous demands encountered during manufacturing, packaging, and shipping. Tablet hardness is defined as the force required to fracture a tablet in a diametric compression test, meticulously assessed using a Monsanto hardness tester. This comprehensive evaluation process ensures that each formulation not only meets but exceeds the established durability standards, thereby guaranteeing optimal performance throughout its lifecycle.

Thickness

Ensuring the precise thickness of tablets is essential for achieving optimal compatibility with packaging. This critical parameter is significantly influenced by a variety of factors, including die fill, the distribution of particle sizes, and the packing density of the compressed material mixture. When the die fill is maintained at a consistent level, any fluctuations in compressive load will have a direct and noticeable impact on the resultant thickness. It is crucial to uphold this thickness within a stringent tolerance of $\pm 5\%$ from a predetermined standard value. Moreover, any inconsistencies that emerge within a specific production lot should be minimal enough to go unnoticed by the untrained eye of consumers. The thickness of each formulation was meticulously measured using a digital vernier standard, ensuring that quality remains uniformly high and consistent throughout the entire batch.

Friability

Friability is an indispensable measure of a tablet's resistance to abrasive forces, articulated as a percentage of weight loss after undergoing a rigorous and standardized testing procedure. This evaluation necessitates that tablets are subjected to specific levels of abrasion over a defined duration, allowing for a comprehensive assessment of their durability throughout various stages, including handling, coating, packing, and transportation. The Roche friabilator emerges as a central apparatus in this analytical process, adeptly exerting combined forces of abrasion and shock upon the tablets. Functioning within a plastic chamber that rotates at a steady speed of 25 revolutions per minute (rpm), this device facilitates the tablets' descent from a height of 6 inches with each rotation. During the testing sequence, a carefully selected sample of twenty tablets is meticulously weighed, placed into the friabilator, and subjected to 100 revolutions—equating to 4 minutes of intensive mechanical stress. Following this procedure, the tablets are systematically de-dusted and reweighed to determine the extent of weight loss. Conventionally, a weight loss threshold ranging between 0.5% and 1% is recognized as acceptable for uncoated tablets, signifying satisfactory resistance to mechanical stress while maintaining their structural integrity.

Disintegration Test

The United States Pharmacopeia (USP) disintegration test mandates that each tablet be accurately positioned within one of the six tubes of the disintegration apparatus. The test is conducted without the inclusion of disks, utilizing simulated gastric fluid at a pH of 1.2 and a controlled temperature of 37°C for a duration of two hours. Upon the completion of this initial phase, the tablets undergo a meticulous evaluation and must exhibit no signs of



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disintegration, cracking, or softening. Following this assessment, disks are introduced, and the apparatus resumes its operation with simulated intestinal fluid at a pH of 7.4, which is carefully maintained at 37°C, for the duration specified in the corresponding monograph. This systematic and rigorous approach ensures a comprehensive evaluation of the tablet's capacity to disintegrate under conditions that closely mimic the physiological environment of the human digestive system.

Weight Variation Test

In the weight variation test, a rigorous methodology is employed to ensure the precise measurement of tablet weights. A random selection of twenty tablets is individually weighed to calculate the average weight, which subsequently serves as a critical reference point for subsequent comparisons. It is imperative that no more than two individual tablet weights deviate from this average by more than the designated percentage, and none should exceed double that percentage. This meticulous procedure is essential for affirming the uniformity and consistency of tablet formulations, thereby guaranteeing that each dosage meets the established pharmacological standards with utmost reliability[17].

Percentage Deviation for Weight Variation Test (Tablet: 4)**In-Vitro Dissolution Studies**

The release of Emorfazone from tablets was meticulously evaluated using the USP Dissolution Testing Apparatus 2, commonly recognized as the paddle method. The investigation commenced with a thorough dissolution phase involving 900 ml of 0.1N HCl, which was precisely maintained at a controlled temperature of $37 \pm 0.5^\circ\text{C}$, alongside a stirring speed of 100 rpm for an initial duration of 2 hours. Following this period, the medium was systematically replaced with a 7.4 pH phosphate buffer, thereby allowing the dissolution process to continue for an extensive total duration of 24 hours. At carefully predetermined intervals, a 5 ml aliquot was methodically withdrawn from the dissolution vessel and immediately replaced with fresh buffer to ensure volume consistency. The extent of drug release was accurately determined by measuring the absorbance of the withdrawn samples relative to a standard. The findings of this comprehensive study were diligently organized and presented in tabular form to facilitate in-depth analysis and interpretation.

Stability Studies

The stability of a formulation is defined as the duration extending from its manufacture to the point at which its chemical or biological activity retains at least the specified level of labeled potency, while its physical attributes remain unchanged or exhibit only minimal alterations. A comprehensive stability analysis is indispensable for the formulation and development of pharmaceutical products, as it thoroughly assesses both their physical and chemical stability, along with their safety for utilization. The primary objective of stability testing is to furnish valuable insights into how the quality of a drug substance or product varies over time when subjected to an array of environmental factors such as temperature, humidity, and light. This vital information is crucial for establishing appropriate storage conditions and determining the optimal shelf life of the product[18].

Accelerated stability studies

The evaluation of a product's degradation rate under standard room temperature conditions necessitates a considerable duration for thorough and accurate assessment. The International Conference of Harmonization (ICH) Guidelines, specifically outlined in the document entitled "Stability testing for new drug substances and products" (Q1A), meticulously delineate the critical requirements for stability testing pertinent to drug registration applications across the European Union and the United States. To facilitate accelerated stability testing, it is essential to adhere rigorously to these ICH guidelines. In this particular investigation, formulation F6 was carefully packaged in high-density polyethylene containers and maintained in a meticulously controlled environment at a precise temperature of $40^\circ\text{C} \pm 2^\circ\text{C}$, coupled with a relative humidity of $75\% \pm 5\%$. The samples underwent systematic analysis for drug content and were subjected to in-vitro dissolution studies at carefully designated intervals of 1, 2, and 3 months, ensuring a comprehensive understanding of the formulation's stability profile[19,20].





RESULTS AND DISCUSSION

The current investigation centered on the sophisticated formulation of colon-targeted matrix tablets encapsulating Emorfazone through the efficient direct compression technique. The powder blend underwent a comprehensive series of evaluation tests, which included bulk density, tapped density, compressibility index, and Hausner's ratio, prior to its transformation into tablet form. Subsequently, the compressed tablets were meticulously assessed for a range of parameters, including thickness, hardness, friability, weight variation, assay, in-vitro dissolution profiles, and accelerated stability assessments. To ensure a precise targeted release at pH 7.4, the tablets were elegantly coated with enteric polymers, specifically Eudragit FS 30 D. Rigorous in-vitro dissolution studies were performed on both the uncoated and coated tablets, followed by strategic packaging in blister packs, which were then subjected to accelerated stability testing. The findings were systematically documented and illustrated in well-organized tables and figures.

Preformulation Studies: (Fig: 1)

FT-IR Spectra of pure Emorfazone

FT-IR Spectra of FT-IR Spectra of pure Emorfazone with Excipients (Fig:2)

Evaluation of Lubricated Powder Blend (Tablet: 5)

Evaluation of Finished Product (Uncoated) (Tablet: 6)

In-vitro Dissolution Profile of Enteric Coated Tablets (Tablet: 7)

Graphical representation of *in-vitro* drug release (Fig: 3)

F1 The methodology employed in this trial is direct compression. The specific quantities of the components utilized are as follows: Eudragit S 100 at a concentration of 80 mg/unit, Ethyl cellulose at 60 mg/unit, and Lactose DCL 21 at 50 mg/unit. Furthermore, the amounts of Talc and magnesium stearate were each precisely measured at 5 mg/unit. However, it became evident that the hardness of the tablets exceeded the established specification limit, indicating a potential issue that requires further investigation.

F2 The modified formulation has led to a strategic reduction in the concentration of Eudragit S100 to 60 mg/unit and Ethyl cellulose to 55 mg/unit, while concurrently elevating the diluent concentration to 75 mg/unit. This deliberate adjustment has significantly enhanced the hardness of the tablets in comparison to the prior formulation. However, this improvement in mechanical strength has also resulted in an extended disintegration time that surpasses the specified limits, underscoring a delicate balance between tablet robustness and the efficacy of disintegration.

F3 The tablets successfully achieved the requisite hardness; however, their disintegration time exceeded the defined specification limits. To rectify this issue, the concentrations of Eudragit S100 and Ethyl cellulose were judiciously reduced to 50 mg/unit and 40 mg/unit, respectively, facilitating a decrease in tablet hardness. Concurrently, the concentration of the diluent was elevated to 100 mg/unit. This optimized formulation was selected for coating, and subsequent in-vitro dissolution studies revealed a release profile of $78.22 \pm 0.78\%$ at 24 hours.

F4 In trial 4, the concentrations of Eudragit S100 and Ethyl cellulose were strategically reduced to 35 mg/unit and 25 mg/unit, respectively, while Lactose DCL21 was increased to 130 mg/unit. This modification resulted in a notable improvement in the disintegration time of the tablets when compared to earlier formulations; however, it still unfortunately exceeded the established acceptable limits. Subsequently, the tablets underwent comprehensive in-vitro dissolution studies to meticulously evaluate their performance and effectiveness.

F5 The formulation adjustments included a strategic reduction in the concentrations of Eudragit S100 to 20 mg/unit and Ethyl cellulose to 15 mg/unit, accompanied by an elevation in Lactose DCL21 concentration to 154 mg/unit. Furthermore, the Magnesium stearate concentration was increased to 6 mg/unit, significantly enhancing the lubricating properties of the granules. Notably, the disintegration time of the tablets remained well within the



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established limits. The incorporation of triethyl citrate in the enteric coating phase was aimed at providing enhanced flexibility to the polymer. In the ensuing in-vitro dissolution studies, the tablets exhibited an impressive drug release percentage of $92.65 \pm 0.95\%$ at the 24-hour mark, reflecting a marked improvement over previous trial outcomes.

F6 The study focused on reducing the concentrations of Eudragit S 100 and Ethyl cellulose to 14 mg/unit and 10 mg/unit, respectively, while simultaneously augmenting the Lactose DCL21 concentration to 165 mg/unit. Following this adjustment, the tablets underwent a comprehensive in-vitro dissolution analysis, which revealed a remarkable drug release percentage of 98.51 ± 0.78 after a 24-hour period. This trial is duly recognized as a confirmatory study and will also be subjected to thorough stability evaluations to ensure efficacy and safety over time.

Stability Studies**Physical Parameters (Tablet: 8)**

The F-6 formulation of enteric coated tablets underwent a meticulous stability evaluation under precisely controlled conditions of $40^\circ\text{C} \pm 2^\circ\text{C}$ and $75\% \pm 5\%$ relative humidity. The results indicated that there were no significant alterations in color; however, a slight increase in both average weight and disintegration time was observed. The stability of the samples was systematically assessed at one-month intervals, effectively demonstrating the formulation's resilience and integrity over the duration of the study.

In-vitro Drug Release and Assay (Tablet: 9)

The stability study of the F6 formulation of enteric coated tablets was executed with precision. The tablets were carefully maintained under controlled conditions of $40^\circ\text{C} \pm 2^\circ\text{C}$ and $75\% \pm 5\%$ relative humidity for a period of three months. Assessments of drug release and assay indicated negligible fluctuations throughout the stability evaluation, thereby affirming the remarkable stability of the product over the entire duration of the study.

CONCLUSION

The preformulation studies unequivocally demonstrated that there was no interaction between the active pharmaceutical ingredient (API) and the selected excipients, thereby validating their compatibility and suitability for effective formulation. The Emorfazonematrix tablets were adeptly formulated utilizing the direct compression method, ensuring adherence to all defined pre-compression and post-compression parameters in accordance with pharmacopoeial standards. Remarkably, the tablets were coated with the enteric polymer Eudragit FS 30D through the pan coating technique, significantly enhancing the stability of the drug under acidic conditions while promoting rapid and efficient drug release in alkaline environments. Among the various formulations evaluated, formulation F6 distinguished itself by achieving an impressive drug release rate of 98.51% over a 24-hour period, underscoring its efficacious profile for therapeutic applications. This formulation not only provided robust protection to the drug core in acidic conditions but also exhibited a rapid release kinetics conducive to intestinal absorption. As a result, formulation F6 emerges as a highly promising candidate for addressing inflammatory bowel diseases, such as ulcerative colitis, while effectively mitigating the risks of gastric irritation and ulceration in patients with a prior history of such conditions. This advancement points to a significant enhancement in the formulation strategies available for Emorfazone highlighting its potential clinical benefits in therapeutic settings.

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Table: 1. Formulation Trial Batches

S. No	INGREDIENTS	QUANTITY OF INGRIDIENTS					
		F1	F2	F3	F4	F5	F6
1	Emorfazone	250	250	250	250	250	250
2	Eudragit S-100	80	60	50	35	20	14
3	Ethyl cellulose	60	55	40	25	15	10
4	Lactose (DCL 21)	50	75	100	130	154	165
5	Talc	5	5	5	5	5	5
6	Magnesium stearate	5	5	5	5	6	6
Total weight (mg)		450	450	450	450	450	450

Tablet: 2. Percentage of Ingredients Used In Trial Batch Formulations

S. No	INGRIDIENTS	QUANTITY OF INGRIDIENTS (%/tab)					
		F1	F2	F3	F4	F5	F6
1	Emorfazone	55.55	55.55	55.55	55.55	55.55	55.55
2	Eudragit S-100	17.77	13.33	11.11	7.77	4.44	3.11
3	Ethyl cellulose	13.33	12.22	8.88	5.55	3.33	2.22
4	Lactose (DCL 21)	11.11	16.66	22.22	28.88	34.22	36.66
5	Talc	1.11	1.11	1.11	1.11	1.11	1.11
6	Magnesium stearate	1.11	1.11	1.11	1.11	1.33	1.33





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Tablet: 3.

S. No	Ingredients	Quantity/1000 Tablet (gm)
1	Eudragit FS 30 D	125
2	Triethyl citrate	1.875
3	Talc	18.75
4	Purified water	120

Tablet: 4. Percentage Deviation for Weight Variation Test

S. No	Average weight of tablet(mg)	Percentage deviation
1	80 mg or less	± 10.0
2	More than 80 mg but less than 250 mg	± 7.5
3	250 mg or more	± 5.0

Tablet: 5. Evaluation of Lubricated Powder Blend

Formulation Code	Bulk density (gm/cm ³)	Tapped density (gm/cm ³)	Carr's Index (%)	Hausner's ratio	Angle of repose (degree)	Moisture content (%)
F1	0.35±0.02	0.40 ± 0.01	11.73±0.79	1.12 ±0.15	29°58'±0.53	1.15 ± 0.05
F2	0.31±0.03	0.35 ± 0.05	12.10±0.54	1.13 ±0.28	33°23'±0.35	1.28 ± 0.02
F3	0.37 ± 0.01	0.42 ± 0.06	13.63±0.38	1.13 ±0.12	30°96'±0.19	1.42 ± 0.02
F4	0.38 ± 0.07	0.40 ± 0.08	11.57±1.05	1.14± 0.85	31°26'±0.60	1.21 ± 0.06
F5	0.35 ± 0.10	0.44 ± 0.06	12.60±0.86	1.12 ±0.74	29°35'±0.48	1.33 ± 0.03
F6	0.41± 0.06	0.46± 0.01	12.98±0.65	1.13 ±0.24	31°05'±0.25	1.15 ± 0.02

All values are expressed as mean ± standard deviation, n=3

Tablet: 6. Evaluation of Finished Product (Uncoated)

Parameters	F1	F2	F3	F4	F5	F6
Average weight (mg)	450±1.18	450±0.89	450±2.00	450±0.61	450±2.68	450±0.21
Thickness (mm)	3.4± 0.16	4.2±0.09	4.7± 0.14	5.9± 0.12	5.7±0.01	5.9 ± 0.16
Hardness (kg/cm ²)	12.6 (± 0.15)	9.4 (± 0.22)	6.2 (± 0.30)	5.2 (± 0.32)	6.0 (± 0.30)	5.8 (± 0.11)
Friability (%)	0.36	0.41	0.39	0.31	0.35	0.33
Disintegration time (min)		24'46''	17'42''	14'45''	8'42''	7'18''
Assay (%)	99.34	99.2	98.51	99.85	99.53	100.21

All values are expressed as mean ± standard deviation, n=3

Tablet: 7. In-vitro Dissolution Profile of Enteric Coated Tablets

Dissolution Media	Sampling time	Cumulative% drug release in different trials			
		F3	F4	F5	F6
Simulated gastric fluid (0.1 HCL)	2 Hrs	1.07	1.60	1.83	2.00
Simulated Intestinal Fluid (7.4pH Phosphate buffer)	5 Hrs	7.43±0.32	8.804±0.13	10.09±0.78	11.58±0.13
	8 Hrs	10.09±0.78	12.74±0.43	16.76±0.13	20.72±0.43
	12 Hrs	26.97±0.52	36.82±1.35	49.76±0.57	53.80±0.78
	16 Hrs	45.18±0.95	61.24±0.52	72.21±0.95	81.51±0.57
	20 Hrs	61.24±0.57	72.19±0.43	84.31±0.57	90.71±0.95
	24 Hrs	78.22±0.78	82.43±0.57	92.65±0.95	98.51±0.78





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Tablet: 8. Physical Parameters

Post compression Parameters	Storage condition: 40°C± 2°C /75±5%RH			
	Initial	1 st month	2 nd month	3 rd month
Description	White coloured Enteric coated tablet	White coloured Enteric coated tablet	White coloured Enteric coated tablet	White coloured Enteric coated tablet
Average weight (mg)	477±0.21	477.38 ± 0.003	477.52 ± 0.006	477.67 ± 0.04
Disintegration time (minutes)	219'63''±0.03	219'13''±0.08	220' 38''±0.08	221' 7'' ±0.05

*All the values are expressed as mean's, n=3.

Tablet: 9. In-vitro Drug Release And Assay

Formulation	Time in hrs	Storage condition 40°C±2°C /75±5%RH					
		In-vitro drug release (%)				Assay (%)	
		Initial	1 month	2 month	3 month	Initial	After Stability
F6	24	98.51	98.31	97.42	97.28	100.21	100.1

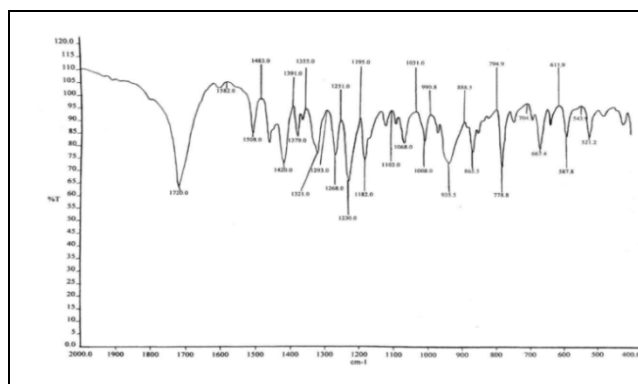


Fig: 1. Preformulation Studies :FT-IR Spectra of pure Emorfazone

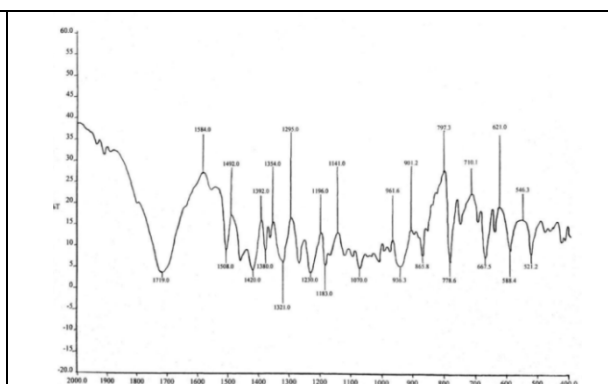


Fig: 2. Ft-Ir Spectra of FT-IR Spectra of pure Emorfazone with Excipients

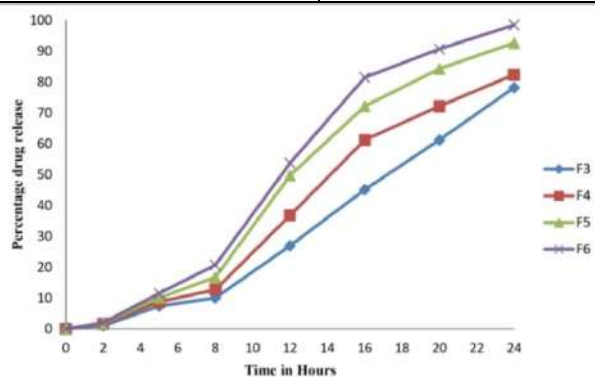


Fig : 3. Graphical representation of in-vitro drug release





RESEARCH ARTICLE

Overview of Dementia

Ranjitha¹ and Vinciya.T^{2*}

¹Assistant Professor, Department of Pharmacognosy, Dr.M.G.R Educational and Research Institute, (Deemed to be University) Maduravoyal, Chennai, Tamil Nadu, India.

²Assistant Professor, Department of Pharmacology, Dr.M.G.R Educational and Research Institute, (Deemed to be University) Maduravoyal, Chennai, Tamil Nadu, India.

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*Address for Correspondence

Vinciya.T

Assistant Professor,
Department of Pharmacology,
Dr.M.G.R Educational and Research Institute,
(Deemed to be University) Maduravoyal,
Chennai, Tamil Nadu, India.
E.Mail: vinciya.pharm@drmgrdu.ac.in;



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ABSTRACT

Cognitive decline and behavioral abnormalities are hallmarks of dementia, especially Alzheimer's disease (AD), a complicated neurological disorder. Several important risk factors for dementia are identified by meta-analyses and systematic reviews. Risk factors for cardiovascular disease, such as diabetes mellitus, dyslipidemia, and hypertension, are linked to an increased risk of dementia. Mild cognitive impairment (MCI) and severe phases are at opposite ends of the clinical continuum of dementia. In order to address dementia and create a more accepting and caring environment for those who live with the illness, healthcare professionals, caregivers, legislators, and society at large must work together.

Keywords: Alzheimer's disease, dyslipidemia, hypertension, environment.

INTRODUCTION

Progressive cognitive decline and neuropsychiatric symptoms are hallmarks of dementia, a syndrome that is most frequently caused by Alzheimer's disease (AD), which accounts for 60–80% of cases [1]. An estimated 24 million people worldwide suffer from dementia, and until 2040, this number is predicted to grow every 20 years. The neuropathological features of the AD brain include intracellular neurofibrillary tangles and widespread and neuritic extracellular amyloid plaques, which are often encircled by dystrophic neurites. These characteristic diseases are frequently accompanied by reactive microgliosis and the death of synapses, neurons, and white matter [2]. Lewy body dementia, the dementia-Parkinson complex, frontotemporal dementia, and vascular dementia are examples of neurodegenerative dementias. The prevalence of other dementia subtypes is less than 1%, and the epidemiological



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markers that are now available are not very reliable [3]. Dementia patients often live for seven to ten years after their symptoms start. Dementia is one of the biggest problems of this century and imposes a great strain on society as well as on caretakers [4]. Although there isn't a cure or disease-modifying treatment for dementia at this time, improved policies can help those who have the illness, and their families cope with it and make sure they have access to high-quality social and health care [1].

"The Global Burden of Dementia: Prevalence, Incidence, and Impact"

With an expected 51.6 million afflicted globally in 2019 [5], the burden of dementia is rising quickly. In sub-Saharan Africa, prevalence rates range from 2–4%, while in Latin America, they range from 8.5% [6]. Prevalence rates are often greater in high-income nations; Japan leads the pack with 3,079 cases per 100,000 [5]. Dementia is expected to affect 75.62 million individuals in 2030 and 135.46 million in 2050, roughly doubling every 20 years [7]. In low- and middle-income nations, where 58% of dementia cases were reported in 2010, this trend is anticipated to climb to 71% by 2050. With worldwide expenses estimated at US \$818 billion in 2015 and expected to reach US \$1 trillion by 2018, the economic impact is significant[6].

Pathophysiology of dementia

Cognitive decline and behavioral abnormalities are hallmarks of dementia, especially Alzheimer's disease (AD), a complicated neurological disorder [8]. Cerebrovascular disease and protein aggregation, including amyloid- β plaques and neurofibrillary tangles, are part of the pathogenesis [9]. Although the precise triggers are yet unknown, the amyloid cascade hypothesis postulates that aberrant amyloid- β synthesis starts secondary events (10). Cholinergic dysfunction, changes in glutamatergic neurotransmission, anomalies in tau proteins, oxidative stress, and calcium dysregulation are other important pathways [11]. Memory problems and other cognitive impairments are caused by these processes, which also cause neuronal death and damage. The clinical picture of dementia in older adults is complicated by the prevalence of mixed neuropathologies [9]. Developing efficient diagnostic methods and therapies for dementia, especially AD, requires an understanding of these fundamental mechanisms.

Pathophysiology of Dementia(Fig: 1)**Risk Factors for Dementia**

Several important risk factors for dementia are identified by meta-analyses and systematic reviews. Risk factors for cardiovascular disease, such as diabetes mellitus, dyslipidemia, and hypertension, are linked to an increased risk of dementia [12]. There is strong evidence linking type 2 diabetes to vascular dementia and Alzheimer's disease. Dementia risk is also highly associated with depression, especially in later life, and decreased social interaction frequency [13]. Although more thorough longitudinal studies are required, environmental factors like air pollution, pesticide exposure, and vitamin D insufficiency may increase the incidence of dementia [14]. Most of the data comes from cardiovascular research, but the quality and geographic representativeness of the evidence vary depending on the risk variables. While not all relationships can be proven to be causal, controlling modifiable risk factors, particularly cardiovascular risks, may help prevent dementia and cognitive decline[12].(Fig: 2).

The Role of Genetics in Dementia

Age-related dementias, especially frontotemporal dementia (FTD) and Alzheimer's disease (AD), are significantly influenced by genetics. While genome-wide association studies have found other risk genes, family forms of AD are associated with mutations in the APP, PSEN1, and PSEN2 genes. Mutations in the MAPT, GRN, VCP, CHMP2B, TARBDP, FUS, and C9orf72 genes are linked to FTD (15). Most instances are caused by intricate combinations between genetic and environmental variables, however others have a definite genetic etiology with autosomal dominant inheritance. Those with a family history have a higher lifetime risk of dementia (20%) than the general population (10%)[16]. By modifying gene expression without modifying DNA sequences, epigenetic processes such as DNA methylation, non-coding RNAs, and chromatin remodeling also contribute to the pathophysiology of AD and FTD[17].



**Ranjitha and Vinciya****The Clinical Spectrum of Dementia**

Mild cognitive impairment (MCI) and severe phases are at opposite ends of the clinical continuum of dementia. Many studies concentrate on early to moderate dementia, however people with severe dementia maintain environmental interactions and display individual distinctions rather than being in a "vegetative state". Cognitive and behavioral state in advanced dementia can be measured using assessment instruments such as the Severe Impairment Battery and the Hierarchic Dementia Scale[18]. Even in very moderately impaired people who don't quite fulfill MCI criteria, the degree of cognitive impairment in day-to-day functioning and neuropsychological test performance can predict the chance of an AD diagnosis within five years[19]. Numerous prognostic factors influence the progression from MCI to dementia, and neuropsychological profiles are important in forecasting results[20]. Correlating clinical data with findings from neuroimaging, neurochemistry, and neuropathology requires an understanding of the full spectrum of dementia[18].

Diagnostic Approaches for Dementia

Dementia diagnostic techniques have changed dramatically, incorporating a range of instruments and techniques. Current methods include biomarker analysis, neuroimaging, cognitive testing, and thorough clinical examinations. Using history taking, physical examinations, and cognitive tests, primary care physicians are essential in early diagnosis [21]. Although there are obstacles to their practical implementation, cutting-edge methods like PET neuroimaging, genetics, and proteomics are being included in updated diagnostic criteria [22]. Although biomarkers can increase the accuracy of diagnosing Alzheimer's disease, a comprehensive clinical evaluation is still necessary[23]. New spectroscopic methods that show promise for dementia detection and monitoring include Raman and infrared spectroscopy. Despite these developments, dementia is still difficult to diagnose because of its variable symptoms, overlapping conditions, and potential for many etiologies, especially in elderly people [22].

Challenges in Diagnosing Dementia

There are many difficulties in diagnosing dementia,

- Early and precise diagnosis is crucial for effective therapy [24]
- Symptoms vary and overlap with other illnesses, hindering diagnosis [22].
- Dementias like Alzheimer's and frontotemporal dementias pose diagnostic challenges [25]

Diagnostic skills have been enhanced by recent developments in biomarker research, such as proteomics, genomics, and neuroimaging. However, to improve biomarker analysis's consistency and dependability, global initiatives and method standardization are required. Although the integration of novel technologies such as PET scanning and biomarkers into updated diagnostic criteria exhibits potential, its clinical implementation is hindered by accessibility and availability issues (26). Research is still being conducted to improve diagnostic methods and get over these obstacles in dementia diagnosis.

Types of Dementia

Multiple underlying reasons contribute to dementia, a degenerative cognitive illness. The four most prevalent kinds are (Table: 1)

Current Treatment Options for Dementia

Pharmacological and non-pharmacological therapies are currently available as dementia therapy alternatives.

Non-pharmacological methods

- Behavioral therapy.
- Sensory stimulation.
- Cognitive and emotion-oriented interventions are advised.
- Music therapy and therapies based on functional analysis have demonstrated notable benefits in the behavioral and psychological symptoms of dementia (BPSD).(31)



**Ranjitha and Vinciya****Pharmacological methods**

- Cholinesterase inhibitors like donepezil and galantamine.
- Both analgesics and antipsychotics may help control BPSD,
- Antipsychotics should be taken with caution because of their side effects. [32]

The origin, symptom profile, and stage of dementia all influence treatment strategies. Although dementia cannot be cured, these treatments try to reduce symptoms, delay the disease's progression, and enhance quality of life.

Cognitive Training and Rehabilitation for Dementia

Interventions for cognitive abnormalities in people with mild to moderate Alzheimer's disease and vascular dementia include cognitive training (CT) and cognitive rehabilitation (CR). The total body of evidence supporting CT is still small and of low to intermediate quality, despite certain studies suggesting possible advantages. The meta-analysis found no differences between the control conditions and cognitive training on any of the primary or secondary results that were analyzed. Because the measures employed for each outcome varied, most comparisons were made using the standardized mean difference approach. Standardized mean differences between cognitive training and control conditions varied from -0.11 to 0.31, depending on the analysis. Additionally, it was generally agreed that the evidence from cognitive training programs up to this point was of poor to intermediate quality. None of the included studies evaluated longer-term outcomes associated with the trajectory of dementia, such as dementia severity and rates of admission to residential care[33]. Results from CT have been conflicting; some studies have found that it improves global cognition and training-specific skills, especially when used in more rigorous programs. There isn't much proof of better day-to-day functioning, though. Despite being less researched, CR has produced encouraging initial findings in one high-caliber RCT [34]. Numerous trials may have produced exaggerated positive results due to methodological flaws such small sample sizes, ambiguous randomization techniques, and multiple testing [35]. More well-planned research is required to offer more conclusive proof of CT and CR's effectiveness.

Supporting Caregivers of People with Dementia

To manage care and lower societal expenditures, it is essential to support those who are caring for individuals with dementia. Numerous interventions have demonstrated efficacy in enhancing the well-being of caregivers and postponing the institutionalization of individuals receiving care. These consist of cognitive behavioral therapy, occupational therapy, and psychoeducation [36]. Supportive group-based therapies have been shown to have a favorable effect on caregivers' psychological morbidity [37]. With features including peer engagement, professional contact, information providing, decision support, and psychological support, internet-based interventions are becoming increasingly valuable resources. These therapies have the potential to lessen caregiver burden, anxiety, and depression, despite the generally poor quality of the research. Online psychological support and tailored information seem especially helpful. All things considered[36], helping caregivers through a variety of interventions can enhance both their own and the dementia patient's well-being while possibly lowering dependency on official care systems.

Future Directions and Research

Elaborate on the emerging trends and gaps in dementia research, including the focus on midlife, genetic risk factors, neuronal resilience, drug-target validation, clinical trial approaches, geographical and diversity gaps, life-course and multi-domain approaches, and the use of big data.

1. Search extensively for contemporary research that highlights midlife as a crucial time for the development of early Alzheimer's disease pathology, paying particular attention to the structural and cognitive alterations in the brain that have been found..[38]
2. Examine the present status of studies on the conversion of genetic risk factors for dementia into biological processes and possible targets for treatment.
3. Examine the most recent research on neuronal resilience in relation to dementia, including its contributing causes and potential applications in therapy or prevention.
4. Examine current developments and ongoing difficulties in drug-target validation for dementia, taking into account both new strategies and the causes of previous failures.



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5. Examine cutting-edge and enhanced techniques being used in dementia clinical trials, such as biomarker enrichment, adaptive designs, and novel outcomes. [39]
6. Recognize and evaluate the lack of diversity and regional gaps in the present dementia research, and investigate efforts to close these gaps.
7. Look into research that use multi-domain and life-course approaches to comprehend the intricate interactions between variables affecting dementia risk and to guide population-level therapies. [40]
8. Examine the application of big data in dementia research, detailing its potential for improving prevention, prediction, and personalized treatment, while also outlining the technical, ethical, and regulatory hurdles that need to be overcome. [41]

New Diagnostic and Therapeutic Approaches for Dementia: Future Directions"

Considerable progress has been made in diagnosing and treating Alzheimer's disease (AD) and other dementias, according to recent studies. The pathological hallmarks of AD, tau tangles, The microtubule-associated protein tau lies at the heart of the tau hypothesis of Alzheimer's dementia (AD). In neuron axons, tau often stabilizes microtubules. Neurofibrillary tangles (NFTs) and microtubule breakdown are caused by unchecked tau phosphorylation in AD. Despite being essential to the pathophysiology of AD, the tau hypothesis is intimately related to the amyloid hypothesis and cannot fully account for all symptoms. According to recent studies, tau pathology may be triggered by amyloid-beta aggregation. Tau aggregates may be targets for early diagnosis and treatment. The goals of current treatment approaches are to stabilize microtubules, enhance tau clearance, or prevent tau phosphorylation or aggregation and amyloid-beta (A β) plaques, are the focus of current methods [42]. While treatment interventions investigate anti-amyloid and anti-tau techniques, novel diagnostic tools strive for early diagnosis (43). Despite advancements, there are still obstacles in the way of creating viable biomarkers for early diagnosis and disease-modifying treatments. Current drugs do not stop the progression of the disease, although they do provide some symptomatic relief. To create more thorough diagnostic and treatment methods, future directions may involve merging several disease pathways. Innovative treatments are becoming more and more necessary as the population ages. To develop drugs with disease-modifying qualities, ongoing clinical research focuses on addressing the underlying pathogenic pathways[44].

Addressing the Global Impact of Dementia

One major worldwide health concern is dementia, which has

- 46.8 million cases globally in 2015
- \$818 billion in expenses
- 131.5 million cases are expected to occur by 2050[45]

Global Reaction

1. More than 20 countries have national dementia policy.
2. Research and reports from the World Health Organization (WHO)
3. G8 gatherings to talk about dementia; a thorough action plan developed by an international committee [46]

Suggestions for an Action Plan

1. Improving healthcare systems: To better care for individuals with dementia, healthcare infrastructure should be strengthened.
2. Increasing research funding: To better understand dementia and create effective treatments, approximately 1% of annual illness expenses should be allocated to research.
3. Implementing risk reduction strategies: Putting strategies in place to lower the risk of dementia, such as controlling chronic diseases and encouraging healthy lifestyles[47].
4. Building a competent workforce: Educating medical personnel to offer dementia patients excellent care.





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Advancements and Difficulties

1. Despite the advancements, more work must be done to combat the escalating dementia crisis:
2. More money is needed to support healthcare services and research.
3. To give dementia patients better treatment, healthcare systems must be changed[46].
4. Greater awareness and understanding of dementia are necessary to reduce stigma and promote supportive communities.

CONCLUSION

A complicated and progressive illness, dementia has a big influence on people, families, and healthcare systems. Early diagnosis, efficient management, and supportive care techniques are crucial for enhancing the quality of life for individuals impacted by dementia, as its prevalence is steadily increasing worldwide. Research advances highlight the significance of lifestyle changes, medical interventions, and community support, offering promise for improved treatments and possible preventive measures. In order to address dementia and create a more accepting and caring environment for those who live with the illness, healthcare professionals, caregivers, legislators, and society at large must work together.

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Table 1. Types of Dementia

S.no	Types	Characteristics	Pathology	Symotoms
1.	Alzheimer's Disease	• Progressive neurological illness. • defined by the buildup of neurofibrillary tangles and amyloid plaques in the brain. • causes a slow deterioration in behavior, memory, and cognitive function. • Memory loss, especially of recent events, is a common early sign. • Later phases include issues with executive processes, language, and spatial awareness.	Neurofibrillary tangles (abnormalities of tau proteins) and amyloid plaques (clumps of beta-amyloid proteins).	Personality changes, language difficulties, disorientation, confusion, and memory loss.[27]
2	Vascular Dementia	• Caused by diminished blood supply to the brain because of cerebrovascular disorders, stroke, or transient ischemic attacks (TIAs). • The location and degree of brain injury can affect the symptoms. • May show up as a sharp or gradual loss in cognitive function.	Brain tissue damage brought on by a shortage of blood flow.	Diminished judgment, Trouble organizing and planning, and issues focusing. Depending on where the strokes occurred, bodily symptoms may also be present.[28]





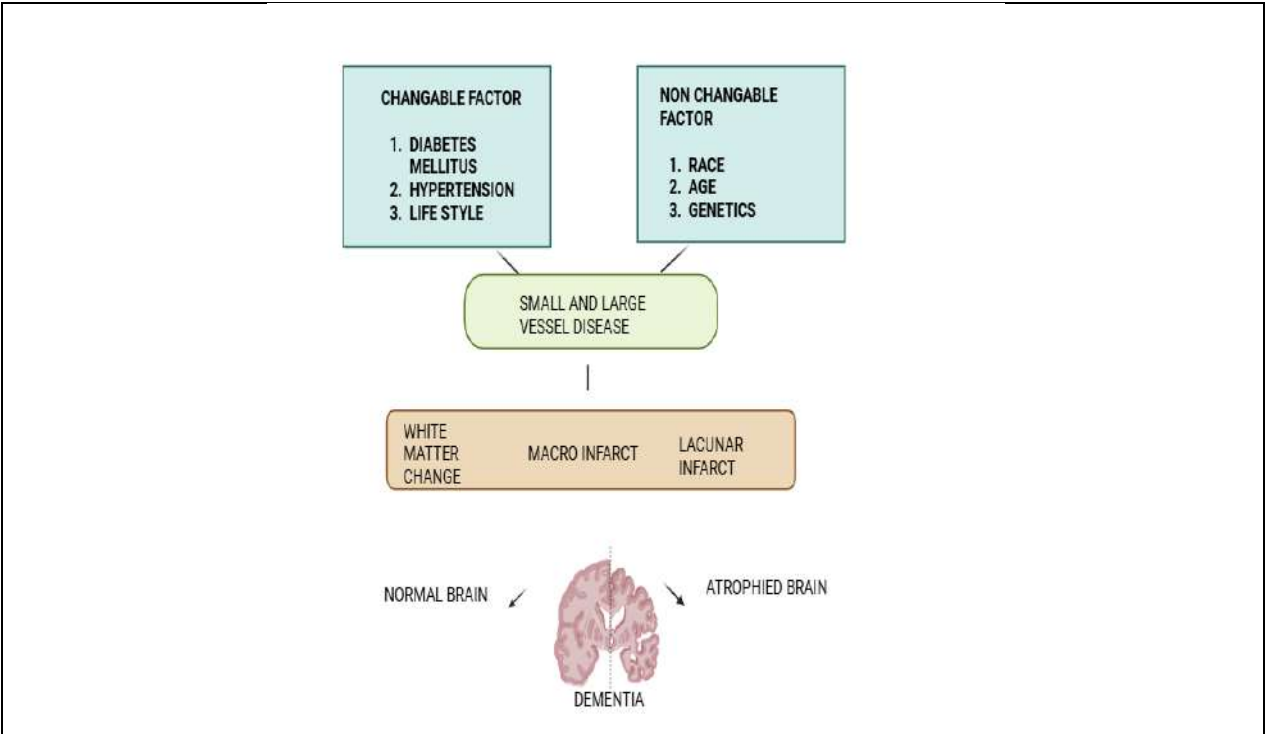
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		• Frequently linked to other vascular risk factors, including diabetes, heart disease, and high blood pressure.		
3.	Lewy Body Dementia	• Distinguished by the brain's aberrant protein deposits, or Lewy bodies. • Visual hallucinations, altered cognition, and parkinsonian symptoms (such as tremors and rigidity) are distinctive clinical characteristics. • Frequently misidentified as Parkinson's or Alzheimer's disease. • One prevalent early sign is REM sleep behavior disorder.	Alpha-synuclein protein aggregates, or Lewy bodies, are seen in brain cells.	Sleep problems, parkinsonian symptoms, Variations in alertness and attention, and Visual hallucinations.[29]
4	Frontotemporal Dementia	• Impacts the brain's frontal and temporal lobes, which oversee language, behavior, and personality. • Exhibits noticeable alterations in language, conduct, and/or personality. • Primary progressive aphasia (PPA) and behavioral variation frontotemporal dementia (bvFTD) are subtypes. • Usually manifests earlier than Alzheimer's.	Several protein anomalies, such as tau, TDP-43, and FUS	Alterations in behavior and personality (impulsivity, apathy), linguistic difficulties (word-finding issues, for example), and a reduction in executive functioning.[30]

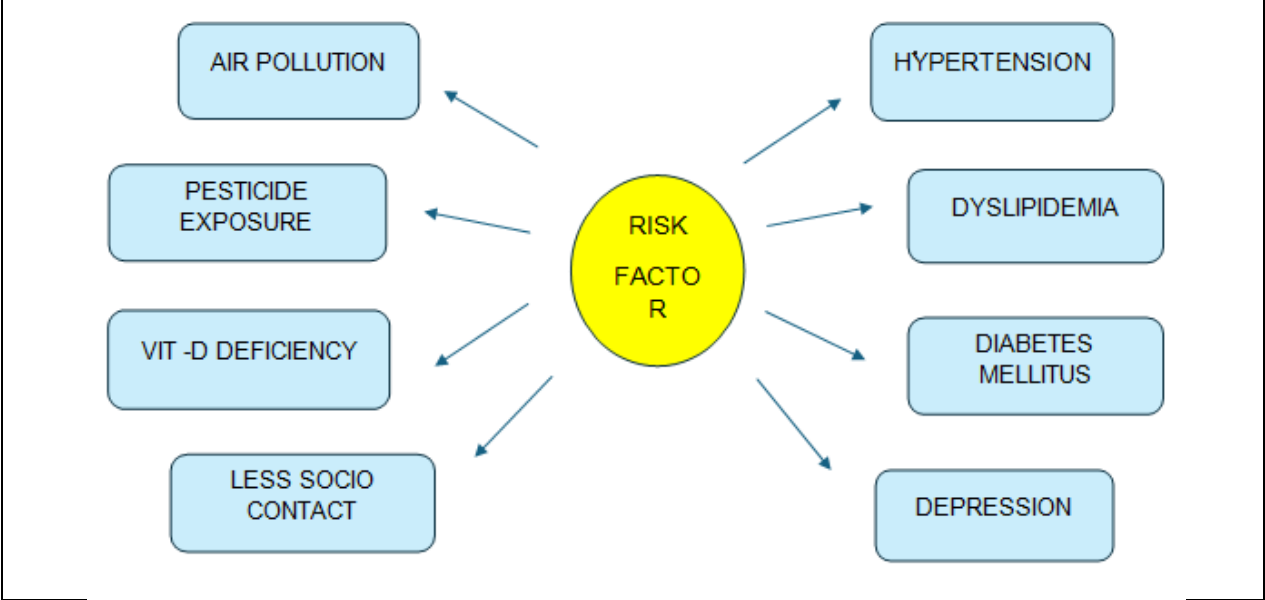




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Pathophysiology of Dementia



Risk Factors for Dementia





RESEARCH ARTICLE

Solving Intuitionistic Fuzzy Assignment Problem using Modified Best Candidate Method

M.Maragatham^{1*} and L.Suzane Raj²

¹Associate Professor of Mathematics, PG and Research Department of Mathematics, Thanthai Periyar Govt. Arts and Science College (Autonomous) (Affiliated to Bharathidasan University), Tiruchirappalli, Tamil Nadu, India.

²Research Scholar, PG and Research Department of Mathematics, Thanthai Periyar Govt. Arts and Science College (Autonomous) (Affiliated to Bharathidasan University), Tiruchirappalli, Tamil Nadu, India.

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*Address for Correspondence

M.Maragatham

Associate Professor of Mathematics,
PG and Research Department of Mathematics,
Thanthai Periyar Govt. Arts and Science College (Autonomous),
(Affiliated to Bharathidasan University),
Tiruchirappalli, Tamil Nadu, India.
E.Mail: maraguevr@yahoo.co.in



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ABSTRACT

An assignment problem is a special type of linear programming problem which deals with assigning various jobs to equal number of machines in such a way that the total cost is minimized by maximizing the profit. In this paper, we investigate a Intuitionistic Fuzzy number by using a ranking procedure. The classical assignment problem expounded is solved by adopting Modified Best Candidate method which optimizes the cost efficiency.

Keywords: Intuitionistic Fuzzy Number, Ranking Method, Defuzzification technique, Best Candidates , Assignment problem.

INTRODUCTION

Assignment problem is used in solving real world problems. Assignment problems is an impressive subject and is employed all the time in solving problems of engineering and management science and has been widely applied in both manufacturing and service systems. In an assignment problem, n jobs are to be performed by n machines depending on their efficiency to do the job. In an assignment problem C_{ij} denotes the cost of assigning the j^{th} job to the i^{th} person. We assume that one machine can be assigned exactly one job. Zadeh (1965) introduced the concept of fuzzy





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set to handle the problem of uncertainty in the evaluation of many real life situations. Atanassov. K introduced Intuitionistic fuzzy set (IFS) as an extension to the fuzzy set, where the degree of membership denoting a non-belongingness to a set is explicitly specified along with degree of membership of belongingness to the set. Annie Varghese, Sunny Kuriakose used Centroid Ranking technique to defuzzify the Triangular Intuitionistic Fuzzy Number. [4] Hlayel Abdallah Ahmad proposed a new method called as Best Candidate Method (BCM) of electing the candidates among the other candidates and finding the solution for the optimization problems. This method increases Solution optimality comparatively than other classic methods. [1] Furthermore with slight modifications Hlayel extended the method and proposed Modified Best Candidate method which reduces the time complexity and size scalability. In this paper we introduce the concept of solving Intuitionistic Fuzzy Assignment Problem Using Modified Best Candidate Method. The TIFN is defuzzified by Centroid ranking method and the obtained classic AP is solved by Modified BCM. The new method is illustrated with an numerical example.

Preliminaries

Fuzzy Sets

If X is a collection of objects denoted generically by x , then the fuzzy set A in X is a set of ordered pairs $\tilde{A} = \{(x, \mu_{\tilde{A}}(x)), | x \in X\}$ is called the membership function of x in A that maps X to the membership space M (When M contains only the two points 0 and 1, $\tilde{A}$ is non fuzzy and $\mu_{\tilde{A}}(x)$ is identical to the characteristic function of a nonfuzzy set). The range of the membership function is a subset of the nonnegative real numbers whose supremum is finite.

Normal Fuzzy Set:

A fuzzy set A of the universe of discourse X is called a normal fuzzy set implying that there exist at least one $x \in X$ such that $\mu_A(x) = 1$.

α – cut:

The α Cut of a α level set of a fuzzy set $\tilde{A}$ is a set consisting of those elements of the universe X whose membership values exceed the threshold level α

$$\tilde{A}_{\alpha} = \{x | \mu_{\tilde{A}}(x) \geq \alpha\}$$

Triangular Fuzzy Number

For a triangular fuzzy number $A(x)$, it can be represented by $A(a,b,c;1)$ with membership function $\mu(x)$ given by

$$\mu(x) = \begin{cases} \frac{(x-a)}{(b-a)}, & a \leq x \leq b \\ \frac{(c-x)}{(c-b)}, & b \leq x \leq c \\ 0 & \text{otherwise} \end{cases}$$

where $a \leq b \leq c$

Intuitionistic Fuzzy set:

An Intuitionistic fuzzy set (IFS) A assigns to each element x of the universe X a membership degree $\mu_A(x) \in [0,1]$ and an on - membership degree $\nu_A(x) \in [0,1]$ such

That $\mu_A(x) + \nu_A(x) \leq 1$. IFS is mathematically represented as $\{(x, \mu_A(x), \nu_A(x)) / x \in X\}$.

Intuitionistic Fuzzy number:

1. Let $A \in F(R)$ and A is normal that is there exists $x \in R$ such that $A(x) = 1$ then A is called a fuzzy number.
2. When ever $\lambda \in [0,1]$ then $A_{\lambda} = \{x, A(x) \geq \lambda\}$ is a closed interval denoted by

$$\lambda[A_{\lambda}^-, A_{\lambda}^+]$$

An Intuitionistic fuzzy subset $A = \{(x, \mu_A(x), \nu_A(x)) / x \in R\}$ of the real line is called an intuitionistic fuzzy number if $x_0, x_1 \in X$ such that $\mu_A(x_0) = 1, \mu_A(x_1) = 1$





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A is convex and μ_A is upper semi continuous and γ_A is lower continuous

Triangular Intuitionistic Fuzzy number:

A TIFN $\tilde{A}$ is an intuitionistic fuzzy set R with the following membership function $\mu_A(x)$ and non – membership function $\gamma_A(x)$:

$$\mu_A(x) = \begin{cases} \frac{x - a_1}{a_2 - a_1}, & \text{for } a_1 \leq x \leq a_2 \\ \frac{a_3 - x}{a_3 - a_2}, & \text{for } a_2 \leq x \leq a_3 \\ 0 & \text{otherwise} \end{cases}$$

$$\gamma_A(x) = \begin{cases} \frac{a_2 - x}{a_2 - a_1}, & \text{for } a_1' \leq x \leq a_2 \\ \frac{x - a_2}{a_3' - a_2}, & \text{for } a_2 \leq x \leq a_3' \\ 1 & \text{otherwise} \end{cases}$$

where

$$a_1' \leq a_1 \leq a_2 \leq a_3 \leq a_3' \text{ and } \mu_{\tilde{A}}^-(x), \gamma_{\tilde{A}}^-(x) \leq 0.5 \text{ for } \mu_{\tilde{A}}^-(x) = \gamma_{\tilde{A}}^-(x) \forall x \in R$$

This Triangular Intuitionistic Fuzzy Number (TIFN) is denoted by

$$\tilde{A}_{TIFN} = (a_1, a_2, a_3)(a_1', a_2', a_3') \text{ or } (a_1, a_2, a_3; a_1', a_2', a_3')$$

Centroid Ranking function

Centroid ranking function of Triangular Intuitionistic Fuzzy Number is given by

$$\tilde{A}_{TIFN} = (a_1, a_2, a_3; a_1', a_2', a_3')$$

$$R(A') = \frac{(a_3' - a_1')(-2a_3' - 2a_1') + (a_3 - a_1)(a_1 + a_2 + a_3) + 3(a_3'^2 - a_1'^2)}{3(a_3' - a_1' + a_3 - a_1)}$$

Problem Formulation:

Fuzzy Assignment Problem:

Let $\tilde{C}_{ij}$ be the triangular fuzzy numbers cost (payment) if j th job is assigned to p th person (see table). The problem is to find an assignment x_{ij} so that the total cost for performing all the jobs is minimum.

The chosen Fuzzy Assignment Problem (FAP) may be formulated into the following fuzzy linear programming problem:

$$\text{Min } Z = \sum_{i=1}^{i=n} \sum_{j=1}^{j=n} \tilde{C}_{ij} x_{ij}$$

subject to :





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$$(AP) = \begin{cases} \sum_{i=1}^n x_{ij} = 1, & j = 1, 2, \dots, n \\ \sum_{j=1}^n x_{ij} = 1 & i = 1, 2, \dots, n \end{cases}$$

$$\text{where } x_{ij} = \begin{cases} 1, & \text{if the } i^{\text{th}} \text{ person assign the } j^{\text{th}} \text{ job} \\ 0, & \text{otherwise} \end{cases}$$

Algorithm for Assignment Problem using Modified Best Candidate Method:

Our method is based on determination of the best candidates then eliminate the unwanted one in order to minimize the number of solution combinations to decide the optimal solution. However, we can notice that the solution approach using this method as one of LAP methods is divide into two phases. We will describe each phase and clarify the new modifications. The first Phase, is to elect the best candidates through choosing the prime candidate and its alternative in each row depending on the objective function (maximum or minimum value) then elect one candidate for the columns that have no candidate. There are no new modifications in this phase and the solution findings with steps are as follows:

Step1: Prepare the matrix. If the matrix is unbalanced, we balance it and we would not use the added row or column candidates in our solution process.

Step2: Determination of the best candidate, it is used for minimization problems (minimum cost) or maximization problem (maximum profit): Elect the best two candidates in each row, if the candidate is repeated more than one time then elect it also. Check the columns that do not have candidates and elect one candidate from them, if the candidate repeated more than one time elect it also.

The second phase, will introduce the following steps:

- At the end of phase one, an index matrix is produced that shows the position for each candidate.
- Find the direct combinations and calculating the cost for each.
- Check the unused candidates, by finding the possible candidates for them then calculate the cost for each.
- Find the optimal solution according to the objective function.

Algorithm to solve fuzzy assignment problem with Modified BCM:

Step 1: First test whether the given fuzzy cost matrix of an fuzzy assignment problem is a balanced/unbalanced. If not change this unbalanced assignment problem by adding the dummy row (s) / column(s) and the values for the entries are zero. If it is a balanced one

then go to step 2. If it is an unbalanced one then convert it into a balanced one and then go to step2.

Step 2: Replace the cost matrix C_{ij} with linguistic variables by triangular intuitionistic fuzzy numbers.

Step 3: Defuzzify the fuzzy cost by using Centroid ranking method.

Step 4: Replace TIFN by their respective ranking indices.

Step 5: Apply Modified BCM to determine the best combination to produce the lowest total weight of the costs, where elect the best two candidates in each row, if the candidate repeated more than one times elect it also. Check the columns that not have candidates and elect one candidate from them, if repeated more than once elect them.

Step 6: Construct an index matrix and find the direct combination. Calculate cost for each combination. Check for unused candidates, find the possible candidates for them and calculate cost for them also. Now find optimal solution from all the combinations.

Numerical Example

A Triangular Intuitionistic Fuzzy Assignment problem with three machines and three jobs with IF assignment cost. The cost matrix is given below whose elements are triangular IFNs





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Solution

The given problem is a balanced problem. Now we have to obtain $R(\tilde{C}_{ij})$ of each $(\tilde{C}_{ij})$ using ranking function as follows,

$$R(A'_i) = \frac{(a'_3 - a'_1)(a_2 - 2a'_3 - 2a'_1) + (a_3 - a_1)(a_1 + a_2 + a_3) + 3(a_3'^2 - a_1'^2)}{3(a'_3 - a'_1 + a_3 - a_1)}$$

For (4,7,14;3,7,24)

$$R(A'_1) = \frac{(24 - 3)(7 - 2(24) - 2(3)) + (14 - 4)(4 + 17 + 14) + 3(24^2 - 3^2)}{3(24 - 3 + 14 - 4)}$$

$$R(A'_1) = \frac{(21)(7 - 48 - 6) + (10)25 + 3(576 - 9)}{93}$$

$$R(A'_1) = \frac{-987 + 250 + 1701}{93}$$

$$R(A'_1) = 10.37$$

Similarly the other values are determined and the reduced problem is given as follows

In Conformation to model the fuzzy assignment problem can be formulated as:

$$\text{Min}\{R(10.37)x_{11} + R(17)x_{12} + R(16.77)x_{13} + R(16.70)x_{21} + R(21.44)x_{22} + R(26.80)x_{23} + R(26.65)x_{31} + R(9.80)x_{32} + R(10)x_{33}\}$$

Subject to

$$x_{11} + x_{12} + x_{13} = 1$$

$$x_{11} + x_{21} + x_{31} = 1$$

$$x_{21} + x_{22} + x_{23} = 1$$

$$x_{12} + x_{22} + x_{32} = 1$$

$$x_{31} + x_{32} + x_{33} = 1$$

$$x_{13} + x_{23} + x_{33} = 1$$

where $x_{ij} \in [0,1]$

We solve it by modified best candidate method to get the following optimal solution.

Phase 1 :Election of Candidates

Step 1: The matrix is Balanced, where the number of rows is equal to the number of columns as shown in table 4.

Phase 2 : Obtain the BCM Combinations.

a. Draw the following index matrix (Table 3) showing the position of each candidate

From the above table we obtain the solution set {A2, A3,B2,B3,C1,C3}.

b. The direct combinations for all the candidates from the solution set and calculate the cost for each:

$$\text{Combination 1 :}\{A2,B3,C1\} = 17+26.8+26.65 = 70.45$$

$$\text{Combination 2 :}\{C1,B2,A3\} = 16.77+21.44+26.65=64.86$$

c. Check for unused candidates in the solution set{C3}, then find the possible combinations:

Combination 3 : {C3,B2} then we add to them A1 and become

$$\{A1,B2,C3\}= 10+21.44+10.37 = 41.81$$

Combination 4 : {C3, A2} then we add to them B2 and become

$$\{A2,C3,B1\}= 10+17+16.70 = 43.7$$

d.Find the optimal solution according to the objective function:In our case it is combination number 3

Job J1 → Machine M1
Job J2→Machine M2
Job J3 →Machine M3





CONCLUSION

In this research article, the fuzzy assignment costs are taken to be as TIFN. The membership and non membership functions are converted of a TIFN are defuzzified using a centroid ranking function. Further the assignment problem is solved by using Modified BCM for its time reducibility and optimal solution.

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Table 1. Fuzzy Assignment cost

$\begin{matrix} \text{Job} \rightarrow \\ \text{Person} \downarrow \end{matrix}$	Job 1	Job 2	Job k	Job n
Person 1	$\widetilde{C}_{11}$	$\widetilde{C}_{12}$	$\widetilde{C}_{1k}$	$\widetilde{C}_{1n}$
Person k	$\widetilde{C}_{k1}$	$\widetilde{C}_{k2}$	$\widetilde{C}_{kk}$	$\widetilde{C}_{kn}$
Person n	$\widetilde{C}_{n1}$	$\widetilde{C}_{n2}$	$\widetilde{C}_{nk}$	$\widetilde{C}_{nn}$

Table 2. Triangular Intuitionistic Fuzzy Assignment cost

Activities	Jobs		
	J ₁	J ₂	J ₃
W ₁	(4,7,14;3,7,24)	(12,14,16;11,14,28)	(8,15,25;7,15,30)
W ₂	(6,18,25;5,18,28)	(13,19,28;12,19,36)	(20,25,33;19,25,38)
W ₃	(20,25,38;19,25,42)	(2,11,14;1,11,19)	(6,12,15;5,12,20)

Table 3. Fuzzy Assignment cost

Activities	Jobs		
	J ₁	J ₂	J ₃
W ₁	10.37	17	16.77
W ₂	16.70	21.44	26.80
W ₃	26.65	9.80	10



**Table 4: Person-Job assignment Profit matrix after balance**

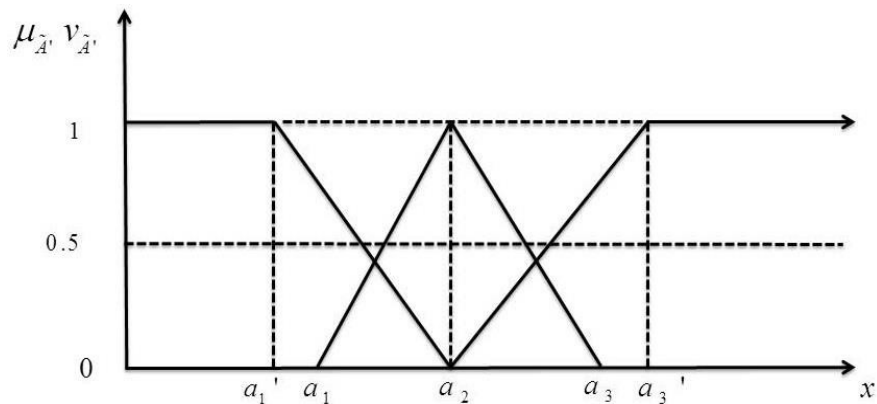
	J ₁	J ₂	J ₃
W ₁	10.37	17	16.77
W ₂	16.70	21.44	26.80
W ₃	26.65	9.80	10

Table 5: Best Candidates Determination Matrix

	J ₁	J ₂	J ₃		
W ₁	10.37	17	16.77		
W ₂	16.70	21.44	26.80		
W ₃	26.65	9.80	10		

Table 6 : Best Candidate Combination Position Matrix.

	J ₁	J ₂	J ₃			
W ₁	-	A2	A3			
W ₂	-	B2	B3			
W ₃	C1	-	C3			

**Figure 1. Membership function of Triangular Intuitionistic fuzzy number**



RESEARCH ARTICLE

Study on Effect of Including Sodium Lauryl Sulfate Salt on Gluten Formation and Formed Wet Gluten

Milan Kanaivalal Gami¹ and Shanmugam. Sivabalan^{2*}

¹Research Scholar, Department of Biochemistry and Biotechnology, Annamalai University, Annamalai Nagar, Chidambaram, Tamil Nadu, India.

²Assistant Professor, Department of Biochemistry and Biotechnology, Annamalai University, Annamalai Nagar, Chidambaram, Tamil Nadu, India.

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*Address for Correspondence

Shanmugam. Sivabalan

Assistant Professor,

Department of Biochemistry and Biotechnology,

Annamalai University, Annamalai Nagar, Chidambaram,

Tamil Nadu, India.

E.Mail: shanmugamsivabalan5@gmail.com



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ABSTRACT

Wheat-based products are among the most widely consumed foods. However, many people around the world are prone to gluten-related disorders. The mechanisms by which gluten causes various health issues have not been extensively studied. Gluten is the major protein of the wheat endosperm, and it forms when gliadin and glutenin form covalent and non-covalent bonds with each other. As these proteins create multiple bonds, they can potentially interact with various biomolecules. If gluten interacts with these biomolecules, it may hinder their function, which could be the cause of various health issues. In this study, we examined the interaction of Sodium Lauryl Sulfate Salt with gluten formation by mixing them with flour, from which gluten was extracted using the hand wash method. Additionally, we investigated the effects of Sodium Lauryl Sulfate on the formed wet gluten. The results show that it hinders gluten formation at approximately the same concentration of bile salt and flour, and they also fragmented the formed gluten.

Keywords: SLS: Sodium Lauryl Sulphates, AACC: American Association of Cereal Chemist, GRD: Gluten Related Disorders, HSD: Honestly Significant Difference

INTRODUCTION

Wheat-based products are a key part of many global diets, with their unique properties largely attributed to gluten, the primary protein in wheat. However, gluten is also linked to several health concerns, including potential



**Milan Kanaiyalal Gami and Shanmugam. Sivabalan**

associations with both immune and non-immune disorders, as well as malnutrition[1]. Gluten is composed of two proteins, gliadin and glutenin [2,3]. These proteins interact through a combination of non-covalent and covalent bonds, both within and between their structures, to form gluten [4]. Given that the gluten components can interact with each other, it is plausible that they may also interact with other molecules in the digestive and gastrointestinal systems. Previous research has explored the interaction of negatively charged gluten peptides with positively charged HLA molecules, which plays a role in immune reactions seen in conditions like Celiac disease and leaky gut [5]. Another study identified around fifty different epitopes on gliadin residues, which can induce immunomodulatory, cytotoxic effects or alter gut permeability [6]. However, there has been no comprehensive study on how gluten might interact with various other biomolecules, potentially contributing to malabsorption and immune interactions in the intestines. How is gluten interacting with various biomolecules is yet to be studied. Salts are having amphipathic in nature. Biologically, bile salts are the important bio molecules plays vital role in lipid and lipid soluble vitamins absorption and emulsification. Moreover it plays very vital role in maintaining the homeostasis of many biochemical interactions such as glucose and fat haemostasis through regulating many pathways on adipose tissues. Here we have examined the interactions of Sodium Lauryl Sulfate on gluten formation on form wet gluten. As Sodium Lauryl Sulfate(SLS) and bile salts share several similarities in their chemical properties and functions, primarily due to their amphiphilic nature (having both hydrophilic and hydrophobic parts). Interactions of gluten with salt molecules may show the capability of gluten to interact with salt molecules which is having hydrophilic as well as hydrophobic nature. If gluten can interact with salts molecules it could possibly interact with any other biological salts and salt like molecules. And interaction of gluten with these salts could render their original functions. So, in this paper, we have investigated the in vitro effects of SLS salts on gluten formation and on already formed gluten. Additionally, we discuss the potential health consequences of these interactions.

MATERIALS AND METHODS

Sample collection

Soft red wheat grains (*Triticum aestivum*) were bought from a local market of Puducherry, India. The grains were carefully cleaned by hand to remove any impurities like stones, husks, or dirt. After cleaning the impurities, the grains were left to dry in the sunlight for 48 hours to reduce their moisture content, which is important before milling. This drying process helps to keep the grains in good condition for milling without losing their nutritional value.

Milling process

After drying, the wheat grains were milled in Rice Mill in Villianur, Puducherry. The milling process was done to produce wheat flour. The flour was immediately placed in airtight polypropylene pouches to protect it from moisture and contamination. To maintain its quality, the flour was stored in a refrigerator until it was needed for further analysis, ensuring it remained in good condition for the experiments.

Removal of fat-soluble substances from the wheat flour

Chloroform removes lipid molecules from wheat flour through a process called solvent extraction. As a non-polar solvent, chloroform has a strong affinity for lipids, which are also non-polar. When the flour is immersed in chloroform, the lipid molecules dissolve into the solvent, separating them from the flour's other components, such as carbohydrates and proteins. After the lipids are dissolved, the chloroform can be evaporated, and purified flour remained left. To remove fat-soluble compounds from wheat flour, it was washed with Chloroform at 27 °C and air-dried for 30 min. The process was performed three times as indicated [7]

Removal of Albumin and Globulin from wheat flour

Albumin and globulin proteins present in wheat flour were extracted by adding 200 mL of a 0.04 M sodium chloride (NaCl) solution in a sodium phosphate buffer to the flour. The resultant suspension was shaken for 10 minutes to facilitate the solubilisation of the proteins. Following the shaking, the mixture was centrifuged to separate the



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components, resulting in the isolation of the supernatant, which contained the solubilized albumin and globulin proteins. This extraction process was repeated twice as per described by [8] to enhance the removal efficiency of the soluble proteins from the flour matrix. After the extraction, the remaining flour was dried in a hot air oven at 37 °C for 24 hours to eliminate residual moisture, thus preparing the flour for subsequent analyses or applications.

Extraction and determination of wet gluten from dough

Wet gluten was extracted by [9] method with modest modification. 500 mg of raw wheat flour and defatted wheat flour were mixed with 350µl distil water and the mixture was kneaded thoroughly to make a dough ball so that the gluten to form completely. The kneaded dough was immersed into the phosphate buffer (Ph-7) for 60 minutes which is shown in Figure no.1. After sixty minutes of shocking in the phosphate buffer, the dough was washed in a stream of tap water over a laboratory sieve size of 32µm, until all the starch were removed. The complete removal of starch from the formed gluten content was determined using the iodine test. The procedure for starch detection is mentioned below. The gluten that remained after starch.

Measurement of dry gluten content

The dry gluten weight was measured after drying the wet gluten at 100°C in hot air oven for 24 hours [9]. And dry gluten yield was measured by the formula given below.

$$\text{Dry gluten yield} = \frac{\text{Weight of dry gluten obtained}}{\text{Weight of wheat flour}} \times 100$$

Detection of starch in the gluten with Iodine test

Iodine test was used to detect the presence of starch in the isolated gluten. Iodine solution was prepared by mixing 2 g of iodine and 4 g of potassium iodide in 200 ml of distil water. And the solution was used to check the presence of starch in the isolated gluten. Gluten was immersed in the water, and the presence of starch was checked by the addition of solution in it [10].

Measurement of moisture content of the gluten

The moisture content of the gluten was calculated by the [9] method. Moisture content of gluten was measured by drying wet gluten in an oven at 100°C for 24 hours. And moisture content was measured by the formula given below.

$$\text{Moisture content} = \frac{\text{Weight of wet gluten} - \text{weight of dry gluten}}{\text{Weight of wet gluten}} \times 100$$

Effect of Sodium Lauryl Sulfate on gluten formation

To assess the effect of SLS on gluten formation, different concentrations of SLS were prepared: a) 100 mg, b) 200 mg, c) 300 mg, d) 400 mg, and e) 500 mg. Each concentration was mixed with 500 mg of wheat flour and 350 µL of distilled water to form a uniform mixture. The mixtures were kneaded for 10 minutes to facilitate gluten development. Subsequently, the kneaded dough were immersed in a phosphate buffer solution at pH 7.0 to maintain optimal conditions for gluten extraction. After immersion, gluten was extracted by washing the dough under tap water to remove residual starch granules.

Effect of SLS on formed wet gluten

To investigate whether SLS interact and disrupt the formed Gluten, the varying concentrations of SLS like T-1)100mg T-2)200mg T-3)300mg T-4) 400mg T-5) 500mg were separately, mechanically mixed with the fixed amount of 230mg of extracted Gluten. After mixing with the spatula, 5ml of di-hydrogen phosphate buffer (pH-7) was added and allowed for 10 min to interact; after that stability, gluten integrity was observed visually and photographed and compared with the control.



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Each experiment was repeated three times to ensure the reproducibility of values. The mean values and standard deviation of each experiment were measured, and the p-value was calculated at the significant difference of (<0.05) using a one-way ANOVA test by Graph pad Prism software.

RESULT AND DISCUSSION**Effect of Sodium Lauryl Sulfate on gluten formation**

To analyze the effect of salts on gluten in its formation and on formed gluten we begun with SLS. After removing the starch and aggregated gluten constituents, the remaining extracted formed gluten is shown in Table no.1, indicating that the augmentation of concentration of SLS reduced the formation up to no gluten formation in (Concentration-6) from (39.40%) and not formed in control. Dry gluten shows the dry matter of gluten present in flour [11]. Dry gluten was also uniformly reduced as the wet gluten was reduced, showing that the remaining gluten constituents that do not interact with salt remains intact and form gluten. The constituents that interacted with the bile salt were washed away without interaction. No significant different were observed in moisture content of the remaining gluten. The experiment demonstrates that increasing sodium lauryl sulfate (SLS) concentration significantly reduces gluten formation, with no gluten formed at the highest concentration (Concentration-6) compared to 39.40% in the control group. This reduction might occur because SLS disrupts protein-protein bonds that are essential for gluten network formation, as reported in other studies. The uniform reduction in wet and dry gluten content indicates that SLS effectively solubilizes gluten components that interact with it, leaving behind less reactive protein fractions. Similar findings have been showing that gluten proteins vary in their sensitivity to disruption by some other chemical agents [12]. Interestingly, there were no significant differences in the moisture content of the remaining gluten across treatments. This suggests that while SLS disrupted the gluten structure, the remaining protein fragments retained their ability to bind water. The observed effect of Sodium Lauryl Sulfate (SLS) on defatted formed gluten aligns with the well-documented ability of surfactants to disrupt protein aggregates and modify protein structures. SLS, an anionic surfactant, interacts with proteins through electrostatic and hydrophobic interactions, leading to the disruption of protein-protein associations and aggregate stability [13].

Effect of Sodium Lauryl Sulfate on formed wet gluten

The impact of Sodium Lauryl Sulfate (SLS) on defatted formed gluten was evaluated through mechanical mixing. As shown in Figure 1, increasing concentrations of SLS led to greater disruption of the formed gluten structure. The control sample, G-1, consisted of intact gluten without SLS mixing. Additionally, a separate control included SLS dissolved in buffer, reflecting its solubility, and was used for comparison with the experimental groups. Across all four groups, higher concentrations of SLS resulted in progressively more significant disruption of the formed gluten. These findings indicate that SLS effectively disrupts insoluble and aggregated gluten structures. The results demonstrate that increasing SLS concentrations result in greater disruption of gluten, consistent with its capacity to destabilize the hydrophobic interactions and hydrogen bonds critical for gluten aggregation. This is supported by studies showing that SLS can bind to hydrophobic domains within protein matrices, thereby solubilizing and disassembling insoluble complexes [14]. The inclusion of control groups, such as intact gluten (G-1) and SLS dissolved in buffer, highlights the specific effect of SLS on gluten aggregates. Intact gluten in the absence of SLS retained its structure, while the SLS-buffer control confirmed that its solubility did not affect the results significantly. Similar findings have. Additionally, the ability of SLS to denature proteins has implications in food science and industrial applications, where surfactants are used to modify protein functionality [15]. These findings underscore SLS's role in disrupting insoluble gluten aggregates and highlight its potential utility in modifying gluten-related properties. As per the result shown here, Gluten formation is completely hindered by Sodium Lauryl sulphates interactions with gluten peptides. Which shows gluten peptides are having high affinity with gluten peptide. If gluten peptides interact with SLS salt, it can possibly interact with the biological salts and salt like molecules and interactions with the molecules could render molecules original function. This interactive capability of gluten with





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various anionic and cationic molecules might be the reasons of various gluten related disorders. It needs further study on interactions of gluten with various other biomolecules and consequences of this reactions.

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Table no 1: Effect of Sodium Lauryl Sulfate on gluten formation

SLS Concentration	Weight of dough(Mg)	Wet gluten(%)	Dry gluten(%)	Moisture content(%)
T-1 Control	773.33 ± 0.011	39.40 ± 0.114	19.13 ± 0.30	53.48 ± 0.680
T-2 (100mg)	973.33 ± 0.015 ^a	35.13 ± 1.646 ^a	16.13 ± 0.50 ^a	54.08 ± 0.22 ^a
T-3 (200mg)	1183.33 ± 0.011 ^{a,b}	11.332 ± 0.114 ^{a,b}	5.4 ± 0.20 ^{a,b}	52.33 ± 1.52 ^{a,b}
T-4	1333 ± 0.064 ^{a,b}	7.490 ± 0.09 ^{a,b}	3.23 ± 0.02 ^{a,b}	55.87 ± 0.98 ^{a,b}





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(300mg)				
T-5 (400mg)	1473± 0.040 ^{a,b}	2.460± 0.12 ^{a,b}	1.036± 0.02 ^{a,b}	57.88 ± 0.66 ^{a,b}
T-6 (500mg)	1654± 0.019	-	-	-

Values are expressed as means± SD of three independent experiments.

^a significant as compared to Control (one-way Anova followed by Tukey HSD, (p<0.05)

^b significant as compared to Concentration-1(one-way Anova followed by Tukey HSD, (p<0.05)

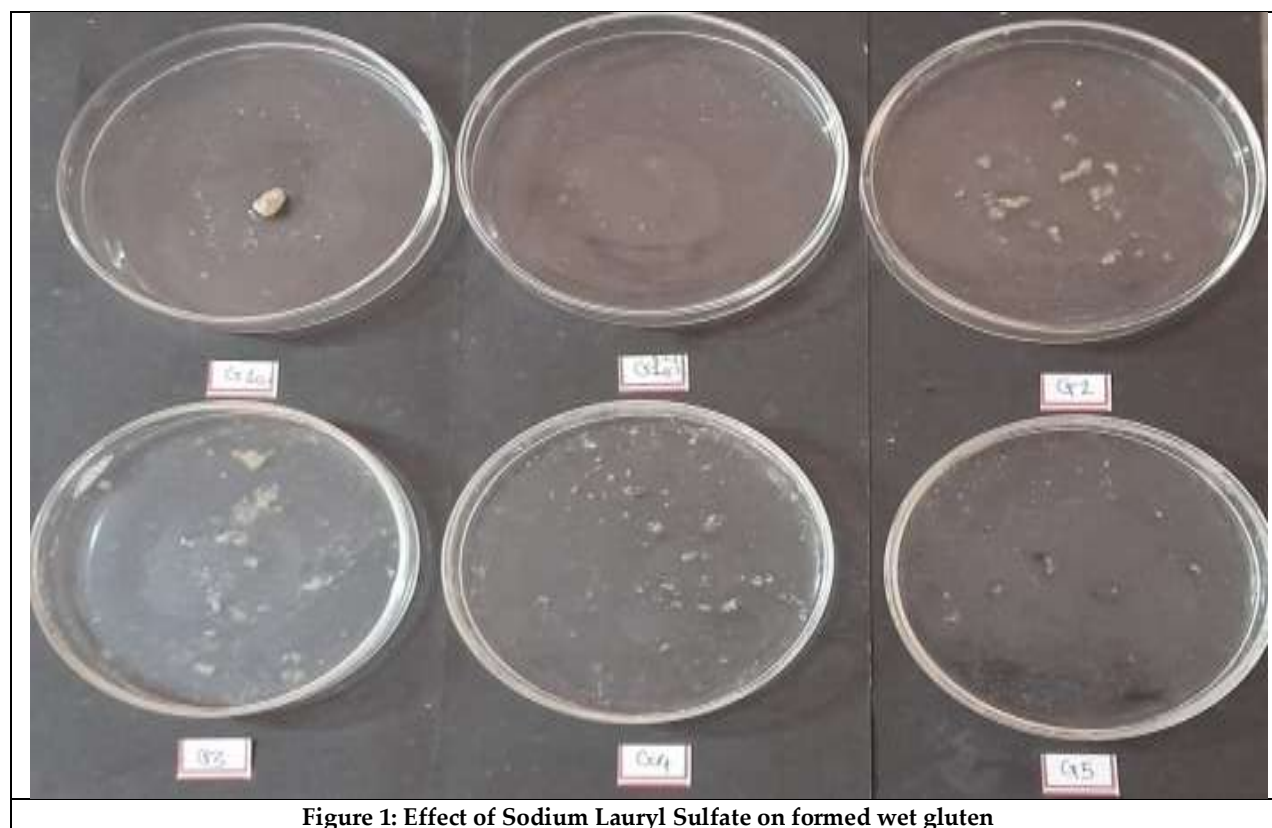


Figure 1: Effect of Sodium Lauryl Sulfate on formed wet gluten





CASE STUDY ARTICLE

Ayurvedic Management of Ischemic Stroke with Dysarthria: A Case Report

Veena G. Rao^{1*} and Raksha S. D²

¹Professor and Head, Department of Panchakarma, JSS Ayurvedic Medical College and Hospital, Mysore, (Affiliated to Rajiv Gandhi University of Health Sciences), Bengaluru, Karnataka, India.

²Final Year MD Scholar, Department of Panchakarma, JSS Ayurvedic Medical College and Hospital, Mysore, (Affiliated to Rajiv Gandhi University of Health Sciences), Bengaluru, Karnataka, India.

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*Address for Correspondence

Veena G. Rao

Professor and Head,
Department of Panchakarma,
JSS Ayurvedic Medical College and Hospital, Mysore,
(Affiliated to Rajiv Gandhi University of Health Sciences)
Bengaluru, Karnataka, India.
E.Mail: drveenagrao@yahoo.in



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ABSTRACT

Stroke ranks as the second leading cause of death worldwide and is a major contributor to disability, resulting in huge economic consequences. Acute stroke can be categorized as ischemic or haemorrhagic, with some overlap in risk factors and clinical presentations; however, their management approaches differ substantially. Ischemic strokes occur when blood vessels are obstructed, limiting the blood supply to the brain. In cardio-cerebral infarction, Acute Myocardial Infarction and Acute Ischemic Stroke are seen simultaneously. Here is a case study of 30-year-old male patient who was diagnosed case of Large subacute infarct in left MCA, smaller subacute infarcts in both ACA territories and LAD Myocardial Infarction in conventional medicine and emergency management was done for the same. Patient presented with the complaints of Balakshaya and Karmakshaya in Dakshina Urdhwa and Adhoshaka associated with Vak Krichrata in the past 3 years. Based on the presenting complaints of the patient, in Ayurveda it can be understood in lines with Dakshina Pakshaghata and treatment was planned accordingly. Panchakarma therapies along with oral medications for 15 days has given the best result to the patient in terms of reduction of clinical features and also quality of life.

Keywords: AIS, Acute Ischemic Stroke Acute, AMI, Myocardial Infarction, Pakshaghata, Vak Krichrata, Panchakarma.



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INTRODUCTION

The term Pakshaghata literally means paralysis of one half of the body, here impairment of Karmendriyas, Gnanendriyas and Manas are seen. Gnanendriyas are considered as part of the sensory system and Karmendriyas are considered a part of the motor system. Pakshaghata is a Vatavyadhi of Nanatmaja[1] variety and Mahavatavyadhi[2] caused either due to Dhatukshaya or Marga Avarana explained in different Ayurveda Samhitas. Pakshaghata is characterized by Chestahani [impaired motor activity], Ruja [pain], Vakstambha [slurring of speech], and Hasta Pada Sankocha [rigidity of limbs], Sandhi Bandhavimoksha [weakness of joints] Vakvakra [mouth deviation], Sphurana of Jihva [fasciculation of the tongue]. Pakshaghata can be correlated with Hemiplegia of varied aetiology. Stroke is defined as a sudden impairment or loss of consciousness, and voluntary movement that is caused by rupture or obstruction [as by a clot] of a blood vessel supplying the brain, and is accompanied by permanent damage of brain tissue. A stroke occurs when the flow of blood to part of the brain is cut off or significantly reduced[3]. The prevalence of stroke in India is approximately 200 per 100000 people[4]. Strokes can be classified into two major categories: Ischemic and Hemorrhagic. Ischemic strokes are caused by interruption of the blood supply to the brain, while hemorrhagic strokes result from the rupture of a blood vessel or an abnormal vascular structure. About 87% of strokes are ischemic, the rest being hemorrhagic[5]. Ischemic strokes include cardioembolism, small-vessel occlusion, large-artery atherosclerosis, and stroke of undetermined etiology[6]. Middle cerebral artery [MCA][7]- It is the most common artery involved in stroke. It supplies a large area of the lateral surface of the brain and part of the basal ganglia and the internal capsule via four segments [M1, M2, M3, and M4]. The MCA distribution involves the lateral cerebral cortex. MCA syndrome is best explained by the understanding of the somatosensory cortex, in which the lateral portion contains motor and sensory functions that involve the face and upper extremity. This correlates to the classical presentation of contralateral hemiparesis, facial paralysis, and sensory loss in the face and upper extremity. The lower extremity may be involved, but upper extremity symptoms usually predominate. Gaze preferences towards the side of the lesion may be seen. Additional symptoms include

- Dysarthria is characterized by difficulty phonating words due to the physical weakness of the muscles of the face used for phonation.
- Neglect where the patient seems to “ignore” a hemisphere of their world due to an inability to see that area.
- Aphasia or the inability to produce or remember words due to injury to the verbal centres of the brain.

Acute ischemic stroke [AIS] and acute myocardial infarction [AMI] are mutual risk factors, and both diseases should be timely diagnosed and treated. Sometimes we encounter patients with simultaneous AMI and AIS. The incidence of acute cardio cerebral infarction is as low as 0.009% [8]. AMI and AIS can occur at the same time or not [simultaneous cardio-cerebral infarction, AMI after AIS, AIS after AMI] [9]. When the two diseases coexist, the condition worsens rapidly. Panchakarma being one of the important treatment modalities of Ayurveda, is very helpful in treating most of the neurological diseases i.e., Vatavyadhi. Here is a case of Ischemic stroke with Dysarthria treated with Panchakarma therapies effectively.

Case Description

A 30-year-old male patient approached JSS Ayurveda hospital on 03/03/24 with the complaints of Balakshaya and Karmakshaya in Dakshina Urdhwa and Adhoshaka associated with Vak Krichrata, and was diagnosed as a case of Large subacute infarct in left MCA, smaller subacute infarcts in both ACA territories for which he underwent Thrombolysis and Thrombectomy, and LAD Myocardial Infarction was treated with supportive measures for 30days.

History

A Male patient aged 30 years was said to be apparently healthy. On 25th June 2021, he suddenly collapsed while exercising in the gym. No H/O of headache and vomiting was present. He was immediately taken to an Allopathic Hospital, and was advised for CT BRAIN. As per the reports the impression was Embolic occlusion of the distal M1, proximal M2 of left MCA, the right A3 ACA and left A4 ACA. MRI revealed Large subacute infarct in left MCA, smaller subacute infarcts in both ACA territories for which he was Thrombolysed and underwent Thrombectomy. Trans-oesophageal Echo cardiogram showed PFO and Cardiac MRI demonstrated LAD Myocardial Infarction. Post



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Operation, the complaints of Balakshaya and Karmakshaya in Dakshina Urdhwa and Adhoshaka associated with Vak Krichrata persisted. He was treated for 30 days and was discharged when his vitals were stable. Since then, patient was undergoing physiotherapy and speech therapy to regain physical independency. As, some amount of speech deficit and neurological deficit persisted. Patient approached JSS Ayurveda hospital for further management.

Past History

N/K/C/O Hypertension, Diabetes mellitus, IHD, Thyroid disorders.

Personal History

Bowel : Once/ day

Micturition : 3-4/1 times D/N.

Sleep : Sound

Appetite : Normal

General Examination

BP - 130/80 mmHg

PR - 74 bpm

RR – 20 cycles/min

Height - 180 cm

Weight - 65 kgs

Ashta Sthana Pariksha

Nadi – 74 bpm

Mala - Once/day

Mutra - 3-4/1-2 times D/N

Jihva - Alipta

Shabda - Prakruta

Sparsha - Prakruta

Drik - Prakruta

Akriti - Madhyama

CNS Examination**Higher Mental Function**

Consciousness - Conscious

Orientation - Well oriented to time, place and person

Behaviour - Cooperative

Attentiveness - Attentive

Memory : Immediate - Intact, Recent - Intact, Remote - Intact

Cranial Nerve Examination

Olfactory Nerve - Intact.

Optic Nerve - Intact.

Oculomotor Nerve, Trochlear Nerve and Abducent Nerve - Intact.

Trigeminal Nerve - Intact.

Facial Nerve: Forehead Furrowing - Possible

Eyebrow raising - Possible

Eye closure - Possible

Teeth showing - Possible

Blowing of cheeks - Possible

Vestibulocochlear Nerve - Intact.



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Glossopharyngeal and Vagus Nerve - Intact.

Spinal Accessory Nerve: Shrugging the Shoulders - Possible with difficulty on right side.

Hypoglossal Nerve: Dysarthria - Present

Motor System Examination

1. Gait – Circumduction Gait

2. Atrophy / Hypertrophy - Absent.

3. Fasciculation and irritability - Absent.

4. Contraction and Contracture - Absent.

5. Involuntary movements - Absent.

6. Muscle Bulk: Normal.

6. Muscle Tone [BT]

Slight Clasp knife spasticity in Right upper limb; Normotonic right lower limb

Normotonic Left upper and lower limb.

7. Muscle Power: [BT]

[Table: 1]

8. Reflexes

Superficial Reflex: Abdominal Reflex - Diminished on right side

Babinski Sign - Positive

Deep Tendon Reflexes:

[Table: 2]

9. Co-ordination test

▪ Finger nose test - Possible.

▪ Knee heel test - Possible.

10. Clonus - Absent.

Sensory System Examination - Intact.

NIH Stroke Scale Assessment [Table: 3]

The maximum score is 42, signifying severe stroke, the minimum score is 0, a normal exam; scores 5-15 are moderate strokes.

Treatment [Table: 4]

Oral Medicines [Table: 5]

Discharge Advice [Table: 6]

RESULTS

Subjective improvements

1. Patient had weakness in the right upper and lower limb initially and after treatment his muscle power got improved.

2. Patient could able to articulate words with clarity and speech got improved dramatically.

DISCUSSION

Acharya Charaka has described Pakshaghata in Vata Nanatmaja Vyadhi and Acharya Sushruta has mentioned in Mahavatavyadhi. It is a disease of the Madhyama rogamarga. The Samprapti of Pakshaghata can be analysed by two ways - either by Dhatu Kshayajanya or via Margavarajanya. According to Acharya Charaka and Sushruta, Chikitsa





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of Pakshaghata includes Snehana, Swedana, Mridu Virechana, Basti Karma, and Murdhni Taila. [10], [11] Accordingly treatment was given to this patient. Treatment was started with Gandharvahastadi Taila being Snigdha Anulomaka, it balances Tridoshas in the body specially Vata. It can be considered effective in reducing the cerebral edema. In the pathogenesis of Pakshaghata, Mastulunga Majja is affected, which is nothing but the Majja Dhara Kala[12]. In classics, it is mentioned that “Nasa Hi Shirso Dwaram”[13]. So, Nasya Karma given through Nasa is the most suitable Marga to reach the Mastishka. Nasya with Karpasastyadi Taila which is indicated in Margavarodhajanya Pakshaghata, by virtue of its Veerya reaches Mastishka and rectifies the underlying pathology. Internally, Tab Vata Rakshasa Rasa and Cap. Freemodex were administered. The contents of Vatarakshasa rasa like Parada, Gandhaka, Kanta Loha, Abhraka Bhasma, Tamra Bhasma, Amruta, Triphala, Chitraka, etc., have the properties like Aama Pachana, Agni Deepana, Anulomana, Rasayana, Lekhana, Madhumehahara, Srotosangha-hara, Hridhya-Nadi balya, and Raktasodhaka. Thus, breaks down the etiopathogenesis of Pakshaghata by acting upon all the three ‘Marmas’ of the body, especially on the Brain which is mainly affected in Pakshaghata. Freemodex Capsule contains herbal actives such as Guggulu, Rasna, Nirgundi that provides anti-inflammatory activity and may help to reduce inflammation; Analgesic principles in herbs such as Rasna, Shunti helps to relieve pain; Natural antioxidants in Ashwagandha and Amrita may help in modifying underlying disease process so as to control the further progression of the condition. Masha Atmagupta Kashaya contains Kapikacchu, Masha, Erandmoola Churna, Balamoola Churna which are made into Kashaya form and added with pinch of Hingu and Saindhava.

The only indication of this Kashaya is Pakshaghata. Kalyanaka Lehya Churna containing Vacha, Yashtimadhu, etc and Naladadi Ghrita with key ingredients- Vacha and Shankhapushpi, promotes clear speech and thus helpful in conditions like dysphasia and dysarthria. The treatment protocol of Pakshaghata which was followed is Ama Nirharana, Vata Shamana and later Brimhana respectively. Initially the patient was treated with Sarvanga Dhanyamla Seka which is a Ruksha Upakrama that helps in relieving the Ama. After the Ama stage has passed, then Sarvanga Abhyanga with Maha Masha Taila followed by Nadi Sweda was performed. Then it was shifted to Sarvanga Shastika Shali Pinda Sweda with Ksheerabala Taila. Shastika Shali Pinda Sweda is a Santarpana/Brimhana therapy which nourishes the body, Mamsa Dhatu and gives Bala. In Ksheera Dhuma, because of the vapours of milk decoction, the face sweats, and this opens up the pores. This helps in relieving the inflammation and stiffness of the face, mouth and throat. It is widely practised in speech disorders and is beneficial in treating slurred speech by preventing neurodegeneration and improving speech function. Yoga Basti was started after Koshta Shodhana with Gandharvahastadi Eranda Taila. Anuvasana Dravya being Mahanarayana Taila is very effective in the treatment of various Vata Vyadhis. Niruha with Mustadi Yapanam Ksheera Kashaya has got Vatahara, Sadyobalajanana, Deepana, Pachana, Rasayana properties and does Vata shamana and Brimhana Karma. In Pakshaghata which is a Apatarpanajanya Vyadhi, Basti does immediate Brimhana, and Vata Shamana. Ksheerabala Taila 101 given at the time of discharge, is commonly used to treat Vata Roga. It is Indriya Prasadaka, Brihmana, Kupita Marga Shodhaka, Snehana and Rakta Prasadaka. Initially, patient had Balakshaya and Karmakshaya in Dakshina Urdhwa and Adhoshaka associated with Vak Kruchrata, but after the treatment for 16 days, he had great improvement in his speech also noticeable improvement in muscle strength was seen.

CONCLUSION

This case study demonstrates a successful management of a case of Pakshaghata with Vak Krichrata using Ayurvedic treatment. There was a significant improvement in all assessments of NIH criteria; the total score reduced from 6 to 0. Significant improvement in muscle power, muscle tone and movements were observed. And remarkable improvement in speech defect was recorded.

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Table. 1: Muscle Power: (BT)

	Right Limb	Left Limb
Upper Limb	4/5	5/5
Lower Limb	4/5	5/5

Table. 2: Deep Tendon Reflexes:

	Right	Left
Biceps	+2	+1
Triceps	+2	+1
Supinator	+2	+1
Knee	+3	+2
Ankle	+2	+1

Table. 3: NIH Stroke Scale Assessment

SN	NIH Scale	Range of Score	Before Treatment	After Treatment
1a	Level of consciousness	0 to 2	0	0
1b	LOC questions	0 to 2	0	0
1c	LOC command	0 to 2	0	0
2	Best gaze	0 to 2	0	0
3	Visual	0 to 3	0	0
4	Facial palsy	0 to 3	0	0
5	Motor arm	0 to 4	2	0
6	Motor leg	0 to 4	2	0
7	Limb ataxia	0 to 2	0	0
8	Sensory	0 to 2	0	0





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9	Best language	0 to 3	0	0
10	Dysarthria	0 to 2	2	0
11	Extinction & Inattention	0 to 2	0	0
	Total	42	6	0

Table. 4: Treatment

SL	Treatment	Duration	Medicine
1	Nasya 2ml(4 Bindu)to each nostril	8 days	Karpasastyadi Taila
2	Sarvanga Dhanyamla Seka	4 days	Ruksha
3	Sarvanga Abhyanga Nadi Sweda	6 days	Ksheerabalataila
4	Ekanga Salvana Upanaha to right upper and lower limbs.	15 days	
5	Talam	15 days	Gorochanadi Vati+Ksheerabalataila
6	Sarvanga Shashtika Shali Pinda Sweda	5 days	Ksheerabala Taila
7	Ksheera Dhuma	7 days	
8	Yoga Basti	7 days	<u>Anuvasana:</u> Mahanarayana Taila - 70ml Niruha: Honey - 100ml Saindava - 6g Mahamasha Taila+Sukumara Ghrita - 140ml Mustadi Yapana Kalka - 25g Mustadi Yapana Ksheera Kashaya - 350ml

Table. 5: Oral Medicines

SL	Medicine	Dose	Duration
1.	Vata Rakshasa Rasa	2-0-2 A/F	16 days
2.	Cap Freemodex	2-0-2 A/F	16 days
3.	Mashatmaguptadi Kashaya	50ml-0-50ml B/F	16 days
4.	Kalyanaka Lehya Churna with Naladadi Ghrita	(5g+10g)-0-(5g+10g) B/F	16 days

Table. 6: Discharge Advice

SL	Medicine	Dose	Duration
1.	Vata Rakshasa Rasa	2-0-2 A/F	15 days
2.	Cap Ksheerabala 101	2-0-2 A/F	30 days
3.	Kalyanaka Lehya Churna with Naladadi Ghrita	(5g+10g)-0-(5g+10g) B//F	15 days
4.	Gandharvahastadi Eranda Taila	0-0-10mlwith warm milk B/F	15 days





RESEARCH ARTICLE

Unraveling Enzyme Kinetics : Analytical Insights into Substrate, Enzyme and Product Concentration

Saranya .K^{1*} and Angel Joy²

¹Research Scholar, Department of Mathematics, Sri GVG Visalakshi College for Women, Udumalpet, (Affiliated to Bharathiar University, Coimbatore), Tamil Nadu, India.

²Associate Professor and Head, Department of Mathematics, Sri GVG Visalakshi College for Women, Udumalpet, (Affiliated to Bharathiar University, Coimbatore), Tamil Nadu, India.

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*Address for Correspondence

Saranya .K

Research Scholar,

Department of Mathematics,

Sri GVG Visalakshi College for Women, Udumalpet,

(Affiliated to Bharathiar University, Coimbatore),

Tamil Nadu, India.

E.Mail: Saranyakumarasamy1@gmail.com



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ABSTRACT

The basic enzyme reaction boundary value problem is described and approximate expressions for substrate and product concentrations are given. This model was initially designed using the classical differential equations and it is extended to the Caputo fractional derivative (FDE's) of order μ . Non-linear reaction equations with a non-linear term related to enzymatic reaction can be approximated and analytically solved using the Homotopy Perturbation method. Dimensionless reaction diffusion parameters $\varepsilon^\mu, k^\mu, \lambda^\mu$ are used to discuss the relevant analytical solutions for the substrate, enzyme, substrate-enzyme, and product concentration profiles.

Keywords: Enzyme kinetics, Non-linear reaction equations, Caputo Fractional differential equations, Homotopy Perturbation method (HPM), Matlab.

INTRODUCTION

Enzymes are proteins that play a remarkable role as catalysts in biochemical reactions that occur continuously in all living organisms. Enzymes have a selective reaction towards specific compounds known as substrates. In red blood cells, hemoglobin acts as an enzyme, and oxygen is the substrate it combines with. Regulation of biological processes is governed by enzymes, which can act as activators or inhibitors in a reaction. To understand their role, the timing of different reactants, and the factors that affect them, enzyme kinetics, which is the study of reaction rates, is necessary. Mathematical introductions are provided in Rubinow's (1975) books, Murray's (1977) books, and Segel's (1980) edited

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books. Biochemically oriented books like Laidler and Bunting (1977) and Roberts (1977) go deeper into the subject. The intuitive concept of fractional calculus has been around as long as integer calculus. It can be observed from a letter that Leibniz wrote to L'Hospital. Fractional derivatives provide a special instrument for the description of the memory effects and hereditary properties of various materials and processes. In the comparison between fractional derivatives and integer-order derivatives, these effects are not taken into account. K.B. Oldham et al. [2] mentioned in their book that applications in physics, chemistry, and engineering play an outstanding role in the development of the subject of applied fractional calculus. In [1], M. Caputo published his book in 1969, in which he systematically used the original definition of fractional differentiation for formulating and solving various types of problems in various applications like viscoelasticity, rheological properties of rocks, and many other fields. This paper investigates the dynamics of the enzyme kinetics reaction mechanisms in classical order non-linear differential equations with boundary value conditions [6] initially and then updated it to Caputo fractional equations. Approximate analytical solutions for the FDE system in fractional order can be obtained using the Homotopy Perturbation method (HPM). To evaluate the impact of different parameter values in different orders on the concentration profile. Additionally, the HPM solutions of the enzyme kinetics reaction mechanisms of fractional order tend to the integer-order HPM solution of the EC mechanism as a special case $\alpha \rightarrow 1$.

2. Preliminaries

In this section, some basic definitions that will be used in the remaining sections are given,

Definition 1. The Caputo fractional derivative of order $\mu \in \mathbb{R}$ is defined as

$${}_0^C D_t^\mu \varphi(t) = \frac{1}{\Gamma(n-\mu)} \int_0^t (t-\tau)^{n-\mu-1} \varphi^{(n)}(\tau) d\tau$$

where $\mu > 0$. If $\mu = n$ then ${}_0^C D_t^\mu \varphi(t) = \frac{d^n \varphi(t)}{dt^n}$.

Definition 2. Let $m\mu > 0$, and $\varphi(t) : (0, \infty) \rightarrow \mathbb{R}$. Then, the Caputo derivative of $\varphi(t)$ of order $m\mu$ is given by

$${}_0^C D_t^{m\mu} \varphi(t) = \frac{1}{\Gamma(n-m\mu)} \int_0^t (t-\tau)^{n-m\mu-1} \varphi^{(n)}(\tau) d\tau$$

where $m \in \mathbb{N}$ such that $(n-1) < m\mu < n$. In particular, if $\mu = 1$, then $m\mu = m$ is an integer and ${}_0^C D_t^{m\mu} \varphi(t) = {}_0^C D_t^m \varphi(t)$ and ${}_0^C D_t^\mu \varphi(t) = \varphi^1(t)$.

Definition 3. The Caputo fractional derivative of $\varphi(t)$ of order $m\mu$ for $(n-1) < m\mu < n$ is said to be the sequential Caputo fractional derivative of order α if the relation is written as

$${}_0^C D_t^{m\mu} \varphi(t) = {}_0^C D_t^\mu \left({}_0^C D_t^{(m-1)\mu} \varphi(t) \right)$$

holds for $m = 2, 3, \dots$

Definition 4. The Riemann-Liouville fractional integral operator ($\mathcal{J}^\mu$) of order $\mu > 0$, of a function $\varphi(t)$ is defined as

$$\mathcal{J}^\mu \varphi(t) = \frac{1}{\Gamma(\mu)} \int_0^t (t-\tau)^{\mu-1} \varphi(\tau) d\tau \quad (\mu > 0),$$

$$\mathcal{J}^0 \varphi(t) = \varphi(t)$$

where $\Gamma(\mu)$ is the well-known gamma function.

Some of the properties for $\mathcal{J}^\mu$ and D^μ can be derived as follows

1. ${}_0^C D_t^\mu \varphi^\delta = \frac{\Gamma(\delta+1)}{\Gamma(\delta-\mu+1)} \varphi^{\delta-\mu}, \mu > 0, \delta > -1, \varphi > 0,$
2. $\mathcal{J}^\mu \varphi^\delta = \frac{\Gamma(\delta+1)}{\Gamma(\delta+\mu+1)} \varphi^{\delta+\mu}, \mu > 0, \delta > -1, \varphi > 0,$
3. $\mathcal{J}^\mu \mathcal{J}^\vartheta \varphi(t) = \mathcal{J}^\vartheta \mathcal{J}^\mu \varphi(t) = \mathcal{J}^{\mu+\vartheta} \varphi(t), \quad \mu, \vartheta > 0,$
4. ${}_a^C D_b^\mu \mathcal{J}^\mu \varphi(t) = \varphi(t), \quad a \leq t \leq b,$
5. $\mathcal{J}^\mu {}_0^C D_t^\mu \varphi(t) = \varphi(t) - \sum_{k=0}^{\gamma-1} \varphi^{(k)}(0^+) \frac{t^k}{k!}, \quad \gamma-1 < \mu < \gamma, t > 0.$





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Nomenclature

S	Substrate.
P	Product.
E	Free Enzyme.
ES	Enzyme – Substrate Complex.
k_1	Forward rate of ES Complex.
k_{-1}	Backward rate constant.
k_2	Rate constant for the transformation of the Enzyme-Substrate complex (ES) into product (P).
c	Concentration of the Enzyme-Substrate complex (ES).
ε	Reaction-Diffusion parameter.
λ	Dimensionless reaction parameter.

Mathematical formulation

In biochemical systems, enzyme kinetics have traditionally been modeled with ordinary differential equations that focus solely on reactions, ignoring spatial concentration variations. In 1913, Michaelis and Menten initially explained a model for enzyme action where a free enzyme binds to a reactant, forming an enzyme-reactant complex. This complex then transforms, releasing both the product and the free enzyme, which can then bind to another reactant. The reactant molecule that binds to the enzyme is known as the substrate S , and the mechanism is often described as follows:



The law of mass action asserts that the rate of a chemical reaction is directly proportional to the product of the concentrations or activities of the reactants. The concentrations of the reactants in (1) are denoted by lowercase letters.

$$s = [S], \quad e = [E], \quad c = [SE], \quad p = [P], \quad (2)$$

The law of mass action leads to the one equation for each reactant and hence the system of nonlinear reaction equations,

$$\frac{ds}{dt} = -k_1 es + k_{-1} c \quad (3)$$

$$\frac{de}{dt} = -k_1 es + (k_{-1} + k_2) c \quad (4)$$

$$\frac{dc}{dt} = k_1 es - (k_{-1} + k_2) c \quad (5)$$

$$\frac{dp}{dt} = k_2 c \quad (6)$$

with the initial conditions,

$$s(0) = s_0, \quad e(0) = e_0, \quad c(0) = 0, \quad p(0) = 0 \quad (7)$$

In [6], by adding the following parameter

$$\xi = \frac{k_1 e_0 t}{\varepsilon}, \quad x(\xi) = \frac{s(t)}{s_0}, \quad y(\xi) = \frac{c(t)}{e_0}, \quad z(\xi) = \frac{p(t)}{e_0} \quad (8)$$

$$\lambda = \frac{k_2}{k_1 s_0}, \quad k = \frac{(k_{-1} + k_2)}{k_1}, \quad \varepsilon = \frac{e_0}{s_0}$$

the system of equations can be represented in dimensionless form as follows:

$$\frac{dx}{d\xi} = -x\varepsilon + \varepsilon(x + k - \lambda)y \quad (9)$$

$$\frac{dy}{d\xi} = x - (x + k)y \quad (10)$$

$$\frac{dz}{d\xi} = \lambda y \quad (11)$$

In [6], the dimensionless concentration of the enzyme can also be obtained





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$$E(\xi) = \frac{e(t)}{e_0} = 1 - y(\xi) \quad (12)$$

with the initial conditions

$$x(0) = 1, \quad y(0) = 0, \quad z(0) = 0$$

A fractional model in Caputo derivative.

The fractional framework for the reaction/diffusion equation (9) – (11) is given as follows:

$${}_0^C D_\xi^\mu x(\xi) = -x\varepsilon^\mu + \varepsilon^\mu(x + k^\mu - \lambda^\mu)y \quad (13)$$

$${}_0^C D_\xi^\mu y(\xi) = x - (x + k^\mu)y \quad (14)$$

$${}_0^C D_\xi^\mu z(\xi) = \lambda^\mu y \quad (15)$$

with the initial conditions

$$x(0) = 1, \quad y(0) = 0, \quad z(0) = 0 \quad (16)$$

where ${}_0^C D_\tau^\mu$ represents Caputo fractional derivative with fractional order μ .

The HPM of solving system of FDE's[26]

Construct the following homotopy

$${}_0^C D_\xi^\mu x(\xi) = p(-x\varepsilon^\mu + \varepsilon^\mu(x + k^\mu - \lambda^\mu)y) \quad (17)$$

$${}_0^C D_\xi^\mu y(\xi) = p(x - (x + k^\mu)y) \quad (18)$$

$${}_0^C D_\xi^\mu z(\xi) = p(\lambda^\mu y) \quad (19)$$

By perturbation technique, x, y and z can be written as a following series in p :

$$x = x_0 + px_1 + p^2x_2 + \dots \quad (20)$$

$$y = y_0 + py_1 + p^2y_2 + \dots \quad (21)$$

$$z = z_0 + pz_1 + p^2z_2 + \dots \quad (22)$$

Substituting (17) – (19) into (20) – (22) and equating terms of the same powers of p yields the following three sets of equations

$$\begin{aligned} p^0 : \quad & {}_0^C D_\xi^\mu x_0 = 0 & p^0 : \quad & {}_0^C D_\xi^\mu y_0 = 0 \\ p^1 : \quad & {}_0^C D_\xi^\mu x_1 = -x_0\varepsilon^\mu + \varepsilon^\mu(x_0 + k^\mu - \lambda^\mu)y_0 & p^1 : \quad & {}_0^C D_\xi^\mu y_1 = x_0 - (x_0 + k^\mu)y_0 \\ p^2 : \quad & {}_0^C D_\xi^\mu x_2 = -x_1\varepsilon^\mu + \varepsilon^\mu(x_1 + k^\mu - \lambda^\mu)y_1 & p^2 : \quad & {}_0^C D_\xi^\mu y_2 = x_1 - (x_1 + k^\mu)y_1 \\ & \vdots & & \vdots \\ p^0 : \quad & {}_0^C D_\xi^\mu z_0 = 0 \\ p^1 : \quad & {}_0^C D_\xi^\mu z_1 = \lambda^\mu y_0 \\ p^2 : \quad & {}_0^C D_\xi^\mu z_2 = \lambda^\mu y_1 \\ & \vdots \end{aligned}$$

Applying the operator of $\mathcal{J}^\mu$ which is inverse operator of D^μ in to $x_0, y_0, z_0, x_1, y_1, z_1, \dots$

$$x_0(\xi) = 1, \quad y_0(\xi) = 0, \quad z_0(\xi) = 0$$

$$x_1(\xi) = -\varepsilon^\mu \frac{\xi^\mu}{\Gamma(\mu+1)}$$

$$x_2(\xi) = \frac{\varepsilon^{2\mu}}{\Gamma(2\mu+1)}\xi^{2\mu} - \frac{\varepsilon^{2\mu}\Gamma(2\mu+1)}{\Gamma(\mu+1)\Gamma(\mu+1)\Gamma(3\mu+1)}\xi^{3\mu} + \frac{\varepsilon^\mu k^\mu}{\Gamma(2\mu+1)}\xi^{2\mu} + \frac{\varepsilon^\mu \lambda^\mu}{\Gamma(2\mu+1)}\xi^{2\mu}$$

$$\vdots$$

$$y_1(\xi) = 1$$

$$y_2(\xi) = -\frac{\varepsilon^\mu}{\Gamma(2\mu+1)}\xi^{2\mu} + \frac{\varepsilon^\mu\Gamma(2\mu+1)}{\Gamma(\mu+1)\Gamma(\mu+1)\Gamma(3\mu+1)}\xi^{3\mu} - \frac{k^\mu}{\Gamma(2\mu+1)}\xi^{2\mu}$$

$$\vdots$$

$$z_1(\xi) = 0$$

$$z_2(\xi) = \frac{\lambda^\mu}{\Gamma(2\mu+1)}\xi^{2\mu}$$

$$\vdots$$

Letting $p \rightarrow 1$ gives therefore,





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$$x(\xi) = 1 - \varepsilon^\mu \frac{\xi^\mu}{\Gamma(\mu+1)} + \frac{\varepsilon^{2\mu}}{\Gamma(2\mu+1)} \xi^{2\mu} - \frac{\varepsilon^{2\mu}\Gamma(2\mu+1)}{\Gamma(\mu+1)\Gamma(\mu+1)\Gamma(3\mu+1)} \xi^{3\mu} + \frac{\varepsilon^\mu k^\mu}{\Gamma(2\mu+1)} \xi^{2\mu} + \frac{\varepsilon^\mu \lambda^\mu}{\Gamma(2\mu+1)} \xi^{2\mu} + \dots$$

$$y(\xi) = 1 - \frac{\varepsilon^\mu}{\Gamma(2\mu+1)} \xi^{2\mu} + \frac{\varepsilon^\mu \Gamma(2\mu+1)}{\Gamma(\mu+1)\Gamma(\mu+1)\Gamma(3\mu+1)} \xi^{3\mu} - \frac{k^\mu}{\Gamma(2\mu+1)} \xi^{2\mu} + \dots \quad (24)$$

$$z(\xi) = \frac{\lambda^\mu}{\Gamma(2\mu+1)} \xi^{2\mu} + \dots \quad (25)$$

ANALYSIS AND DISCUSSION

In this section, we established the significance of the parameters $\varepsilon^\mu, k^\mu, \lambda^\mu$ on the Concentration of x, y, z, E with different order μ . Concentration x, y, z, E versus Dimensionless time ξ computed using (23) to (25), (12) for various values of μ , and for some fixed value of parameters $\varepsilon^\mu, k^\mu, \lambda^\mu$. (Fig 1). The HPM solution of the Caputo fractional differential equation (23) to (25), (12), yields the solution of the corresponding integer-order differential equations (A7) – (A9) as special case $\mu \rightarrow 1$. (Fig. 2). Concentration x, y, z, E versus Dimensionless time ξ computed using (23) to (25), (12) for various values of $\mu, \varepsilon^\mu, k^\mu, \lambda^\mu$. (Fig 3). The fractional order enzyme kinetics reaction model is simulated by using HPM for some fixed value of $\varepsilon^\mu, k^\mu, \lambda^\mu$ and for different values of μ . The response of concentration of substrate, enzyme-substrate complex and product are shown in figure 1. For each value of μ , concentration of substrate and enzyme are gradually decreasing from their initial conditions. The concentration of enzyme-substrate complex and product increases slowly from their initial conditions, eventually attains constant value. Figure (2) shows that the HPM solution of the Caputo fractional differential equations (23) – (25), (12), yields the solution of the corresponding integer-order differential equations (A7) – (A9) as special case $\mu \rightarrow 1$. Figure (3) shows the response of concentration of substrate, enzyme-substrate complex, product and dimensionless variables for four different sets of fractional orders. The inference can be derived from this analysis that approximate solutions are continuously depending on fractional order. As the value of μ diminishing, the concentrations of substrate and enzyme-substrate intermediate complex are slowly coming close to zero and the product concentration reaches to its highest value.

CONCLUSION

In this paper, a new mathematical model based on the Caputo fractional differential systems of the enzyme kinetics mechanism was investigated with steady-state assumptions. The fractional model of the enzyme kinetics mechanism gives more accurate results as compared to the classical integer-order model. The approximate solutions derived using HPM for various combinations of fractional order and dimensionless reaction parameters could represent the true behaviour of fractional order enzyme kinetics reaction model in large time domain, which has very high accuracy. This method is effective and efficient not only for classical differential equations but also for fractional derivatives. The influence of the various parameters on catalytic efficiency was discussed. Additionally, we demonstrate that the sequential system of fractional equations yields the solution of the integer-order differential equations as a special case as $\mu \rightarrow 1$.

Appendix

The Homotopy Perturbation method of solving system of non-linear differential equation of Enzyme kinetics mechanism

Here we can solve the system of second order non-linear differential equations (9) – (12) with boundary conditions analytically using Homotopy Perturbation method [4] in the following way.

Using Homotopy for the equations (9) to (11) are

$$(1-p) \frac{dx}{d\xi} + p \left[\frac{dx}{d\xi} + x\varepsilon - \varepsilon(x+k-\lambda)y \right] = 0$$





$$\frac{dx}{d\xi} + x\varepsilon - \varepsilon(x + k - \lambda)y = 0 \quad (A1)$$

$$(1 - p)\frac{dy}{d\xi} + p\left[\frac{dy}{d\xi} - x + (x + k)y\right] = 0$$

$$\frac{dy}{d\xi} - x + (x + k)y = 0 \quad (A2)$$

$$(1 - p)\frac{dz}{d\xi} + p\left[\frac{dz}{d\xi} - \lambda y\right] = 0$$

$$\frac{dz}{d\xi} - \lambda y = 0 \quad (A3)$$

By Perturbation technique, x, y and z can be written as a series in p as follows :

$$x = x_0 + px_1 + p^2x_2 + \dots \quad (A4)$$

$$y = y_0 + py_1 + p^2y_2 + \dots \quad (A5)$$

$$z = z_0 + pz_1 + p^2z_2 + \dots \quad (A6)$$

Equating the identical powers of p on both sides of equation (A1) and (A4) to (A6) gives,

$$\begin{array}{ll} p^0 : & \frac{dx_0}{d\xi} = 0 \\ p^1 : & \frac{dx_1}{d\xi} = -x_0\varepsilon + \varepsilon(x_0 + k - \lambda)y_0 \\ p^2 : & \frac{dx_2}{d\xi} = -x_1\varepsilon + \varepsilon(x_1 + k - \lambda)y_1 \\ & \vdots \\ p^0 : & \frac{dz_0}{d\xi} = 0 \\ p^1 : & \frac{dz_1}{d\xi} = \lambda y_0 \\ p^2 : & \frac{dz_2}{d\xi} = \lambda y_1 \\ & \vdots \end{array} \quad \begin{array}{ll} p^0 : & \frac{dy_0}{d\xi} = 0 \\ p^1 : & \frac{dy_1}{d\xi} = x_0 - (x_0 + k)y_0 \\ p^2 : & \frac{dy_2}{d\xi} = x_1 - (x_1 + k)y_1 \\ & \vdots \end{array}$$

Applying the operator of J^μ which is inverse operator of D^μ in to $x_0, y_0, z_0, x_1, y_1, z_1, \dots$

$$x_0(\xi) = 1, \quad y_0(\xi) = 0, \quad z_0(\xi) = 0$$

$$x_1(\xi) = -\varepsilon\xi$$

$$x_2(\xi) = \varepsilon^2 \frac{\xi^2}{2} - \varepsilon^2 \frac{\xi^3}{3} + \varepsilon k \frac{\xi^2}{2} - \varepsilon \lambda \frac{\xi^2}{2}$$

$$\vdots$$

$$y_1(\xi) = \xi$$

$$y_2(\xi) = -\varepsilon \frac{\xi^2}{2} + \varepsilon \frac{\xi^3}{3} - k \frac{\xi^2}{2}$$

$$\vdots$$

$$z_1(\xi) = 0$$

$$z_2(\xi) = \lambda \frac{\xi^2}{2}$$

$$\vdots$$

Letting $p \rightarrow 1$ gives therefore,

$$x(\xi) = 1 - \varepsilon\xi + \varepsilon^2 \frac{\xi^2}{2} - \varepsilon^2 \frac{\xi^3}{3} + \varepsilon k \frac{\xi^2}{2} - \varepsilon \lambda \frac{\xi^2}{2} + \dots \quad (A7)$$

$$y(\xi) = \xi - \varepsilon \frac{\xi^2}{2} + \varepsilon \frac{\xi^3}{3} - k \frac{\xi^2}{2} + \dots \quad (A8)$$

$$z(\xi) = \lambda \frac{\xi^2}{2} + \dots \quad (A9)$$





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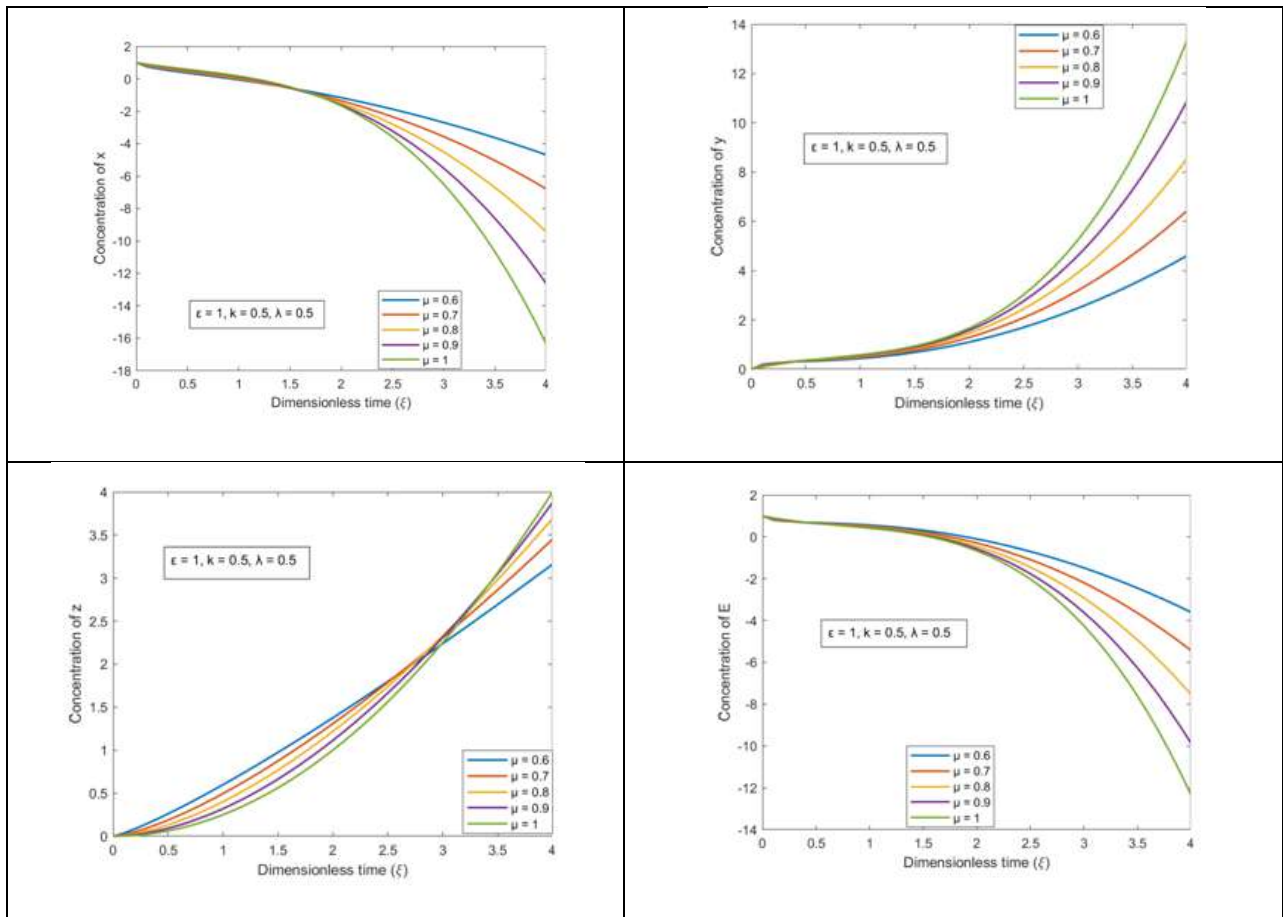
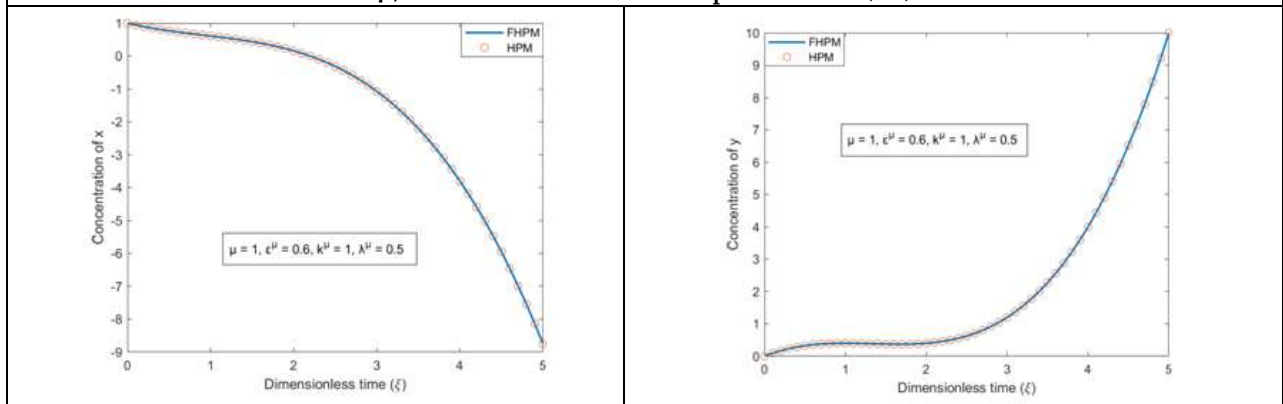


Fig. 1: Concentration x, y, z, E versus Dimensionless time ξ computed using (23) to (25), (12) for various values of μ , and for some fixed value of parameters $\varepsilon^\mu, k^\mu, \lambda^\mu$.





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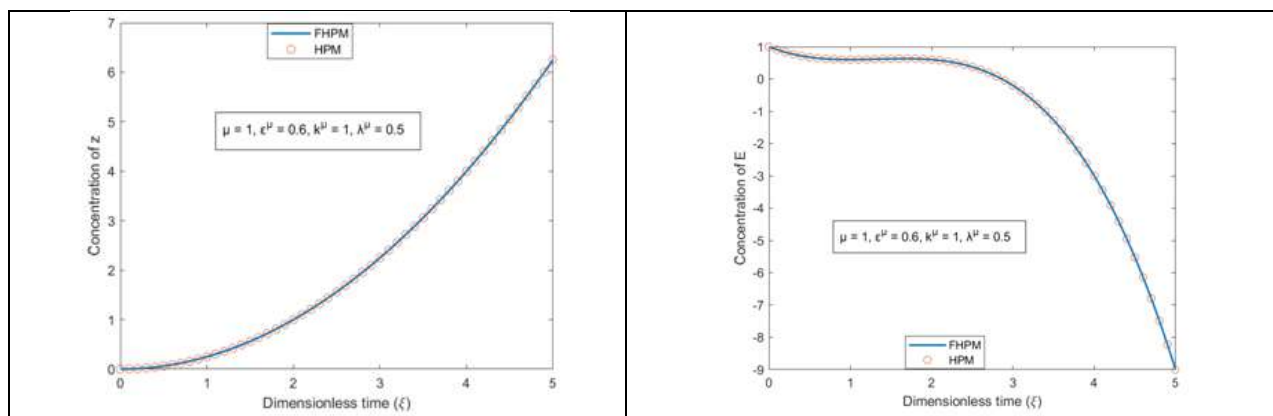


Fig. 2: The HPM solution of the Caputo fractional differential equation (23) to (25), (12), yields the solution of the corresponding integer-order differential equations (A7) – (A9) as special case $\mu \rightarrow 1$.

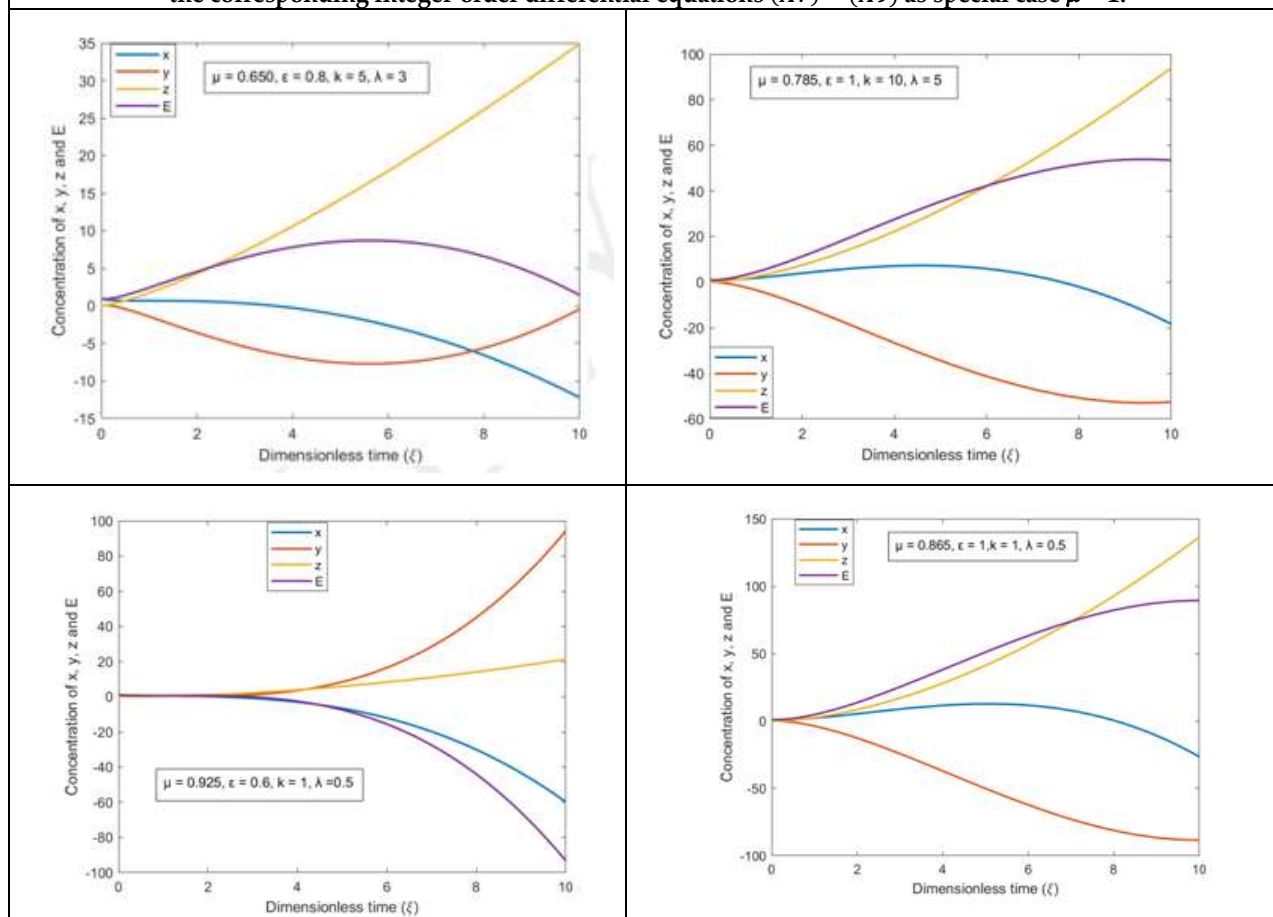


Fig. 3: Concentration x, y, z, E versus Dimensionless time ξ computed using (23) to (25), (12) for various values of $\mu, \varepsilon^\mu, k^\mu, \lambda^\mu$.





RESEARCH ARTICLE

Analysis and Extraction of Secondary Metabolites of Marine and Mangrove Bacteria Grown in Varying Temperature

J. Joonu*

Assistant Professor, Department of Zoology, Bishop Heber College, Puthur, (Affiliated to Bharathidasan University) Tiruchirappalli, Tamil Nadu, India.

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*Address for Correspondence

J. Joonu

Assistant Professor, Department of Zoology,
Bishop Heber College, Puthur,
(Affiliated to Bharathidasan University)
Tiruchirappalli, Tamil Nadu, India.
E.Mail: joonucharles@gmail.com



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ABSTRACT

Antibiotics are the low molecular compounds which can be produced via way of means of micro-organism are used to remedy precise diseases. They are the goods of secondary metabolites created from microbes. Bacteria are remoted from marine and mangrove water samples. Bacteria like *Pseudomonas putida*, *Pseudomonas aeruginosa*, and *Bacillus cereus* are remoted. *Pseudomonas aeruginosa* is a Gram negative, rod fashioned microorganism produces antibiotics. Antibiotic manufacturing media is ready and decided on microbes are inoculated and incubated at diverse temperatures. Then way of life is centrifuged and supernatant is accumulated. The accumulated supernatant is examined for antibiotic pastime via way of means of nicely diffusion method. The antibiotics are precise for a few precise bacterial diseases. 16S –r RNA sequencing is completed to pick out the precise microorganism. The sequenced bacterial species is then submitted with inside the NCBI Gene bank.

Keywords: Antibiotics, secondary metabolites, Bacterial diseases, Genbank , marine bacteria, mangrove bacteria.

INTRODUCTION

Marine microorganisms are life forms living in a marine environment either within the saltwater of a ocean or sea or the brackish water of a coastal estuary (Dash *et al.*, 2013). A microorganism is minuscule living being, which is in any life frame as well little for the bare human eye to see which needs a magnifying lens. Microorganisms can be single-celled or multicellular and incorporate all microscopic organisms' Archaea and most Protozoa and a few species of organisms, green growth, certain tiny creatures, such as Rotifers. Mangroves are environments shifting in saltiness, water level and supplement accessibility which are complex and energetic and contain assorted and unmistakable





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microbial communities. Mangroves are considered to be the foremost beneficial biological systems within the world. They are of biological, financial and societal significance. (Alongi DM,2002) Auxiliary metabolites are the natural compound created by microbes, parasites, or plants. They don't have direct inclusion within the typical development, advancement, or generation of the living being. Auxiliary metabolites are created within the idiophase of bacterial cell cycle which are molecular weight compounds of less than 2.5 KDa. Microbes like *Pseudomonas*, *Bacillus* and *Streptomyces* are the life forms which create greatest auxiliary metabolites. They can be gathered as a few of normally delivered compounds such as peptides, polypeptides, cyclic lipopeptides, polyketides, pyrroles, phenazines, phloroglucinols, lantibiotics, bacteriocins, lactones, macrolactone, anthracyclines, alkaloids, quinones, polyenes, pyrone, quinolones, isoquinoline, aminoglycosides, macrolides, bithiazoles, isocoumarins, aminosugars, phospholipids, siderophores and volatiles (Pathma *et al.* 2011b). They display fabulous antimicrobial, plant development administrative, plant protein inhibitory, herbicidal, insecticidal and anti-parasitic properties. Be that as it may its natural properties has been utilized as biocontrol specialists in agriculture. Antibiotic generation are gathered into three strategies: common aging, semi-synthetic, and synthetic. These microbes proceed to create resistance to as of now created anti-microbials, there's require for the advancement of modern anti-microbials. Modern strategies have been formulated to make strides the capacity to include anti-microbials straightforwardly into embedded gadgets, aerosolization of anti-microbials for coordinate conveyance, and combination of anti-microbials with non-antibiotics for superior results. The fast increment of anti-microbial safe strains of pathogenic microscopic organisms has driven to an expanded criticalness for the improvement of modern and way better anti-microbials.

MATERIALS AND METHODS

The disconnected bacterium was subjected to recognizable proof by recoloring and biochemical tests. Gram recoloring strategy was carried out to recognize the gram response of the life form. The motility test was performed by hanging drop strategy to distinguish motility of the living being. The biochemical tests such as Indole, Methyl ruddy, Voges Proskauer, citrate, Urease test, starch hydrolysis, catalase test, mannitol aging etc. were performed to recognize the living beings (Cappuccino and Sherman, 2014).

Indole test (Tryptone broth) Vaccinate a loopful of microbes into a tryptone broth. Brood 48 hours. After hatching: The broth must be turbid. A clear broth indicates that the life form did not develop and cannot be tried. Include a number of drops of Indole reagent to the broth culture (tryptone broth). A positive result encompasses a ruddy layer at the beat. A negative result includes a yellow or brown layer (Fig.1)

Methyl Ruddy test (MRVP broth) Vaccinate a loopful of microbes into MRVP broth. Hatch 3 to 5 days. After brooding: The broth must be turbid. A clear broth shows that the life form did not develop and cannot be tried. Evacuate 1 ml of broth and put into a sterile tube. Include 3-4 drops of methyl ruddy to the initial broth. A positive result features a particular ruddy layer at the beat of the broth. A negative result encompasses a yellow layer. Numerous gram-negative intestinal microscopic organisms like *Escherichia*, *Salmonella*, and *Proteus* can be differentiated.

Voges-Proskauer test: Immunize a loopful of microscopic organisms into MRVP broth. Brood 3 to 5 days. After incubation: A clear broth demonstrates that the life form did not develop and cannot be tried. Barritt's reagent A (VP A) contains naphthol and Barritt's B (VP B) contains KOH. Test 1 ml of the culture from the MRVP broth. Include the complete substance of the VP A reagent (15 drops) and 5 drops of the VP B reagent to the 1 ml of the broth culture. With a positive response the medium will alter to pink or ruddy showing that acetoin is display. With a negative response the broth will not alter color or will be copper colored. Enterobacter, Serratia and a few species of *Bacillus* appears positive comes about.





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Citrate test (Simmons citrate Agar): A loopful of microbes is streaked onto a citrate agar incline, don't cut the butt. Brood 24 to 48 hours, longer for *Bacillus* species. Hatch with a free cap. After hatching: A positive response is shown by a incline with a Prussian blue color. A negative incline will have no development of microbes and will stay green.

Urease test: Inoculate a tube of urea broth together with your test life form and hatch at room temperature for 24 to 48 hrs. Urea broth is composed of yeast extricate, urea and the pH pointer phenol ruddy. In case urease is present, ammonia will be discharged and the pH will rise. A positive urease test may be a change from yellow to cerise (a light cherry color; pH 8.1 or more noteworthy). No alter within the color of the marker may be a negative test.

Mannitol fermentation: Mannitol Salt Agar contains 7.5% NaCl, which is inhibitory to most microscopic organisms. Microbes that can develop on this agar can be separated based on mannitol fermentation. Fermentation of mannitol comes about in acidic products which turn phenol ruddy pH pointer from ruddy to yellow. Streak MSA plate and hatch at 37°C for 2 days. Positive test demonstrates colour alter from ruddy to yellow. Negative test appears there's nocolor alter.

Starch Hydrolysis: Vaccinate a starch plate with the living being to be tried. Brood at ideal temperature for at slightest 48 hours. Surge plate with iodine, watch comes about. Blue color shows no hydrolysis, whereas a clear zone demonstrates hydrolysis. *B.subtilis* is the living being which shows positive comes about Catalase test: Expel a small sum of your natural obscure from your agar incline, or a loopful of control test living beings from a broth culture and put it on a glass slide. Blend the life forms with a drop of 3% H₂O₂ and check for the appearance of gas bubbles (a positive test). No bubbles are a negative test. *Bacillus spp.* is utilized as the positive control and Streptococcus

Well Strategy of Anti-microbial Test (Schmalenberger *et al.*, 2005)

Supplement agar medium is ready and sterilized and is poured into Petriplates beneath aseptic conditions in a Laminar discuss stream. The Petri plates are kept for setting of medium for a few times. Presently the wells are made at chosen ranges in Petri plates. Presently the test organism's micrococcus and the bacillus strains are swabbed on the Petri plates with a sterile swab. The Petri plates are cleared out for a few times. The unrefined extricate gotten from centrifugation of generation medium is taken with a micropipette and is stacked into the wells. Each well is provided with a volume of 100micro liters. Presently these petriplates were incubated overnight without rearranging at ideal temperature of 37 °C for 24 hours. Strain appearing the more restraint was chosen and checked for the expanding concentration of anti-microbial with impact to the expanding concentrations of the sodium nitrate

Molecular Biology

Bacterial Identification- 16S rRNA Sequencing

DNA Extraction

1. Lysis/homogenization: Cells grown in monolayer should be lysed by suspending 1-3 colonies aseptically and mixed with 450 µl of "B Cube" lysis buffer in a 2ml micro centrifuge tube and lyse the cells by repeated pipetting.
2. Add 4 µl of RNA se A and 250 µl of "B Cube" neutralization buffer.
3. Vortex the content and incubate the tubes for 30 minutes at 65°C in water bath. To minimize shearing the DNA molecules, mix DNA solutions by inversion.
4. Centrifuge the tubes for 20 minutes at 14,000 rpm at 10 °C.
5. Following centrifugation, transfer the resulting viscous supernatant into a fresh 2 ml micro centrifuge tube without disturbing the pellet.
6. Add 600 µl of "B Cube" binding buffer to the content and mix thoroughly by pipetting and incubate the content at room temperature for 5 minutes.
7. Transfer 600 µl of the contents to a spin column placed in 2 ml collection tube.
8. Centrifuge for 2 minutes at 14,000 rpm and discard flow-through.
9. Reassemble the spin column and the collection tube then transfer the remaining 600 µl of the lysate.
10. Centrifuge for 2 minutes at 14,000 rpm and discard flow-through.





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11. Add 500 μ L “B Cube” washing buffer I to the spin column. Centrifuge at 14,000 rpm for 2 mins and discard flow-through
12. Re assemble the spin column and add 500 μ L “B Cube” washing buffer II and Centrifuge at 14,000 rpm for 2 mins and discard flow-through
13. Transfer the spin column to a sterile 1.5-ml microcentrifuge tube
14. Add 100 μ L of “B Cube” Elution buffer at the middle of spin column. Care should be taken to avoid touch with the filter.
15. Incubate the tubes for 5 minutes at room temperature and Centrifuge at 6000 rpm for 1 min.
16. Repeat the above-mentioned step 14 and 15 for complete elution. The buffer in the microcentrifuge tube contains the DNA.
17. DNA concentrations were measured by running aliquots on 1% agarose gel.
18. The DNA samples were stored at -20°C until further use.

Composition of Production Media (Gopikrishna, 2018)

Bacterial Production Media: 1. Glucose(3gm) 2. NaNO_3 (0.6gm) 3. KH_2PO_4 (0.1gm) 4. KCl (0.5gm) 5. MgSO_4 (0.02gm) 6. FeSO_4 (0.01gm) 7. Peptone (5gm) 8. Beef Extract (3gm) 9. H_2O (100 ml)

Preparation of production media: All components are weighed and added to distill and is made up to 50ml. Now this 50ml broth is sterilized in autoclave at 120°C at 15 lbs for 15 minutes. Sterilized broth is inoculated with test culture under aseptic conditions and is transferred shaker incubator. The production medium along with the inoculated test culture is kept in shaker incubation for incubation, for 1 day. Then the production medium is transferred from shaker incubator to normal incubation and is kept for incubation for 1 day. Now the test culture is checked for growth by testing the optical density of culture.

Extraction

The secondary metabolites will have been produced as the maximum amount of antibiotic and are released into the medium during their stationary phase. It can be extracted. The fermentation broth is processed by various purification methods ,basedon the specific antibiotic producedThe dissolved antibiotic is then recovered using various organic chemical means. It can be further refined into different product types. Two different temperature parameters are used. (31°C , 38°C).

Preparation of Crude Extract 5ml of the inoculated production broth is taken and is subjected to centrifugation at 6000 rpm for 10 minutes. Bacterial cells were pelleted out. The pelleted cells is discarded and supernatant is stored at 4°C in a refrigerator this supernatant is the crude extract which is tested for the antibiotic activity.

RESULTS

Marine and mangrove water tests were collected from ECR, Chennai and Muthupettai mangrove timberland, Pudhukottai separately. The tests were collected from the over specified places and wereput away at room temperature. The tests were serially weakened. The water tests were diluted in five diverse concentrations which appears the greatest number of bacterial colonies. To distinguish the given bacterial tests the biochemical tests were done and gram recoloring was done .Table 1 appears the comes about of biochemical tests like IMViC tests. The atomic tests like 16srRNA sequencing was done and the comes about were submitted within the Genbank (Table 2). The phylogenetic tree comes about appears the developmental connect between the life forms *Pseudomonas putida* and *Bacillus cereus* (Fig 1 and 2). Antibiotic generation media is ready and *Pseudomonas aeruginosa* is immunized. Media improves the bacterial development and auxiliary metabolite generation (Fig 3, 4 and 5). Antimicrobial action was tried by agar well dissemination strategy. A few counts of microbial culture are spread over the agar plate and the supernatant is included into the wells punctured in it. Plates were then brooded for 48 hours at 37°C within



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the hatchery and after that watched for the zone of hindrance around the wells. The results showed maximum affectability to the microbes refined by using auxiliary metabolic items like anti-microbials.

Serial Dilution (Table: 1)

The sample were collected from the above mentioned places and were stored at room temperature. The sample were serially diluted. The water sample were diluted in five different concentrations which shows the maximum number of bacterial colonies

Molecular Tests

Phylogenetic tree of *Pseudomonas putida* (Fig. 1)

Phylogenetic tree for *Bacillus cereus* (Fig. 2)

GenBank submission (Table:2)

Antibiotic Production**Growth of secondary metabolites in different temperatures(Fig. 3)****Temperature**

Difference in temperature also enhances the secondary metabolite production. Two different temperatures 32°C and 38°C are maintained inside the orbital incubator shaker for two days.

Media at 33°C(Fig. 4)

Media at 38°C(Fig. 5)

Agar Well Diffusion Method

Zone observed at the temperature range of 31°C (Table: 3)

Zone observed at the temperature range of 38°C (Table: 3)

DISCUSSION

Pseudomonas putida could be a flagellated, gram-negative bar shaped bacterium that's found in most soil and water living spaces. It grows optimally at 25-30°C and can be effectively separated. *Pseudomonas putida* features a assorted high-impact digestion system which is able to debase natural solvents such as toluene conjointly to change over styrene oil to biodegradable plastic Polyhydroxyalkanoates (PHA). It makes a difference to debase the polystyrene froth which was thought to be non-biodegradable. These microscopic organisms are able to corrupt natural toxins, analysts utilize *Pseudomonas putida* for investigate on bioremediation in soil forms (Marcus,2003). It is interesting since it has most of the qualities included in breaking down fragrant or aliphatic hydrocarbons caused by burning fuel, coal, tobacco, and other natural matter. There's incredible intrigued in sequencing the genome of *Pseudomonas putida* due to its solid impact in bioremediation. *Pseudomonas aeruginosa* is a typified, Gram-negative, rod-shaped bacterium that can cause illness in plants and creatures, counting people. *P. aeruginosa* the omnipresent multidrug safe pathogen has inherently high-level anti-microbial resistance components and can cause genuine hospital-acquired contaminations such as ventilator-associated pneumonia and different sepsis disorders. (Balcht *et al.*, 1994). Auxiliary metabolites, counting anti-microbials, are delivered in nature and serve survival capacities for the life forms creating them. The anti-microbials are a heterogeneous gather, the capacities of a few being related to and others being disconnected to their antimicrobial exercises. Although antibiotics are not obligatory for sporulation, some secondary metabolites (including antibiotics) stimulate spore formation and inhibit or stimulate germination. Formation of secondary metabolites and spores are regulated by similar factors. This similarity could insure secondary metabolite production during sporulation (Arnold *et al.*,2001).





CONCLUSION

The Marine and Mangrove water samples have been accumulated aspectically with inside the autoclaved field from Muthupettai mangrove wooded area and ECR Beach, Chennai. Analysis and extraction of secondary metabolites from marine and mangrove microorganism with acidic surroundings have been done. The biochemical assessments have been achieved for each the samples. The biochemical check which includes Indole, Methyl red, Vogues Proskauer, Citrate, Urea's check, Catalase check, oxidase check TSI (triple sugar iron) etc. The microorganism like *Pseudomonas putida*, *Bacillus cereus* and *Pseudomonas aeruginosa* have been remoted from the water samples. Temperature performs a chief function in manufacturing of antibiotics. High temperature and occasional temperature are maintained withinside the culture. Varying temperature suggests appropriate effects in antibiotic manufacturing. The agar properly diffusion technique confirmed the sensitivity of the classy microorganism withinside the petriplate via way of means of the antibiotics produced as secondary metabolites.

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Yaazh genomics, Coimbatore, Tamilnadu, India.

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Table :1 Biochemical tests – IMViC

	<i>Pseudomonas putida</i>	<i>Bacillus cereus</i>	<i>Pseudomonas aeruginosa</i>
Morphological properties			
1.Gram's staining	Gram negative	Gram negative	Gram negative
2.Motility	Motile	Non Motile	Non- motile
3.Shape	Rod	Rod	Long Rod





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B. Cultural Properties			
5.Nutrient agar	white colonies	Translucent, bluish green pigmented diffused colonies	
6.Eosin methylene blue	Pink colour colonies form	Yellow colour colonies form	-
7.MacConkey agar	-	-	Pink colour colonies form
C. Biochemical Properties			
8.Indole test	+	+	-
9.Methyl red test	+	+	-
10.Voges Proskauer	+	+	+
11.Citrate test	+	+	+
12.Catalase test	+	+	+
13.Triple Sugar Iron(TSI)Test	+	-	+

Table : 2 GenBank submission

Sl. no	Name of the organism	GenBank accession number	Authors
1.	<i>Pseudomonas putida</i>	Yet to be submitted	Dr. J.JOONU, M. G. Vinusri, V. Deepthi, S. Junita RalenySherlina
2.	<i>Bacillus cereus</i>	SUB5347443 Seq1 MK673906	Dr. J.JOONU, M. G. Vinusri, V. Deepthi, S. Junita RalenySherlina

Table 3: Zone observed at the temperature range of 31°C

Organisms	Zone of inhibition	Sensitivity
<i>Pseudomonas putida</i>	4mm	Resistant
<i>Pseudomonas aeruginosa</i>	6mm	Sensitive
<i>Bacillus cereus</i>	5mm	Resistance

Table 3: Zone observed at the temperature range of 38° C

Organisms	Zone of inhibition	Sensitivity
<i>Pseudomonas putida</i>	4mm	Resistant
<i>Pseudomonas aeruginosa</i>	6mm	Sensitive
<i>Bacillus cereus</i>	5mm	Resistance





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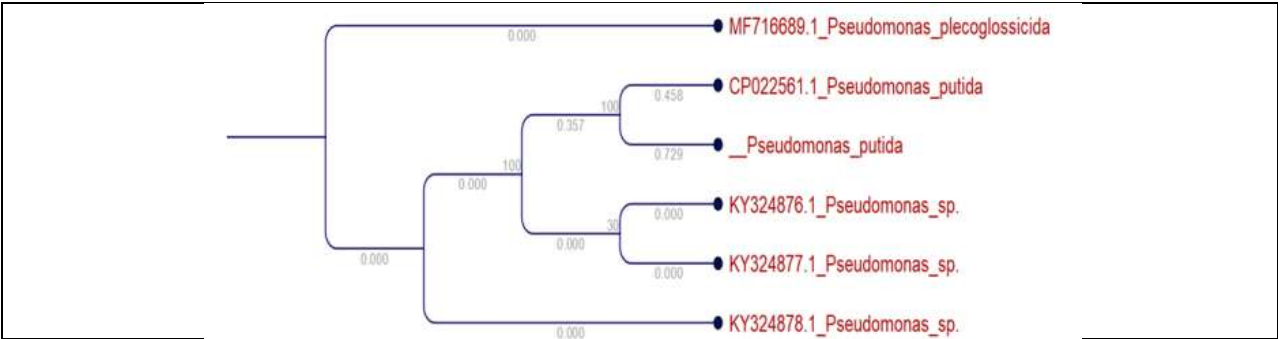


Fig. 1: Phylogenetic tree of *Pseudomonas putida*

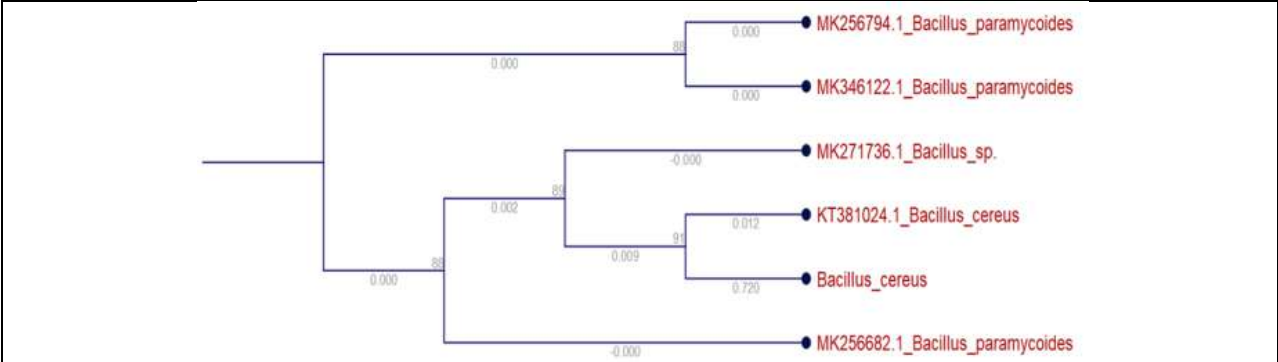


Fig. 2: Phylogenetic tree for *Bacillus cereus*



Fig. 3: Growth of secondary metabolites in different temperatures



Fig.4: Media at 38°C





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Fig.5: Zone observed at the temperature range of 31°C





RESEARCH ARTICLE

Synthesis, Growth and Characterization Study of Nonlinear Optical Studies of 3Pheny l 2-Bromophenol (3p2bp) for Frequency Conversion

P.Aruna¹ and N.Lavanya^{2*} and B. Ravindran³

¹Research Scholar, Department of Physics, Thiru.Vi.Ka Govt. Arts College, Thiruvarur, (Affiliated Bharathidasan University, Tiruchirappalli), Tamil Nadu, India.

²Associate Professor, Department of Physics, A.D.M College for Women (Autonomous), Nagapattinam, (Affiliated Bharathidasan university, Tiruchirappalli), Tamil Nadu, India.

³Assistant Professor, Department of Physics, Thiru.Vi.Ka Govt. Arts College, Thiruvarur (Affiliated Bharathidasan University, Tiruchirappalli), Tamil Nadu, India.

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*Address for Correspondence

N.Lavanya

Associate Professor,

Department of Physics,

A.D.M College for Women (Autonomous), Nagapattinam,

(Affiliated Bharathidasan university, Tiruchirappalli),

Tamil Nadu, India.

E.Mail: lavanyaphysics1983@gmail.com



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ABSTRACT

This is the first time 3 phenyl 2- bromophenol(3P2BP) of a new organometallic nonlinear optical crystal has been reported in the literature. It was synthesized and grown at room temperature by the slow evaporation method. The cell parameters of the 3 phenyl 2-bromophenol (3P2BP) crystal are confirmed by using powder X-ray diffraction. And single X-ray analysis. This research is concerned with the nonlinear optical, fluorescence, UV, FT-IR, thermal and structural properties of organically grown 3 phenyl 2-bromophenol(3P2BP) single crystals. By employing Fourier Transform Infrared (FT-IR) spectral analysis, the functional groups and characteristic vibrations of 3 phenyl 2-bromophenol(3P2BP) crystals were determined. UV- visible NIR spectrum analysis showed the optical quality of the grown crystal. The high optical transmittance is evidence by the grown crystal in the range of 200-1100 nm.

Keywords: Crystal growth, UV-visible, FT-IR, SEM, Fluorescence

INTRODUCTION

Nonlinear optical (NLO) materials have played a significant role in advancing contemporary technology, which in essential broadens their applicability in technological and industrial processes. The past few years have witnessed an





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abundance of studies focused on synthesizing newer NLO materials whose properties match other NLO materials because of their extensive use for opto electronics, photonics, broad terahertz imaging and spectroscopy, laser remote sensing, optical information processing, optical switching, pharmaceuticals, color display and frequency conversion. Thus, the growth and merging of novel organic, semi-organic and inorganic NLO materials has hence become a topic of great scientific interest. Organo-metal crystals are unique here as potentially very promising due to their huge spontaneous birefringence and nonlinearities, high packing density, very good long-term stability and modifications of their chemical structures to perfection. The most attractive materials among these are organic crystals, which have high packing densities often large macroscopic nonlinearities, outstanding long-term orientation and photo chemical stabilities and tenability of the chemical structure. However, the production of large and good-quality crystals has been limited by the difficulty level of doing this. This is why bulk growth of novel nonlinear optical crystals falls under the research spotlight. Clear and defect-free single crystals of large size are important for use in optical devices and further improve the possibility of optical switching and optical limiting applications and researchers are focusing on synthesizing such crystals. In particular, organic crystals have push-pull p-conjugated bridges with electron-donor and acceptor groups on each side of the p-bond system. The increased mobility is caused by the overlap between the p-orbits and the delocalized electronic charge. Optical nonlinearity increases as the ground or excited state electron charge density distribution is improved. Typically, well known organic materials such as aldehydes, ketones, hydrocarbons, amines, amides and amino acids possess strong electron-withdrawing characteristics and exhibit significant second and third order nonlinear optical responses.

Aldehyde derivatives are considered one of the most important classes of hetero-cycles that provide chemical scaffolds to the development of synthetic drugs as they are involved in the manufacture active medicines, given that fragrances, cosmetics, dyes, flavorings, disinfectants and preservatives are just a few of the production benefits. The primary benefits of this group of compounds are leveraged in colorants, fragrances, fumigation, preservatives, medicaments and synthesis. Other than that, they are also used for manufacturing plastics, disinfectants and embalming fluids and function as medicines with anti-inflammatory, anti-cancer, anti-fungal and anti-diabetic properties. Aldehydes, especially aromatic aldehydes, have attracted interest for nonlinear optics (NLO) applications owing to their ability for nonlinear optical property. Aldehydes –based organic nonlinear optical crystals have a high thermal and environmental stability, as well as significant microscopic and macroscopic nonlinear optical susceptibility. They also generate powerful broadband THz waves when pumped at near –infrared and infrared wavelengths. Cinnamaldehyde is a one-dimensional donor- π – acceptor($D - \pi - A$)system used in nonlinear optics and organic electronics [1]. It consists of an electron donor group, a π -conjugated system and an electron acceptor group. This combination enables the molecule to making it useful for optoelectronics and NLO applications. These groups form a 180- degree bond with a simple aromatic benzene ring's-crystal/adduct technology develops unique solid forms of drugs with diverse physiochemical features-conjugated organic systems have become a popular choice for synthesizing efficient second and third order compounds due to their rapid reaction. In this present study, we synthesized organic and metal compound to form new organic crystals 3 Phenyl to bromo propanol has been synthesized and grew optically high quality single crystal using slow evaporation solution technique with ethanol as solvent. The grown crystals were characterized, using single crystal X-rays diffraction (XRD), Powder XRD (PXRD), Fourier transform Infra-red (FTIR), UV-Visible-NIR, thermogravimetric (TG) and Differential thermal analysis (DTA), fluorescence examination, SEM with EDAX and nonlinear optical methods.

EXPERIMENT

Material synthesis

In a 100 ml beaker, weight 10 g of potassium bromide (KBr) and dissolve it in 50 ml of pure water. Add 20 g of weighed cinnamon aldehyde to the KBr solution. Until the cinnamon aldehyde has completely dissolved, stir. Warm the blend to 100 °C. For twenty-four hours, the solution was constantly agitated with a magnetic stirrer. The appropriate amount of ethanol solvent was added to the calculated amount of material. Let the mixture cool gradually until it reaches room temperature [2]. It then showed up as a transparent solution with a yellowish tint.





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Whatman filter paper was used to filter the prepared solution, and pour the mixture into a crystallization dish or a dry, clean glass container. Allow the solution to stand at room temperature 20 to 25 degree Celsius for slow evaporation until some light yellow crystals of 3 phenyl 2-bromophenol(3P2BP) have been collected. Allow the solution to stand at room temperature (20⁰-25⁰) C for slow evaporation until some light-yellow crystal 3 phenyl 2-bromophenol(3P2BP) have been collected.

Characterization Studies

The 3 phenyl 2-bromophenol (3P2BP) cell characteristics were determined from single crystal x-ray diffraction investigations (MoK α radiation (λ =0.7170Å) the Enraf Nonius CAD4 diffractometer was employed for the measurements. This compound was studied using PXRD on the single crystal stage with an Xpert pro diffractometer and CuK α radiation (λ =1.54060Å) in the range of 10-60 degrees. Optical transmission spectra for the 3P2BP single cinnamaldehyde and potassium cinnamate were coordinated in the 4000-400 cm⁻¹ range (KBr pellet approach), using a BRUKER 66 VFT-IT spectrometer. The thermal behavior was analyzed in a nitrogen atmosphere using thermo gravimetric and differential thermal methods collected with the SDT Q 600 V8.0 thermal analyser. The melting points were taken with the crystal were recorded using a shimadzu UV-Vis spectrophotometer between 200 and 1100 nm range. FTIR analyses determined that melting point apparatus[3]. 1,3-Dibromo-1-phenylpropan-1-one and potassium hydroxide are the products of an electrophilic addition process with the bromine ions (from KBr) and cinnamaldehyde (CHO).

The mechanism of reaction

1. The bromine ions (Br-) from KBr) and cinnamaldehyde to form the intermediate bromonium ion.
2. The intermediate bromonium ion forms 2,3-Dibromo-1-phenylpropan-1-onea dibromo compound by the addition of an addition Br-ion.
3. The hydroxyl ions(OH-) generated combine with each of the K⁺ions at the end of the reaction to generate potassium hydroxide(KOH).

RESULTS AND DISCUSSION

Single Crystal X-ray diffraction

Single crystal x-ray diffraction (SXRD) analysis of the grown 3 phenyl 2-bromophenol(3P2BP) crystal was carried out using a Enraf Nonis CAD 4 X-ray diffractometer equipped with graphite monochromatic Mok radiation(λ =0.710Å). The grown crystal belongs to monoclinic crystal system α =90⁰, β =96.98⁰ γ =90⁰and the crystal cell volume is 779Å³. Which is in good agreement with the earlier reported values a=5.64,b=17.98,c=7.74 and it is given in Table.1. Single XRD was carried out as a confirmation of the associated monoclinic crystal structure and P space group, basic requirements for nonlinear optical applications. The produced chemical exhibits non-Centro symmetry as may be expected due to relatively good correlation between literature values and predicted lattice parameters. [4].

Powder X-ray Diffraction

With powder X-ray diffractometers, the sample type of crystallinity was determined; the peak intensity shows the level of crystalline nature of the compound. Figure demonstrates the 3P2BP crystal powder XRD pattern observed. This pattern provides additional information besides establishing that the crystalline nature of the crystal is different. Differences that may lead to patterns of crystals viewed within two hours are established through the (hkl) indices. The peaks were tried to be identified by powder XRD.A fine example of the same is the overlap of the hkl peaks and intensities for the simulated PXRD patterns and the ones that were actually obtained experimentally. The PXRD pattern diffraction peaks were tried to be indexed with the d-spacing for the corresponding (hkl) values [5]. The 3 phenyl 2-bromophenol(3P2BP) X-ray powder diffraction pattern was recorded on a Rigaku Mini Flex 600 diffractometer. The powder sample was scanned once every minute over a time period of 10 to 40 minutes. From Table, the unit cell parameters of the crystal are a a=5.64, b=17.98, c=7.74, α =90⁰, β =96.98⁰, γ =90⁰and the crystal cell volume is 779Å³.These values agree well with the published values. The type of crystallinity of the sample was





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determined with powder X-ray diffractometers; the degree of crystalline nature of the compound is reflected in the sharp peak of intensity. The triclinic nature of the crystal was also confirmed by powder X-ray diffraction and the lattice parameters were found to be quite close to the reported values. The solid diffraction peak and triclinic crystal structure of the melt-grown 3 phenyl 2-bromophenol(3P2BP) were confirmed. The value of 2θ suggests good crystalline purity and quality, which can be beneficial in NLO devices. XRD pattern for potassium bromide form 3 phenyl 2-bromophenol(3P2BP) crystal doped with cinnamon aldehyde, is shown in Table Distinct finely refined peaks at defined 2θ angles indicate a high degree of crystallinity of the 3 phenyl 2-bromophenol (3P2BP). X-ray diffraction has showed markedly increased signal intensity with sharp peaks suggest high quality and single crystal growth for 3 phenyl 2-bromophenol(3P2BP).

UV-Vis Spectral Analysis

The visible spectrum reveals the sequence pattern of molecular structure. Absorption in the UV-visible spectrum involves the transition of the electron in the π and π^* orbital from the ground state to the excited energy state. The UV-visible absorption and transmission spectra were recorded in the solid phase using Perkin Elmer Lambda 935. Transparent single crystals are suited for use in optical devices [6]. In broad terms, the transmittance properties are highly correlated with the substance atomic structure, band gap and quality. A UV-Vis-NIR spectrometer for the 200-1100 nm range is displayed in fig. Description of the optical transmission spectrum and was found to possess good optical transmittance in the visible and near-infrared ranges. The cut-off wavelength was 275.9 nm, growingly towards the surface. The optical absorption coefficient (α) is one of many important factors in choosing a material for optical applications. In the inset of figure, the crystal shows significant transmittance around 81% in the 300-1100 nm range. This also shows that the crystal has arbitrary absorbance of less than 0.12. One key features of the window of constructive transmittance is combined with devices that need to emit blue-green light [7].

Optical Band Gap Energy

The optical energy gap of the formed crystal computed using the transmittance spectrum using the equation mentioned. $\alpha h\nu = A(h\nu - E_g)^m$. Where A is a transition-dependent constant, E_g is the Energy gap of the material and n is a constant according to the type of electronic transitions $\frac{1}{2}$ for allowed direct transitions, $\frac{3}{2}$ for allowed indirect transitions, 2 for forbidden direct transitions and 3 for forbidden indirect transitions [8]. In this case, n is chosen as $\frac{1}{2}$ for a permitted direct transition and α is the absorption coefficient calculated using this formula, $\alpha h\nu = A(h\nu - E_g)^{1/2}$. The grain distribution and a few microcrystals on the surface of the growing crystal are clearly visible in fig. Tauc's plot can also be used to obtain an extrapolation value for direct band gap, which is 3.62 eV between $(\alpha h\nu)^2$ and $h\nu$. Due to improved optical band gap and attenuated absorption in the UV and visible regions, the material is a suitable candidate for optoelectronic applications.

FTIR Analysis

The geometry of a molecule and the interaction among its numerous functional groups is exposed by the FT-IR spectra. Molecules are made to show bands of bending and stretching due to infrared radiation. This is shown in the spectroscopic images of 3 phenyl 2-bromophenol(3P2BP) in fig .6. Olefin and aromatic C-H stretching are accountable for the sharp peak at 3065cm^{-1} and the peak at 3027.42cm^{-1} in the higher energy region.[9] The C-H aldehydic doublet stretching is represented by the peaks at about 2942.23cm^{-1} and 2749cm^{-1} , respectively. C-H aldehydic stretching appears in the band at 2942.23cm^{-1} . A maxima at 690cm^{-1} and at 750cm^{-1} are due to monostable benzene ring and aromatic C-H out of plane bending stretching vibrations, respectively. Double bonds C=O are identified by bands at 1681.39cm^{-1} . The C-O stretching vibration of an un-saturated aromatic aldehyde is represented by the edge at 1125cm^{-1} . Wave numbers and corresponding assignments are tabulated. All its functional groups were determined to exist in 3 Phenyl 2-bromophenol (3P2BP). A weak absorption band may be present around 3400cm^{-1} due to water vapour or moisture. The C-O alpha, beta unsaturated aromatic stretching vibration was found to be at a frequency of 1681.39cm^{-1} . The skeletal structure of benzene vibration is exhibited by the 1504cm^{-1} peak.





Thermal Analysis

Because of the high quality of heat generated during the cutting process, thermo gravimetric analysis (TGA) are crucial for assessing thermal stability in the fabrication technology. DTA and TGA of the prepared 3 phenyl 2-bromophenol(3P2BP) crystal were done from 30 to 987°C. The simultaneous TGA and DTA thermo grams are shown in fig. The melting temperature of the material may be found by locating the strong endothermic peak at 146°C according to the DTA curve. The narrow peak at 146 °C shows that can therefore, be made is that phase transitions have not been recorded until the melting point is reached, thus enlarging the temperature range within which this crystal will work well in NLO applications.[10] Thus, there is no weight loss almost until 250°C, which implies absence of water in the structure of the compound. The maxima were found at 270.2°C due to the compound decomposition stage. There are three phases of weight loss as seen on the TGA curve. This, coupled with a quick drop in weight over the region starting at around 200.8°C and marking the commencement of melting, corresponds to the first phase. The subsequent weight loss takes place in a region ranging from 296.7 to 557.4°C and maintain their overlap with respect to the second stage of weight loss(stage II). Weight loss at temperatures greater than 557.4°C could be attributed to the chemical breakdown associated with the third stage of weight loss(stage III).

Micro Structure Morphology Analysis

Scanning electron microscopy photographs of 3P2BP chloride crystal are shown in figure. SEM was used to study the surface topography of the evolving 3p2bp sample. Figure shows the SEM photograph of the 3p2bp crystal. The absorb particle can take many different shapes and be composed of small crystals in aggregates. They existed in bulk form and nano scale form with the mean diameter of the bulk particle being 10 mm. Nanoparticles prepared under experimental conditions exhibit detectable early aggregation in the micrographs. The smaller particles are likely to agglomerate into larger particles as they possess more surface activity. While scanning at 20 keV, the scanning electron microscope effectively utilizes an estimated beam of 10-10 amp. Micrographs reveal a clear early aggregation of the spherical nanoparticles produced under experimental conditions. Smaller particles are more surface active and aggregate to form larger particles. Scanning electron microscope successfully employs a beam of approximately 10-10 amp at 20 keV. Produced crystals with even surfaces and well-defined planes were the only one selected for SEM study; no polishing was performed. The researchers also found that the crystals produced exhibit a very fine rod-like morphology by employing a scanning electron microscope.

EDAX Analysis

The samples of crystals that were produced and analyzed by a JEOL JSM JSM 5610 LV scanning electron microscope to analyze for energy dispersive X-rays in an effort to confirm the presence of metal ions in the 3 phenyl 2-bromophenol(3P2BP) crystal. Figure is the integration of the cinnamaldehyde into the crystalline matrix of 3 phenyl 2-bromophenol. EDAX analysis confirmed the presence of cinnamaldehyde in the doped material. The surface analysis at some points indicates that the incorporation of cinnamaldehyde was not uniform throughout the crystal surface. Figure gives the EDAX spectra of the 3 phenyl 2-bromophenol(3P2BP) crystal. Figure 10 indicates the weight percentage of each element as obtained from the EDAX spectrum. The weight percentage bar chart made it very apparent that 3 phenyl 2-bromophenol(3P2BP) was the primary component in the crystal mixture. The peak reveals that potassium and sulfur are present in the crystal. Atomic percentages of C, O, K, Br were 78.66, 15.55, 3.24, 2.55 respectively as shown in figure.

Fluorescence

Fluorescence is typically expected in aromatic compounds or molecules with many conjugated double bonds and high resonance stability. Fluorescence is widely used in the fields of medicine and biochemistry. Fluorescent lights, light Emitting Diode (LED) lampstands other lighting devices also use it. Figure 11 displays the excitation and emission spectra for 3 phenyl 2-bromophenol(3P2BP) that were captured using the FP-6500 spectro fluorometer.[28] The measurement range of the emission spectrum was 350-600 nm. The carbonyl chromophore causes the compound 3 phenyl 2-bromophenol(3P2BP)





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NLO Studies

The optical crystals of 3 phenyl 2-bromophenol (3P2BP) subjected to this experimental analysis were tested for nonlinear optical property with a modified kurtz and perry powder technique. A Q-switched Nd-YAG laser beam operating with a repetition rate of 10 Hz and each pulse for 10 ns was employed at I.I.Sc., Bangalore, at a wavelength of 106 nm and with an input power of 1.2 mJ.[11] The powdered 3 phenyl 2-bromophenol(3P2BP) single crystals of uniform particle size are passively packed into a glass micro capillary tube. A photo-multiplier tube allows second harmonic generation (NLO-SHG) with cathode ray oscilloscope excitation. The source of the 532 nm output generated by the emission of green light was investigated to confirm the non-centrosymmetric space group of the 3 phenyl 2-bromophenol(3P2BP) grown single crystal. The nonlinear optical activity of this crystal with respect to the green light of 530nm provides evidence to an inner coordination of space group symmetry SHG. The output power is assessed to be 10 mW for 3 phenyl 2-bromophenol(3P2BP) and 8 mW for KDP, respectively, the constant input energy being 1.2 mJ pulse for both crystals. According to older studies, SHG efficiency of crystals is comparable to that of normal KDP. While the current study indicates that the efficiency of SHG of the herein - produced crystal is 1.25 times higher than normal KDP. Bearing this in mind, it is likely that the increased efficiency value influences its NLO characteristics.

CONCLUSION

For the first time, 3 phenyl 2-bromophenol(3P2BP) single crystals with well-defined structures have been synthesized by the slow evaporation solution method. The 3P2BP crystal possesses a monoclinic crystal structure, as confirmed by SXRD studies. The FTIR was utilized to ascertain the functional group positions of the target molecule. The optical quality at the absorption edge of 282 nm is excellent, as confirmed by the UV-Vis NIR study; with transmittance exceeding 80%. It is found that the optical band gap energy is 3.62 eV. The crystals have two peaks at wavelength of 330.97 and 643.33 nm. This result does, indeed, show that the crystals give off blue and red light. In addition, it can be seen that the crystal is of extremely high crystallinity since only two are most prominent. SEM analysis of the crystal indicated that, even though it had a very strong resemblance to a rock, its surface was level. Various non-instructive techniques were employed to study the composition of the crystal. EDAX experiments on the formation of the crystal were conducted with the aim to determine its elemental composition. Also, TG and DT experiments were performed to research the thermal behavior of the 3 phenyl 2-bromophenol(3P2BP) crystal.

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Table.1 Single Crystal XRD of 3P2BP crystal

Crystal System	a	b	c	α	β	γ	Volume
Monoclinic	5.64	17.98	7.74	90	96.98	90	779

Table.2 FT-IR Assignment of 3P2BP crystal

Wavenumber (cm ⁻¹)	Vibrational assignment
3065	Olefinic C-H stretching vibration
3027.42	Aromatic C-H Stretching vibrations
2924.23	Aldehydic C-H Stretching in aromatic ring
2749	Aldehydic C-H Stretching
1681.39	C=O stretching vibration of an-unsaturated aromatic aldehyde
1504	Skeletal system of benzene vibration
1344	C-H plane bending vibration of aldehyde group
1125	C-O stretching vibration of an -unsaturated aromatic aldehyde
3400	weak absorption band
769	Aromatic C-H out of plane bending vibration
690	Aromatic C-H out of plane bending vibration

Table.3 EDAX Analysis of 3P2BP Crystal

Element	Line	Mass%	Atom%
C	K	62.00±0.16	78.66±0.20
O	K	16.32±0.18	15.55±0.17
K	K	8.31±0.06	3.24±0.03
Br	L	13.36±0.11	2.55±0.02
Total		100.00	100.00
Spc_005	Fitting ratio	0.0414	





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Figure. 1: Grown 3 phenyl 2-bromophenol (3P2BP) Crystal

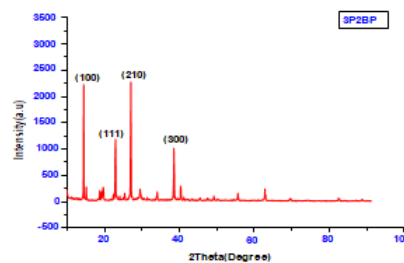


Figure.2: Powder X-ray Diffraction of 3P2BP Crystal

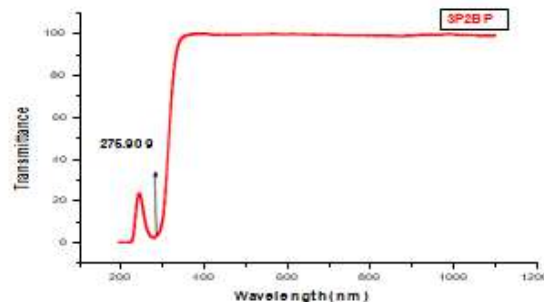
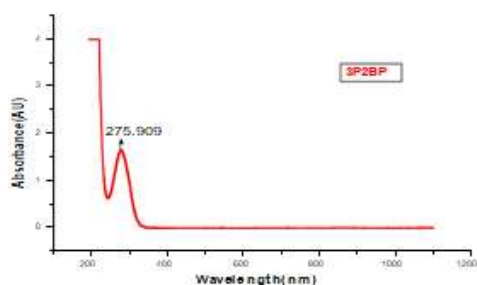


Figure.3: UV-Vis NIR Spectrum of 3P2BP Crystal

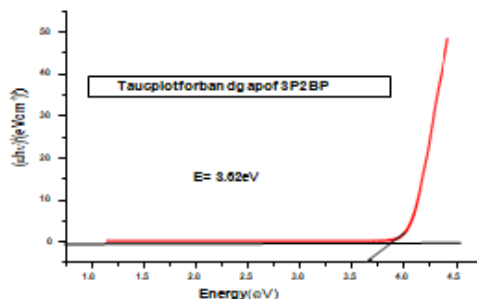


Figure.4: Tauc's Plot of the 3P2BP crystal

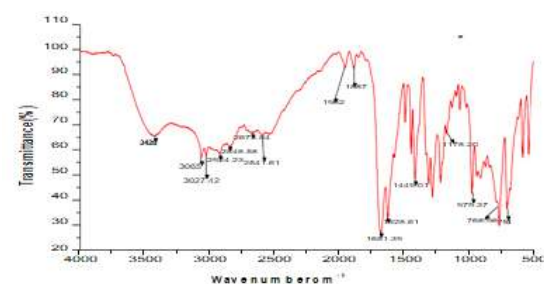


Figure.5: FT-IR Spectrum of 3P2BP crystal

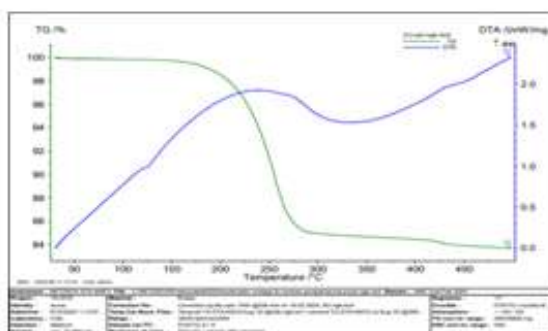


Figure.6: Thermal analysis of 3P2BP Crystal

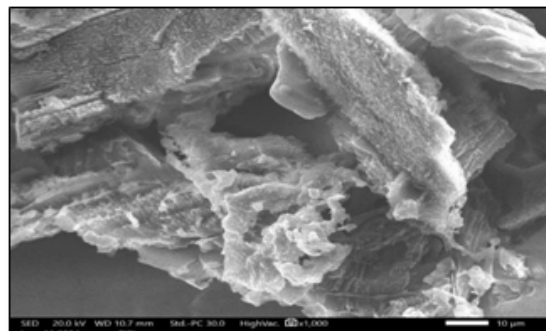


Figure.7: SEM Analysis of 3P2BP Crystal





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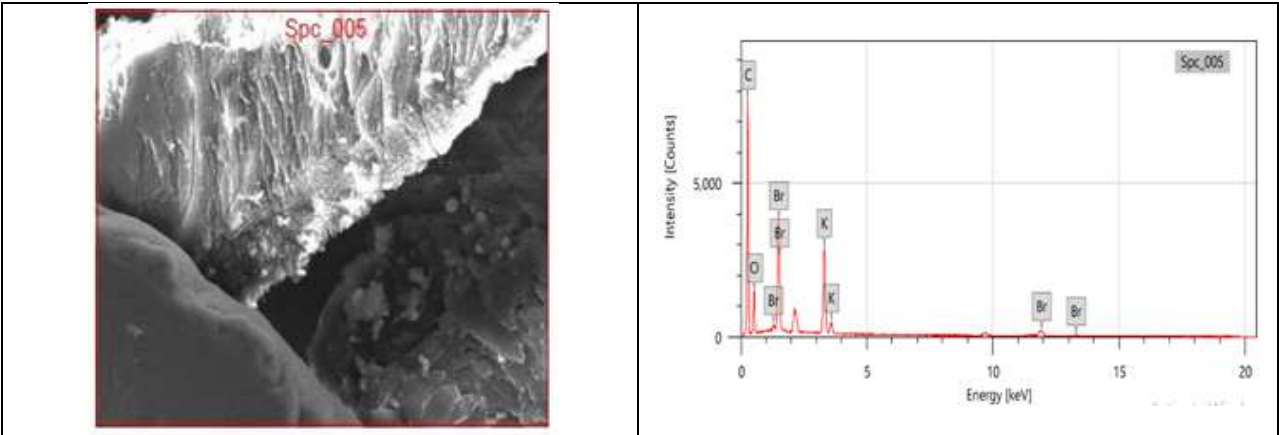


Figure.8: EDAX Analysis of 3P2BP Crystal

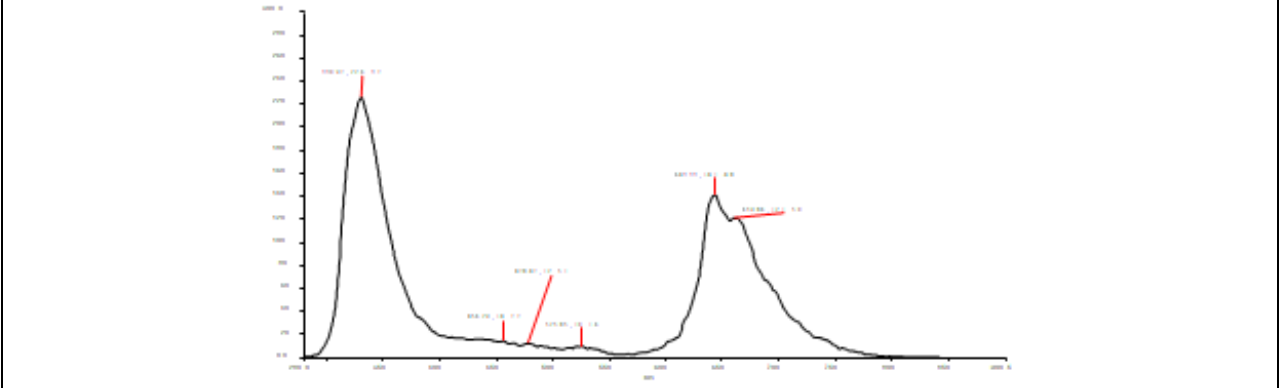


Figure. 9: Fluorescence Spectrum of 3P2BP Crystal





RESEARCH ARTICLE

The Relationship between Abdominal Endurance, Hamstring Flexibility and Dynamic Balance in Recreational Cricket Players : A Correlational Study

Pratiksha Chauhan^{1*}, Shewta Mistry² and Gaurav J. Patel³

¹MPT, Department of Physiotherapy, Ahmedabad Physiotherapy College, Ahmedabad, Parul University, Vadodara, Gujarat, India.

²Assistant Professor, Department of Physiotherapy, Ahmedabad Physiotherapy College, Ahmedabad, Parul University, Vadodara, Gujarat, India.

³Principal, Ahmedabad Physiotherapy College, Ahmedabad, Parul University, Vadodara, Gujarat, India.

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*Address for Correspondence

Pratiksha Chauhan

MPT, Department of Physiotherapy,
Ahmedabad Physiotherapy College,
Ahmedabad, Parul University, Vadodara,
Gujarat, India.

E.Mail: cpratiksha228@gmail.com



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ABSTRACT

The three abilities of cricket batting, fielding, and bowling require strength, muscular endurance, postural control, explosive bursts, and fitness. Numerous studies have already looked at the flexibility of the hamstrings, balance control, and abdominal endurance in various sports. The purpose of the study was to ascertain how recreational cricket players' dynamic balance, hamstring flexibility, and abdominal endurance relate to one another. To find out how recreational cricket players' dynamic balance, hamstring flexibility, and abdominal endurance relate to one another. A total 100 recreational cricket players with the average age of 20.42 ± 1.64 years and their body mass index (BMI) was 21.36 ± 2.14 kg/m². Among all participants, the average weekly hours played was 3.29 ± 0.62 . The ACSM Curl-up, V Sit and Reach, and Y Balance tests were performed to evaluate dynamic balance, hamstring flexibility, and abdominal endurance, respectively. To determine the correlation between the variables, the Pearson correlation coefficient test was employed. The findings indicated that among recreational cricket players, there was a favorable association between dynamic balance, hamstring flexibility, and abdominal endurance. The current study concludes that among recreational cricket players, dynamic balance, hamstring flexibility, and abdominal endurance are significantly correlated.

Keywords: Endurance, Flexibility, Balance, Core.





INTRODUCTION

A popular sport in many nations, cricket is loved by players of various skill levels. from hobby to competitive athletics. Despite being a non-contact sport, injuries can result from a wide range of factors in cricket[1]. Batting, fielding, and bowling are the three abilities needed to play cricket, and they all call for strength, muscular endurance, postural control, fitness, and explosive bursts[2]. Another important element that is necessary for all three of the cricket-related talents is balance. Balance is the capacity to maintain the center of mass of the body within the bounds of the base of support[3]. The ability of muscles to extend, enabling one joint or many joints in succession to move through a range of motion, is known as muscle flexibility[4]. A lack of flexibility impairs natural biodynamic balance and function, damages the musculoskeletal system, results in overuse pain, and lowers physical performance[5]. Insufficient hamstring suppleness is frequently suggested as a risk factor for soft tissue damage. The ability of the muscle to extend quickly without harm is thought to be diminished by a tighter musculotendinous structure[6]. The hamstrings have a major impact on body flexibility, and when the gluteus maximus and abdominal muscles are not properly adjusted, trunk stability and balance are negatively impacted[5]. Anatomically speaking, the "core" of the body is a box in which the diaphragm is on top, the pelvic floor and hip muscles are on the bottom, the abdominals are at the front, and the spinal and gluteal muscles are rear. The four main muscles of the abdomen are the transverse abdominis, external oblique, internal oblique, and rectus abdominis[4]. Key dynamic stabilizers of the spine, lumbopelvic region, and entire trunk-pelvic segment—collectively known as the "core" are the transversus abdominis and internal obliques during reaction-based actions (such as running and landing). Position of the trunk in relation to its base of support is controlled by the rectus abdominis, external obliques, and erector spinae joints. The first muscle to contract during lower body motions is the transversus abdominis[7]. Studies demonstrating the connection between these variables are hard to find still. In order to determine whether ideal endurance, hamstring flexibility, and balance management affect athletes' performance capacities, the goal of this study was to examine the correlations among abdominal endurance, hamstring flexibility, and balance in recreational cricket players. Therefore, it will be crucial for the coaches and physiotherapists to establish plans and provide them with the right training if we discover any correlation between these variables. This will help them perform better in the future.

MATERIALS AND METHODOLOGY

This is a co-relational research from Ahmedabad Physiotherapy College at Parul University in Ahmedabad. One hundred cricket players who played for fun were taken. An informed consent form authorized by the University Ethics Committee was signed by the participants. To collect demographic data, each participant was requested to fill out an information questionnaire. The nature of the research, the methodology, and the tests that would be used throughout the study were all explained to the subjects. Males between the ages of 18 and 25 who played cricket for at least two to three hours a week and had a BMI between 19.5 and 24.9 are included[8]. Individuals with neurological impairments, congenital deformities, recent surgical procedures, or musculoskeletal conditions were not allowed to participate[8]. All participants had their demographic information gathered. The ACSM Curl-up, Sit and Reach, and Y-Balance tests were performed to evaluate dynamic balance, hamstring flexibility, and abdominal endurance, respectively.

Procedure

ACSM curl-up test [9]

It is performed with the subject on his or her back on a mat, feet on the ground, and knees bent at a 90° angle. The fingers of the extended arms are in contact with a piece of masking tape. A second piece of tape is positioned 12 centimeters past the first. The metronome for this study was set to 40 beats per minute. By stretching the spine until the fingertips touch the second piece of tape, the patient raises his or her shoulder blades off the mat at the first beep. When the second beep sounds, the patient flattens their lower back and gradually brings their shoulder blades back to the mat. The individual undertakes as many curl-ups as they can without stopping, up to a maximum of 75 repetitions.



**V sit and reach test [10]**

The subject takes off their shoes, sits on the floor with the measuring line between their legs, places the soles of their feet immediately behind the baseline, and places their heels about 20 cm apart. The thumbs are clasped so that the hands are together, palms down, and placed on the measuring line. The subject holds their legs flat while slowly reaching forward as far as they can, keeping their feet flexed and their fingers on the baseline. The movement should be smooth and free of bounce, and they stay for two seconds. The test is conducted twice, with a brief break in between. Scoring: Zero point is at the level of feet. (We note negative values towards our body and positive values outward from our body.) The best trial is recorded in centimeters.

Y balance test [11]

The Y Balance was completed by the participants. The participants used their opposing leg, the reach leg, to push the reach indicator box as far as they could in the anterior, poster lateral, and posteromedial directions while standing with one leg, the stance leg, on the beginning block. Attempts were not counted if the participant kicked the indicator box forward to get more distance, rested the left foot on top of the indicator box while reaching, failed to return to center with maintained balance, or was unable to maintain a single leg stance throughout the entire movement. After completing six practice trials which were meant to acquaint the subject with the testing maneuvers. Each participant did three testing trials in each direction with each leg. To avoid tiredness, participants were permitted to take a brief break in between repetitions if necessary. The subject's scores were determined only using the values from the three testing trials. The average reach distance (in cm) was divided by the participant's leg length (in cm), and the percentage of the leg length was then multiplied by 100 to determine the scores for each direction (anterior, posteromedial, and poster lateral). The length of the patient's leg was measured from the distal point of the ipsilateral medial malleolus to the most noticeable part of the anterior-superior iliac spine. The total of the maximum reaches in each of the three directions was divided by three times the leg length to determine the composite score.

Statistical Analysis

Statistical analysis was carried out using SPSS Version 22.0 software; Results were tested for normal distribution using a Shapiro-Wilk test Pearson correlation coefficient test was used to find the correlation between abdominal endurance, hamstring flexibility and dynamic balance. Confidence interval was set at 95% and any value <0.05 was considered as significant and <0.001 as highly significant.

Demographic data

A total 100 recreational cricket players with the mean age of 20.42 ± 1.64 years and body mass index (BMI) mean was 21.36 ± 2.14 kg/m² The average number of hours played by all the participants per week was 3.29 ± 0.62 .

Abdominal Endurance

Using the ACSM Curl-up test, the abdominal endurance was evaluated. Male recreational cricket players in this study demonstrated exceptional abdominal endurance (30.97 ± 11.23). The Y balance test for both limbs in all three directions and the V sit and reach test ($r=0.722$, $p=0.000$) had a good association, according to the Pearson association Test. L Ant: $r=0.506$, $p=0.000$; L Post. Lateral: $r=0.342$, $p=0.000$; L Post. Medial: $r=0.460$, $p=0.000$; R Post. Lateral: $r=0.371$, $p=0.000$; R Post. Medial: $r=0.446$, $p=0.000$; and R Post. Ant: $r=0.471$, $p=0.000$. We can therefore conclude that hamstring flexibility and dynamic balance are strongly correlated with abdominal endurance.

Hamstring Flexibility

The V sit and reach test was performed to measure the flexibility of the hamstrings. The average score on the V sit and reach test was 38.17 ± 9.05 cm, indicating that recreational cricket players showed good hamstring flexibility. Second, dynamic balance and abdominal endurance for both limbs showed a high positive association in all three directions (p value > 0.001).



**Pratiksha Chauhan *et al.*,****Dynamic Balance**

The Y Balance test was used to evaluate the dynamic balance of male recreational cricket players. The mean standard deviation for each of the three directions and both limbs. The ACSM curl-up test, the V sit and reach test, and the Y balancing test all showed a significant positive connection with one another. Additionally, we discovered a good association between the variables of the left and right Y Balance tests.

DISCUSSION

The current study examined how recreational cricket players' dynamic balance, hamstring flexibility, and abdominal endurance relate to one another. Abdominal endurance and hamstring flexibility were found to be significantly correlated in this study. This is clarified by Kibler and colleagues. Kibler *et al.* state that the ideal way to conceptualize core muscle activity is as the pre-programmed integration of local, single-joint muscles and multi-joint muscles to generate motion and provide stability. For distal movement, this integrated core muscular action produces proximal stability[12]. The formation of interaction moments that move and protect distal joints follows a proximal to distal pattern, as does the patterning of force generation. Moments at joints that are produced by the movement and posture of neighboring body segments are known as interactive moments. Nevertheless, there is a dearth of research to precisely explain the connection between hamstring flexibility and abdominal endurance. To the best of our knowledge, this study is the first to look at how hamstring flexibility and abdominal endurance relate to one another in recreational cricket players. As several populations were included in earlier research. In the literature, it might have yielded conflicting results. However, we may believe that both abdominal and hamstring endurance are a part of a complex unit with connected functions, such that they influence one another's function in various contexts. A study by Jatin P. Ambegaonkar *et al.* found that there were fair positive correlations between left lateral core endurance and right posteromedial SEBT scores, but that the correlation was not consistent in all other directions. This finding is consistent with our significant correlation between dynamic balance and abdominal endurance. Another study by Gordon *et al.* [13] contrasted with ours and found no connections between core endurance and (as determined by the test for lowering the bent knee) as determined by the SEBT, and equilibrium. An additional investigation into the connections between soccer players' performance on the Star Excursion Balance Test and their sprint, flexibility, and upper extremity strength was conducted by A Kartal *et al* [14].

They found that dynamic equilibrium is maintained by strengthening the abdominal muscles. Stabilizing the trunk and pelvis in various soccer game scenarios. Thus, it is essential to continuously engage in abdominal strength training to enhance young soccer players' dynamic balance. This study's findings were comparable to ours. A study by Anoop Aggrawal *et al* [15] assessed the connection between lower extremity static balance performance and core stability performance in recreationally active people. The standing stoop test on both legs and the prone plank test were used to evaluate core stability and static balance, respectively. The results showed a substantial correlation between the performance on the prone plank test and static balance. These findings corroborate our hypothesis that balance is substantially correlated with the endurance of core muscles. They evaluated the correlation with static balance instead of dynamic balance, though. Cricket players exhibited a correlation between static balance and core endurance, according to Shanali Jain *et al.* [16]. However, in cricket players, there is no relationship between power performance, core endurance, and dynamic balance. It's possible that the disparity between these earlier research and the present findings results from different evaluation techniques. Furthermore, a variety of characteristics, including age, maturity, and training experiences, can influence the relationships between endurance and balance [17]. It is important to note, however, that a large number of these investigations have employed assessments of lower extremity strength unlike the current study. Our study also attempted to determine the relationship between dynamic balance and hamstring flexibility in recreational cricket players, and we discovered a considerable positive correlation between the two. Our results are in line with those of Alpaslan Kartal, who discovered some connections between hamstring flexibility and dynamic balance. Athletes with optimal flexibility may be better at dynamic balancing, whereas athletes with varying degrees of flexibility may find it more difficult to perform postural control[18].





CONCLUSION

It is concluded from the present study that there is significant relationship among abdominal endurance, hamstring flexibility and dynamic balance in recreational cricket players. Hence, it indicated that these capacities are dependent of each other and so they should be trained simultaneously. The finding of this study would benefit sports physiotherapist, athletic and fitness when dealing with athletes and sports person.

Limitations

There are important limitations in this study. First, we included recreational cricket players who performed batting, bowling, wicket keeping as well as fielding. Thus, Cricketers can be grouped according to their specific skills such as batsmen, bowlers, fielding and wicketkeepers and thus the study could be more specific and could have yield different results. Secondly, only recreational players were assessed who played cricket for 2 to 4 hours per week, thus the results cannot be generalized to the professional cricket players who play the game for longer duration.

Future recommendations

Future studies with different sports players and athletes can be done to get more generalized results and to explain the exact relationship among different fitness components. Secondly, future studies with female cricket players can also be carried out. Lastly, we had only assessed dynamic balance, thus future studies assessing dynamic as well as static balance can be done in order to get the clear picture about the relationship of balance with other components.

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Table1: illustrate descriptive statistic of all participants

Demographic data	Mean±SD
Age	20.42±1.64 years
BMI	21.36±2.14 kg/m ²
Hours of play	3.29±0.62 hours
*Data Mean±SD(95% Confidence interval)	

Mean±SD of all outcome measures.

Table2: illustrate Mean±SD of all outcome measures.

Outcome measure	Mean±SD		
ACSM Curl-up test	30.97±11.23		
V Sit and Reach test	38.17±9.05 cms		
Y- Balance test	Right	Anterior	70.15±9.56 cms
		Posteromedial	66.28±10.16 cms
		Posterolateral	60.75±9.68 cms
	Left	Anterior	68.58±8.47 cms
		Posteromedial	64.26±9.26 cms
		Posterolateral	60.06±10.38 cms

Pearson correlation among all the outcome measure

Table 3: Illustrate the Pearson correlation among all the outcome measure.

	ACSM Curl up test	V Sit and Reach test	Right Anterior	Right Posteromedial	Right Posterolateral	Left Anterior	Left Posteromedial	Left Posterolateral
ACSM curl up test	1	0.72** 0.00	0.47** 0.00	0.37** 0.00	0.44** 0.00	0.56** 0.00	0.32** 0.00	0.46** 0.00
V Sit and Reach test	0.72** 0.00	1	0.43** 0.00	0.50** 0.00	0.49** 0.00	0.47** 0.00	0.51** 0.00	0.52** 0.00
Right Anterior	0.47** 0.00	0.43** 0.00	1	0.81** 0.00	0.90** 0.00	0.90** 0.00	0.81** 0.00	0.82** 0.00
Right	0.37** 0.00	0.50** 0.00	0.81** 0.00	1	0.89** 0.00	0.82** 0.00	0.94** 0.00	0.90** 0.00





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Posteromedial	0.00	0.00	0.00		0.00	0.00	0.00	0.00
Right	0.44**	0.49**	0.90**	0.89**	1	0.84**	0.88**	0.95**
Posterolateral	0.00	0.00	0.00	0.00		0.00	0.00	0.00
Left	0.50**0.00	0.47**	0.90**	0.82**	0.84**	1	0.77**	0.84**
Anterior		0.00	0.00	0.00	0.00		0.00	0.00
Left	0.34**	0.51**	0.81**	0.94**	0.88**	0.77**	1	0.88**
Posteromedial	0.00	0.00	0.00	0.00	0.00	0.00		0.00
Left	0.46**	0.52**	0.82**	0.90**	0.95**	0.84**	0.88**	1
Posterolateral	0.00	0.00	0.00	0.00	0.00	0.00	0.00	

** Correlation is significant at 0.01 level (2-tailed)





RESEARCH ARTICLE

Comparative Analysis of the Pericervical Dentin Reinforcement Potential with Four Intra-Orifice Barrier Materials in Root-Filled Mandibular Molars : An *In-vitro* Study

Mallika Rawat¹, Mamta Singla^{2*}, Kushagar Chauhar¹, Sumeet Sharma³ and Meera Nair¹

¹Post Graduate Student, Department of Conservative Dentistry and Endodontics, Faculty of Dental Sciences, SGT University, Gurugram, Haryana, India.

²Professor, Department of Conservative Dentistry and Endodontics, Faculty of Dental Sciences, SGT University, Gurugram, Haryana, India.

³Professor and Head, Department of Conservative Dentistry and Endodontics, Faculty of Dental Sciences, SGT University, Gurugram, Haryana, India.

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*Address for Correspondence

Mamta Singla

Professor,

Department of Conservative Dentistry and Endodontics,

Faculty of Dental Sciences,

SGT University, Gurugram, Haryana, India.

E.Mail: mamta.singla@sgtuniversity.org



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ABSTRACT

Endodontically treated teeth are structurally weaker due to pulp loss, instrumentation, and dentin dehydration, making them prone to fractures—especially vertical root fractures, which account for 11–13% of failures. Preserving pericervical dentin (PCD), which absorbs occlusal forces, is crucial for fracture resistance. Intra-orifice barriers (IOBs) help reinforce PCD and enhance the coronal seal post-obturation.

This in vitro study assessed and compared the fracture resistance of mandibular molars restored with four distinct intra-orifice barrier (IOB) materials in endodontically treated teeth. Fifty extracted human mandibular molars with three canals were decoronated and standardized to a root length of 14 mm. They were then instrumented to a working length of size F3 using the ProTaper Gold system (Dentsply) and obturated with AHplus sealer and gutta-percha. The samples were then divided into five groups (n = 10). Group I served as the control (no IOB). In contrast, Groups II to V received a 3 mm intra-orifice barrier comprising Type II GIC, Mineral Trioxide Aggregate (MTA), Resin Composite, and Cavit, respectively. All specimens were implanted in acrylic resin and fracture tested with universal testing equipment (Instron). One-way ANOVA was used for statistical analysis, and Tukey's post hoc test was applied to assess group-wise differences. The group with the MTA barrier had the highest fracture resistance, which was followed by composite, GIC, Cavit, and control. The control and experimental groups showed a statistically significant difference, with MTA outperforming the others. Endodontically treated teeth have



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much higher fracture resistance when intra-orifice barriers are placed. Among the studied materials, MTA provided the most efficient strengthening of pericervical dentin.

Keywords: Intra-orifice barrier, Pericervical Dentin, Mineral Trioxide Aggregate(MTA), Endodontically Treated, Cavit

INTRODUCTION

Endodontically treated teeth have structural flaws and are more likely to shatter when compared with healthy teeth. The increased fragility is due to pulp tissue loss, extensive canal instrumentation, and dentin dryness. Studies have showed vertical root fractures account for 11%–13% of failures in endodontically treated teeth, underscoring the importance of post-endodontic reinforcement strategies[1,2,3]. Preserving pericervical dentin (PCD) is an important aspect in improving fracture resistance. Pericervical dentin is described as dentin that extends 4 millimeters above and below the crestal bone level. According to Swartz P *et al.*, the rate of failure of endodontically/root canal-treated teeth was approximately twofold in the cases where proper post-endodontic restoration was not provided. In this regard, preservation of the pericervical dentin (PCD) is of interest[4]. The occlusal stress propagates along the root's long axis through the PCD. Research indicates that long-term tooth retention and resistance to fractures are closely linked to the quantity of PCD that remains. The intra-orifice barrier (IOB) is also known as a coronal plug or barrier orifice. It is a restorative material applied to the opening of a root canal after obturation to enhance the coronal seal and strengthen the tooth structure. Ideally, an IOB material should exhibit mechanical properties similar to dentin, resist microbial penetration, be biocompatible, and be retrievable in case of retreatment[5]. Fig. 1 depicts the diagrammatic picture of the positioning of an intra orifice barrier above the root filling material. Fig. 2 shows a radiographic image of an endodontically treated maxillary molar with a composite and a GIC intra-orifice barrier placed over the gutta percha. Fig. 2 (i) Radiograph showing (A) gutta percha, (B) GIC intraorifice barrier and (C) GIC intracoronal restoration in an endodontically treated maxillary molar (ii) Radiograph depicting (A) gutta percha, (B) GIC as intraorifice barrier and (C) resin composite intracoronal restoration in an endodontically treated maxillary molar. (Courtesy: Dr Mallika Rawat). Although materials such as composite resin, GIC, MTA, and Cavit have been individually investigated, comparative data on their reinforcing capabilities are limited[6,7,8]. This study aimed to assess and compare the fracture resistance of endodontically treated mandibular molars restored with four different intra-orifice barrier (IOB) materials, with a particular focus on their impact on the pericervical dentin.

MATERIALS AND METHODOLOGY

Sample Size and Preparation

50 freshly extracted human mandibular molars with distinct canals (mesiolingual, mesiobuccal, and distal) were selected for this in vitro study. Teeth exhibiting anatomical anomalies such as more than three canals, root resorption, fractures, or significant curvature were excluded. To standardize sample dimensions, the crowns were sectioned at the cemento-enamel junction with a high-speed diamond disc and water cooling, resulting in a uniform 14 mm root length.

Root Canal Preparation and Obturation

Working lengths were calculated by inserting a K-file of #10 then subtracting 1 mm from radiographic apex. The Pro Taper Gold system (Dentsply) was used to perform biomechanical preparation in a crown-down procedure up to size F3. Following each instrumentation stage, Irrigation with 5.25% sodium hypochlorite (NaOCl) solution followed by a final rinse with 17% EDTA and saline. The canals were dried with paper points before being obturated with gutta-percha cones and AH Plus sealer (Dentsply) using the lateral condensation technique. Excess gutta-percha was removed using a hot tool, and the samples were incubated for 8 hours at 37°C to allow the sealer to fully set.





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Group allocation and placement of the IOB (intra-orifice barrier)

The specimens were randomly divided into five groups (n = 10 per group)

- Group I (Control): No intra-orifice barrier; 3 mm coronal gutta percha left intact.
- Group II (GIC): 3 mm of the gutta-percha removed coronally; restored with Type II GIC (Shofu).
- Group III (Composite): 3 mm gutta percha was removed; the hollow walls were etched with 37% phosphoric acid for 15 seconds, then washed with distilled water for 10 seconds before gently drying with moist cotton. IvoclarBluephase N MC was used to light-cure the universal bonding agent (TeEconom, IvoclarVivadent) for ten seconds. the tooth was rebuilt with a resin composite (TeEconom Plus, IvoclarVivadent) in two 1.5mm increments. light-cured with Ivoclar Bluephase N MC.
- Group IV (MTA): 3 mm gutta percha removed; restored with MTA(Angelus)
- Group V (Cavit): 3 mm gutta percha removed; restored with Cavit.

Specimen Embedding and Fracture Testing

Each root was embedded vertically in the self-curing acrylic resin blocks with dimensions (10 mm × 10 mm × 20 mm), leaving 3 mm of the coronal portion exposed. Fracture resistance testing was conducted using a universal testing equipment (Instron). A compressive load was applied at the crosshead speed of 1 mm/min until fracture. The maximum force required to induce fracture was recorded and evaluated in Newtons (N).

Statistical Analysis

A one-way analysis of variance (ANOVA) was employed to discover differences between groups in Table 3, followed by Tukey's post hoc test for pairwise comparisons in Table 4. Figure 3 depicts a line chart exhibiting the distribution of mean fracture resistance across all the five groups, revealing MTA's better performance, followed by composite resin.

RESULTS

Table 1 summarizes the fracture resistance values for each group. The mean fracture resistance values (in Newtons) for each group were measured and evaluated (Table 2). The findings revealed a statistically significant difference in fracture resistance across the experimental groups when compared to the control group.

Interpretation of Standard Deviation (SD)

- Low SD in Groups II and III (≈ 0.6) and Group I (~ 1.0) suggests high consistency in results across samples.
- Group IV (MTA) had a slightly higher SD (3.01), still indicating reasonable consistency.
- Group V (Cavit) had the highest variability (SD = 9.51), likely due to the inherent weakness and inconsistency of Cavit as a restorative barrier material. One-Way ANOVA Summary (Table 3)

Interpretation

- The F-value is very high (15,683.36), and the p-value is extremely low (4.14×10^{-70}), which is < 0.05 .
- This confirms that there is a highly significant difference in fracture resistance between at least two groups. Tukey's Post Hoc Test: Pairwise Comparisons (Table 4)

Analysis and Interpretation

1. All pairwise comparisons showed statistically significant differences ($p < 0.05$), confirming that each material provides a different level of reinforcement to endodontically treated teeth.
2. MTA (Group IV) exhibited the highest fracture resistance, significantly superior to all other groups including composite.
3. Composite resin (Group III) was also highly effective, significantly outperforming GIC, Cavit, and the control.
4. Glass Ionomer Cement (Group II) offered moderate strength but was significantly weaker than Composite and MTA, while still being significantly stronger than Cavit and Control.



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5. Cavit (Group V) showed slightly better resistance than Control, but with high variability and significantly lower strength than all other materials, suggesting limited clinical utility for long-term reinforcement.

Figure 3: Line chart illustrating the distribution of mean fracture resistance across all five groups, clearly demonstrating the superior performance of MTA followed by composite resin.

DISCUSSION

Endodontically/ root canal treated teeth are naturally more prone to structural failure due to the cumulative impact of pulp removal, canal instrumentation, and restorative treatments. Dietschi *et al.* believe that the loss of coronal tissue as a result of restorative surgeries or carious infections reduces tooth strength proportionally^[9]. The extent of dentin loss, particularly in the pericervical region, plays a pivotal role in determining a tooth's ability to resist functional and parafunctional forces. Susceptibility of fracture of endodontically treated tooth increases as excess dentin is removed when rotary files of increasing taper are used. Additionally, the use of intracanal irrigants and disinfectants may reduce the microhardness of root canal dentin, making it more brittle^[4]. Therefore, the emphasis should be on strengthening both the radicular and coronal portions. That is why we need to make use of materials that have good reinforcement properties. The current study compared the fracture resistance of endodontically/root canal treated mandibular molars to four frequently used intra-orifice barrier (IOB) materials: MTA, resin composite, glass ionomer cement (GIC), and Cavit.

Key Findings of study

Among all groups, Mineral Trioxide Aggregate (MTA) (Group IV) exhibited highest mean fracture resistance, followed by composite resin (Group III) and glass ionomer cement (Group II). Cavit (Group V) demonstrated a marginal improvement over the control group (Group I), which had no IOB placement, but the difference was not statistically significant. These findings are consistent with previous literature suggesting that intra-orifice barriers contribute significantly to reinforcing the remaining tooth structure post-endodontic treatment^[4,6,7,8]. Interpretation of Results MTA's superior performance can be attributed to its excellent biocompatibility, sealing ability^[14], and favourable interaction with dentin, promoting biomineralization and enhancing the mechanical properties of adjacent tooth structure^[10,11,12]. Although some earlier studies have reported concerns regarding MTA's handling and initial physical strength^[5], advancements in its formulation have improved its consistency and reinforcement capabilities. Composite resin, a widely accepted restorative material used commonly for posterior restorations shows the high compressive strength. They strengthen dental structure because adhesive composite binds to cusps and reduces bending, which is thought to be the leading cause of fracture in nonbonded restorations^[4]. Composite resins, because of their low elastic modulus, can transfer compressive stress to surrounding dental tissues, strengthening deficient tooth structure^[15]. Its adhesive properties allow for micromechanical retention, effective stress distribution, and reinforcement of weakened cusps—especially when used with high-filler nanohybrid formulations^[15]. Results are similar to study done by Aboobaker *et al.* who demonstrated that composite resins were more successful in enhancing fracture resistance as an intraorifice barrier than bonded amalgam and RMGIC¹³. GIC, while showing improved fracture resistance compared to the control, performed less effectively than MTA and composite. Despite its chemical bonding to dentin and fluoride release, GIC is more prone to polymerization shrinkage and lacks the modulus of elasticity and rigidity needed for high-stress environments^{16,17}. Cavit, commonly used as a temporary material, lacks the mechanical integrity necessary to provide long-term reinforcement. Its performance in this study was similar to the control group, reaffirming that it should not be relied upon for structural reinforcement.

Clinical Relevance

These findings reinforce the importance of selecting appropriate intra-orifice barrier materials in post-endodontic restorations. Emphasis should be placed not only on sealing ability but also on mechanical reinforcement—particularly in regions such as the pericervical dentin, which is critical for long-term tooth survival.





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Limitations

While the study was carefully standardized, several factors may influence fracture resistance in clinical scenarios, including

- The quantity and location of residual tooth structure
- Direction, magnitude, and duration of occlusal forces
- Tooth type and morphology
- Quality of coronal restoration and presence of full-coverage restorations
- Difference in initial and final strengths of materials

Further in vivo studies and long-term clinical trials are necessary to validate these findings and establish clinical protocols for optimal intra-orifice barrier selection.

CONCLUSION

Given the limitations of this in vitro investigation, it is possible to infer that the installation of an intra-orifice barrier greatly improves the fracture resistance of endodontically treated mandibular molars. Mineral Trioxide Aggregate (MTA) had the highest reinforcing potential of all the materials evaluated, followed by composite resin and glass ionomer cement. Cavit, due to its inferior mechanical properties, provided minimal reinforcement and showed no significant advantage over the control group. These results underscore the critical role of material selection in post-endodontic restoration, particularly for the protection of pericervical dentin. Incorporating intra-orifice barriers—especially MTA or composite resin—can contribute substantially to the structural longevity of the endodontically treated teeth.

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Table 1: Recorded values of Fracture Resistance of each group (in Newtons)

	Group 1 (control)	Group 2 (GIC)	Group 3 (Composite)	Group 4 (MTA)	Group 5 (Cavit)
1	200.1	350.1	551.2	556.0	204.2
2	198.3	348.9	550.5	564.8	203.5
3	196.7	349.3	549.8	565.2	203.8
4	197.5	348.7	550.9	565.7	234
5	198.0	349.0	551.0	566.3	203.7
6	197.2	349.5	551.1	564.9	203.9
7	196.9	349.2	550.4	565.5	203.6
8	198.4	349.1	550.3	565.1	204.1





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9	197.6	348.8	552.1	565.0	203.4
10	197.1	347.6	550.6	566.0	205.9

Table 2: Mean Fracture Resistance and Mean Standard Deviation of each group

Group	Material Used	Mean Fracture Resistance (N)	Mean Standard Deviation (SD)
Group I (Control)	No Barrier	197.78	1.00
Group II	Glass Ionomer Cement	349.02	0.64
Group III	Composite Resin	550.79	0.63
Group IV	Mineral Trioxide Aggregate (MTA)	565.45	3.01
Group V	Cavit	203.91	9.51

Table 3: One-Way ANOVA Summary

Source of Variation	Sum of Squares (SS)	Degrees of Freedom (df)	Mean Square (MS)	F-Value	p-Value
Among Groups	2,586,503.47	4	646,625.87	15,683.36	4.14×10^{-70}
Within Groups	1,842.96	45	40.95		
Total	2,588,346.43	49			

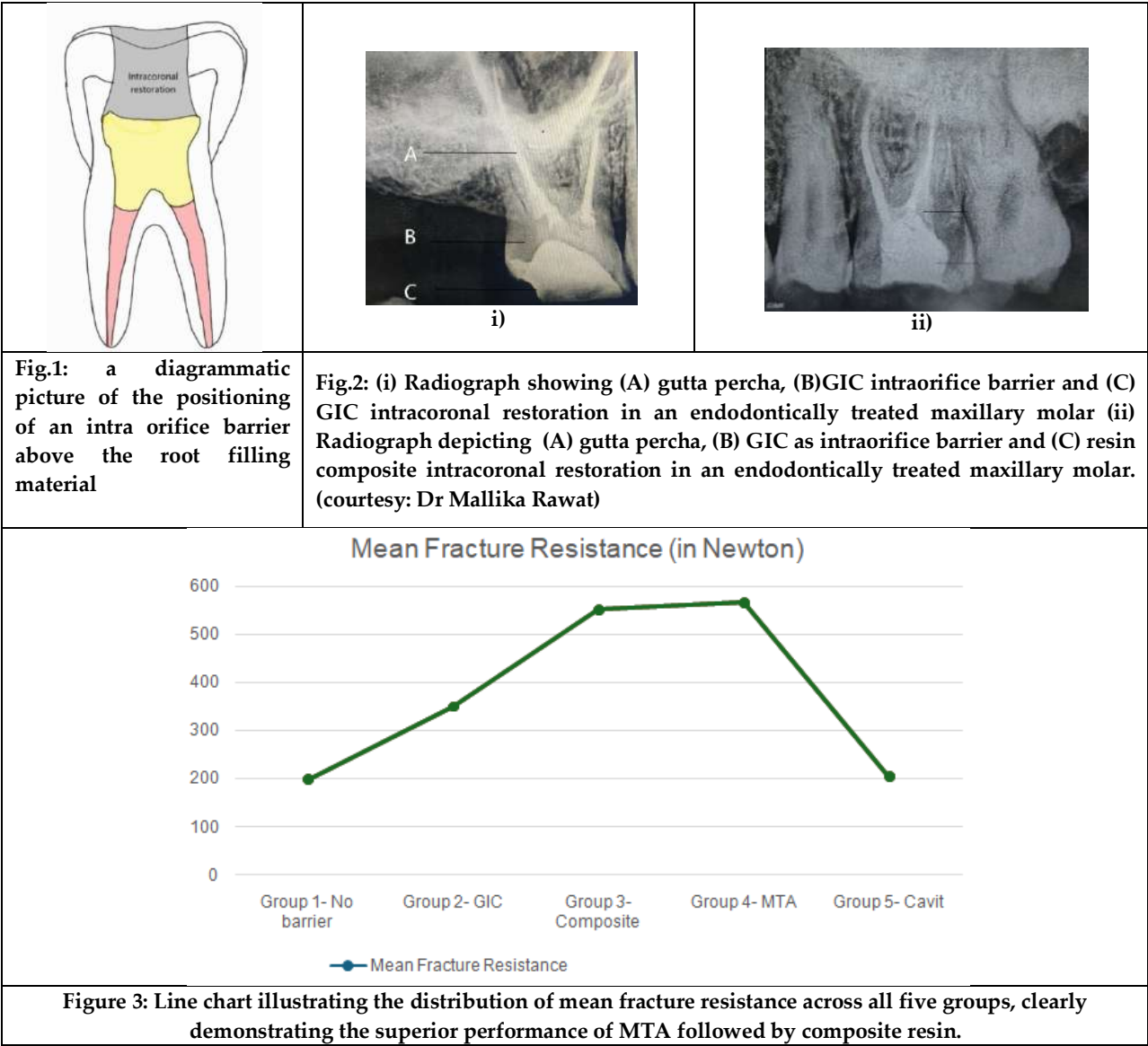
Table 4: Tukey's Post Hoc Test: Pair wise Comparisons

Comparison	Mean Difference (N)	p-value	95% CI (Lower – Upper)	Significant?
Group 1 (Control) vs Group 2 (GIC)	151.24	<0.0001	145.52 – 156.96	Yes
Group 1 (Control) vs Group 3 (Composite)	353.01	<0.0001	347.29 – 358.73	Yes
Group 1 (Control) vs Group 4 (MTA)	366.67	<0.0001	360.95 – 372.39	Yes
Group 1 (Control) vs Group 5 (Cavit)	9.23	0.0003	3.51 – 14.95	Yes
Group 2 (GIC) vs Group 3 (Composite)	201.77	<0.0001	196.05 – 207.49	Yes
Group 2 (GIC) vs Group 4 (MTA)	215.43	<0.0001	209.71 – 221.15	Yes
Group 2 (GIC) vs Group 5 (Cavit)	-142.01	<0.0001	-147.73 – -136.29	Yes
Group 3 (Composite) vs Group 4 (MTA)	13.66	<0.0001	7.94 – 19.38	Yes
Group 3 (Composite) vs Group 5 (Cavit)	-343.78	<0.0001	-349.50 – -338.06	Yes
Group 4 (MTA) vs Group 5 (Cavit)	-357.44	<0.0001	-363.16 – -351.72	Yes





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RESEARCH ARTICLE

A Finite Dimensional Optimal Filter Problem

V. Sathya^{1*} and V. Krishnan²

¹Assistant Professor and Research Scholar, Department of Mathematics, Jamal Mohamed College, (Affiliated to Bharathidasan University) Tiruchirappalli, Tamil Nadu, India.

²Assistant Professor, Department of Mathematics, Jamal Mohamed College, (Affiliated to Bharathidasan University) Tiruchirappalli, Tamil Nadu, India.

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*Address for Correspondence

V. Sathya

Assistant Professor and Research Scholar,
Department of Mathematics,
Jamal Mohamed College,
(Affiliated to Bharathidasan University)
Tiruchirappalli, Tamil Nadu, India.
E.Mail: vinayagaviswak234@gmail.com



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ABSTRACT

Consider a given diffusion coefficient for the state equation, observation function, and finite-dimensional exponential family of probability densities. We construct a drift for the state equation such that the resulting nonlinear filtering problem admits a finite-dimensional filter evolving in the prescribed exponential family augmented by the observation function and its square.

Keywords: Scalar Nonlinear Diffusion Processes, Stochastic Differential Equations, Finite- Dimensional Filters.

MSC Code: 60H30

INTRODUCTION

We consider the nonlinear filtering problem in continuous time. For a quick introduction to the filtering problem. For a more complete treatment from a mathematical point of view for a more applied perspective. The nonlinear filtering problem has an infinite-dimensional solution. Constructing nonlinear systems for which the optimal filter is finite dimensional is a problem which received considerable attention in the past. It turned out that such systems are quite rare. Instead, general results on nonexistence of such systems, based on Lie-algebraic techniques, were made available and related works appeared we construct scalar nonlinear filtering problems admitting finite dimensional filters. The solution of the filtering problem is a Stochastic Partial differential Equation (SPDE) which can be seen as a generalization of the Fokker-Planck equation expressing the evolution of the density of a diffusion process. This filtering equation is called Kushner-Stratonovich equation, and an unnormalized version of it is known





as the Duncan–Mortensen–Zakai Stochastic Partial Differential Equation. In the Fisher metric is used to project the Kushner–Stratonovich equation onto an exponential family of probability densities, yielding the new class of approximate filters called projection filters. In the Gaussian projection filter is studied in the small-noise setting. We model the state according to a SDE whose drift may depend on the observations. We consider a given diffusion coefficient for the state equation, a given observation function, and a given finite-dimensional exponential family of probability densities. We construct a drift for the state equation such that the resulting nonlinear filtering problem admits a finite-dimensional filter evolving in the prescribed exponential family augmented in a particular way.

PROBLEM FORMULATION

On the probability space $(\Omega, \mathcal{F}, P)$ with the filtration $\{F_t, t \in [0, T]\}$ we consider the following scalar state and observation equations:

$$\begin{aligned} dX_t &= f_t(X_t, Y_t) dt + \sigma_t(X_t) dW_t, \quad X_0, \\ dY_t &= h(X_t) dt + dV_t, \quad Y_0 = 0 \end{aligned} \quad (1)$$

We set

$$a_t(\cdot) := \sigma_t(\cdot)^2$$

Time invariance of h is needed to simplify exposition. These equations are Itô stochastic differential equations (SDE's). We shall use both Itô SDE's and McShane–Fisk–Stratonovich (MFS) SDE's. The MFS form will be denoted by the presence of the symbol 'o' in between the diffusion coefficient and the Brownian motion of a SDE. The noise processes $\{W_t, t \in [0, T]\}$ and $\{V_t, t \in [0, T]\}$ are two standard Brownian motions. Finally, the initial state X_0 and the noise processes $\{W_t, t \in [0, T]\}$ and $\{V_t, t \in [0, T]\}$ are assumed to be independent. This model is different from the models given usually, Davis and due to the presence of Y_t in the drift f_t of the state equation. A general formulation is given of which our model is a particular case. For example, the application of SPDEs theory to filtering, where the used model class allows dependence of the coefficients f , a and h on the observation process Y . Such models are often encountered in stochastic control. The nonlinear filtering problem consists in finding the conditional probability distribution π_t of the state X_t given the observations up to time t , i.e. $\pi_t(dx) := P[X_t \in dx | Y_t]$, where $Y_t := \sigma(Y_s, 0 \leq s \leq t)$. We shall say that a filtering problem such as satisfies condition if for all $t \in [0, T]$, the probability distribution π_t has an unnormalized density q_t w.r.t. the Lebesgue measure, and $\{q_t, t \in [0, T]\}$ satisfies the Itô-type stochastic partial differential equation.

$$dq_t = L_t^* q_t dt + q_t h dY_t \quad (2)$$

in a suitable functional space, where for all $t \geq 0$, the forward diffusion operator L_t^* is defined by

$$L_t^* \phi = -\frac{\partial}{\partial x} [f_t \phi] + \frac{1}{2} \frac{\partial^2}{\partial x^2} [a_t \phi],$$

For any test function ϕ .

Conditions under which holds, and more general results on solutions of the DMZ–SPDE. The corresponding MFS form of the SPDE (2) is:

$$dq_t = L_t^* q_t dt - \frac{1}{2} q_t |h|^2 dt + q_t h \circ dY_t.$$

It is known that in general the density q_t does not evolve in a finite-dimensional parametrized family, say $\{q(\cdot, \zeta), \zeta \in U \subset \mathbb{R}^{m+1}\}$. For example, in the linear case q_t evolves in the manifold of the unnormalized Gaussian densities. Let σ and h ensuring that q_t evolves in a finite-dimensional family however, that in these examples the drift f is not allowed to depend on the observation process Y .

Definition 2.1

Let $\{c_1, \dots, c_m\}$ be scalar functions defined on $\mathbb{R}$, such that $\{1, c_1, \dots, c_m\}$ are linearly independent, have at most polynomial growth and are twice continuously differentiable. Assume that the convex set

$$\Theta_0 := \{\theta \in \mathbb{R}^m : \psi(\theta) = \log \int \exp[\theta^T c(x)] dx < \infty\},$$

has non-empty interior. Then

$$\begin{aligned} EU(c) &= \{q(\cdot; \theta, \beta), (\theta, \beta) \in U\}, \\ q(x; \theta, \beta) &:= \exp[\theta^T c(x) + \beta], \end{aligned}$$





where $(\theta, \beta) := [\theta_1, \dots, \theta_m, \beta]^T$ and $U \subseteq \Theta_0 \times \mathbb{R}$ is open, is called an unnormalized exponential family of probability densities. The $m + 1$ quantities (θ, β) are called the canonical parameters for the unnormalized exponential family EU (c). Consider the nonlinear filtering problem for the system (1). Suppose that the nonlinear coefficients $\sigma_t(\cdot)$ and $h(\cdot)$ are given a priori. Let be given an exponential family. To find a drift $f = u$ such that the resulting filtering problem has a solution in the given exponential family augmented by the functions h and h^2 in the exponent.

SOLUTION OF THE PROBLEM

Theorem 3.1. If the drift

$$u_t(x, \zeta_t) := \frac{1}{2} \frac{\partial a_t}{\partial x}(x) + \frac{1}{2} \alpha_t(x) \zeta_t^T \frac{\partial c^*}{\partial x}(x),$$

with

$$\zeta_t^1 := Y_t + \zeta_0^1, \quad \zeta_t^2 := \zeta_0^2 - \frac{1}{2} t, \quad \zeta_t^i := \zeta_0^i, \quad i = 3, \dots, m, \quad (3)$$

As a consequence, for the resulting nonlinear filtering problem with coefficients u_t , a_t and h , the optimal filter is expressed by the density $q_t = q(\cdot, \zeta_t, \beta_0)$ which evolves in the finite dimensional exponential family EU (c^*).

PROOF

Consider a candidate drift $u_t(\cdot, \zeta_t, \beta_t)$ and the associated forward differential operator

$$u_t^* \phi = - \frac{\partial}{\partial x} [u_t(\cdot, \zeta_t, \beta_t) \phi] + \frac{1}{2} \frac{\partial^2}{\partial x^2} [\alpha_t \phi]. \quad (4)$$

The corresponding state equation originates the filtering problem for the system

$$\begin{aligned} dX_t &= u_t(X_t; \zeta_t, \beta_t) dt + \sigma_t(X_t) W_t, \quad X_0 \\ dY_t &= h(X_t) dt + dV_t. \end{aligned} \quad (5)$$

In order to check under which conditions this filtering problem has solution $q_t = q(\cdot, \zeta_t, \beta_t)$ Write the right-hand side of the DMZ-SPDE for the density $q(\cdot, \zeta_t, \beta_t)$ and equate it to the differential of $q(\cdot, \zeta_t, \beta_t)$ computed via the chain rule:

$$\begin{aligned} \sum_{i=1}^{m+2} \frac{\partial q(\cdot; \zeta_t, \beta_t)}{\partial \zeta_t^i} \circ d\zeta_t^i + \frac{\partial q(\cdot; \zeta_t, \beta_t)}{\partial \beta} \circ d\beta_t^i \\ = u_t^* q(\cdot; \zeta_t, \beta_t) dt - \frac{1}{2} q(\cdot; \zeta_t, \beta_t) |h|^2 dt + q(\cdot; \zeta_t, \beta_t) h \circ dY_t. \end{aligned} \quad (6)$$

By dividing both sides by q and straightforward calculations, one obtains

$$\begin{aligned} \sum_{i=1}^{m+2} c_i^* \circ d\zeta_t^i + d\beta_t = h \circ dY_t - \frac{1}{2} h^2 dt - u_t(\cdot; \zeta_t, \beta_t) \zeta_t^T \frac{\partial c^*}{\partial x} \\ \bullet \frac{\partial u_t(\cdot; \zeta_t, \beta_t)}{\partial x} + \frac{1}{2q(\cdot; \zeta_t, \beta_t)} \frac{\partial^2 [a_t q(\cdot; \zeta_t, \beta_t)]}{\partial x^2} \end{aligned} \quad (7)$$

A first step in finding curves $t \rightarrow \zeta_t$ and $t \rightarrow \beta_t$ such that this equation is satisfied is to set

$$\begin{aligned} d\zeta_t^1 := dY_t, \quad d\zeta_t^2 := -\frac{1}{2} dt. \text{ then the differential equation} \\ \frac{\partial u_t(\cdot; \zeta_t, \beta_t)}{\partial x} + \zeta_t^T \frac{\partial c^*}{\partial x} u_t(\cdot; \zeta_t, \beta_t) \\ = - \sum_{i=3}^{m+2} \zeta_t^i c_i^* - \beta_t + \frac{1}{2q(\cdot; \zeta_t, \beta_t)} \frac{\partial^2 [a_t q(\cdot; \zeta_t, \beta_t)]}{\partial x^2} \end{aligned} \quad (8)$$

By solving this last equation in u one obtains

$$\begin{aligned} u_t(x; \zeta_t, \beta_t) &= \frac{1}{2} \frac{\partial a_t(x)}{\partial x} + \frac{1}{2} \alpha_t(x) \zeta_t^T \frac{\partial c^*}{\partial x} \\ \bullet \quad &\theta_t^T \exp[-\zeta_t^T c^*(x)] \int_{-\infty}^x c(z) \exp[\zeta_t^T c^*(z)] dz \\ \bullet \quad &\beta_t \int_{-\infty}^x \exp[\zeta_t^T c^*(z)] dz. \end{aligned} \quad (9)$$

We are free to choose the curve $t \rightarrow (\theta_t, \beta_t)$ as we wish, as long as it is regular. Set $\theta_t := \theta_0$ for all $t \in [0, T]$, and $\beta_t := \beta_0$ for all $t \in [0, T]$.

APPLICATION

Example 4.1

Cubic observations





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The present example is inspired by the cubic sensor studied, where it is proven that for the cubic sensor problem there exists no finite dimensional filter. Here we consider the case where the diffusion coefficient for the state equation is constant say $a(x)=1$ for all $t \in [0, T]$ and $x \in \mathbb{R}$ and with cubic observation function ($h(x) = x^3$ for all $x \in \mathbb{R}$).

The filtering problem for the system

$$dx_t = \left[\frac{3}{2} Y_t X_t^2 - 3 \left(1 + \frac{1}{2} t \right) X_t^5 \right] dt + dW_t, \quad qx_0 \sim \exp[-x^6], \quad (10)$$

$$dY_t = X_t^3 dt + dV_t, \quad Y_0 = 0, \quad (11)$$

is finite dimensional and has conditional law with density

$$Px_t | Y_t(x) \propto \exp[Y_t x^3 - (1 + \frac{1}{2} t) x^6], \quad t \in [0, T], \quad x \in \mathbb{R}. \quad (12)$$

Example 4.2

Linear Observations

We consider the case of linear observations. For simplicity, take h equal to the identity function. The optimal filter for the filtering problem

$$dx_t = \left\{ \frac{1}{2} \frac{\partial a_t}{\partial x} (X_t) + \frac{1}{2} a_t (X_t) \left[Y_t + \frac{\mu_0}{v_0} - \left(t + \frac{1}{v_0} \right) X_t \right] \right\} dt \quad (13)$$

$$+ \sigma_t (X_t) dW_t, \quad X_0 \sim N(\mu_0, v_0), \quad a_t = \sigma_t^2, \quad (14)$$

$$dY_t = X_t dt + dV_t, \quad Y_0 = 0,$$

is finite dimensional and has conditional law with density

$$X_t | Y_t \sim N\left(\frac{\mu_0 + Y_t v_0}{1 + v_0 t}, \frac{v_0}{1 + v_0 t}\right). \quad (15)$$

CONCLUSION

Hence we have contradicts the classical results on nonexistence of finite dimensional filters, and the related works. This contradiction appears a natural consequence of the arbitrariness of σ and h . since $\{\zeta_t, t \in [0, T]\}$ depends on the observation process Y , the drift itself depends on the observations. We cannot construct a nonlinear filtering problem with prescribed σ and h , with drift u which does not depend on the observation process Y and whose solution remains finite dimensional.

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RESEARCH ARTICLE

Automated Detection of Leukemia Cells using Watershed Transform and Fuzzy C-Means Clustering Algorithm

M. Annies Stelina^{1*} and S. Subbulekshmi²

¹Research Scholar (Reg.No.: 22223152282014), Department of Computer Science, S.T. Hindu College, Nagercoil, Kanyakumari, (Affiliated to Manonmaniam Sundaranar University, Tirunelveli), Tamil Nadu, India.

²Associate Professor, Department of Computer Science and Application, S.T. Hindu College, Nagercoil, Kanyakumari, (Affiliated to Manonmaniam Sundaranar University, Tirunelveli), Tamil Nadu, India.

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*Address for Correspondence

M. Annies Stelina

Research Scholar (Reg.No.: 22223152282014),

Department of Computer Science,

S.T. Hindu College, Nagercoil, Kanyakumari,

(Affiliated to Manonmaniam Sundaranar University, Tirunelveli),

Tamil Nadu, India.

E.Mail: anniestelina@gmail.com



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ABSTRACT

Leukemia is a tumor of the blood or bone marrow, characterized by the uncontrolled growth of White Blood Cells. Automated leukemia detection plays a crucial role in early diagnosis, improving treatment accuracy, and reducing diagnostic errors. It enhances efficiency by processing large datasets, leading to faster and more reliable patient care. Existing automated leukemia detection systems face challenges such as data quality variability, limited generalization across diverse populations, and difficulty distinguishing between leukemia subtypes. Issues like false positives/negatives, lack of interpretability, and integration with clinical systems also hinder their effectiveness. Overcoming these barriers requires better data, more interpretable algorithms, and seamless integration with healthcare infrastructure. This research proposes a hybrid approach entitled 'Automated Detection of Leukemia Cells Using Watershed Transform and Fuzzy C-Means Clustering Algorithm (ADL-WTFCC)' which integrates watershed transform and Fuzzy C-Means (FCM) clustering algorithm to achieve precise segmentation and detection of leukemia cells. The watershed transform is utilized for initial segmentation by treating the image as a topographic surface and identifying cell boundaries through a flooding process. Subsequently, FCM clustering refines the segmentation by assigning pixels to clusters based on membership values, accommodating the ambiguity in cell boundaries, and displaying the detected leukemia cells. The proposed method is evaluated using the datasets BCC_DS, ALL_DS, and SNAM_DS, which comprise annotated microscopic images of blood smears. Performance metrics such as recall, precision, F1-score, and Dice coefficient are employed to



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assess the segmentation accuracy. The experimental results demonstrate that our approach achieves precision of 87.2%, recall of 86.4%, FScore of 86%, and Dice coefficient of 92.2%. These findings highlight the potential of combining watershed transform and FCM clustering for robust and accurate leukemia cell detection, offering significant benefits for clinical diagnostics.

Keywords: Leukemia, Cancer Cells, Watershed Transform, FCM Clustering, Medical Image Processing

INTRODUCTION

Leukemia is a type of cancer that affects blood and bone marrow, characterized by the abnormal proliferation of white blood cells [1]. Effective therapy and better patient outcomes depend on an early and precise diagnosis. Traditionally, leukemia diagnosis relies on manual examination of blood smear images by trained hematologists, a process that is both time-consuming and prone to human error. Automated image analysis techniques present a promising solution, offering the potential for consistent and objective evaluation of microscopic images [2], [3]. The field of medical image processing has seen significant advancements with the advent of powerful computational techniques and algorithms. Among these, the watershed transform and FCM clustering algorithm [4] have been widely utilized for image segmentation tasks due to their effectiveness in handling complex and noisy data [5]. The watershed transform[6] is a morphological-based method that considers the image to be a topographic surface, with elevation represented by the intensity values. By mimicking the process of floods, the watershed transform delineates distinct regions, making it particularly useful for separating overlapping objects in an image. However, it can be sensitive to noise and may result in over-segmentation. To address these limitations, the watershed transform can be complemented with the FCM clustering algorithm. FCM is a soft clustering technique that assigns each pixel a degree of membership to multiple clusters, rather than forcing a hard assignment. This flexibility allows FCM to handle better the inherent ambiguity in cell boundaries and variations in cell morphology. By integrating the watershed transform with FCM clustering, we aim to leverage the strengths of both methods to achieve more accurate and robust segmentation of leukemia cells. In this research, we propose an automated detection system for leukemia cells using a hybrid approach that combines the watershed transform and FCM clustering algorithm. We assess our method's performance using a dataset that includes annotated microscopic images of blood smears, comparing our results against baseline techniques. Our objective is to demonstrate this hybrid approach's potential in improving leukemia cell detection's precision and reliability, which ultimately contributes to more effective clinical diagnostics.

LITERATURE REVIEW

Genc *et al.* (2023) emphasized that improving healthcare infrastructure, diagnostic timelines, and treatment access can reduce inequalities in AML management. However, implementation challenges, especially in resource-limited settings, remain a significant barrier [7]. Shaik and Yeasin (2009) developed the FASIC algorithm, integrating fuzzy memberships to improve DEG identification from microarray data, validated through multiple approaches. However, while effective, its reliance on specific clustering techniques may limit generalizability to diverse datasets [8]. Yang *et al.* (2005) introduced the robust color GVF snake, integrating robust estimation and Luv color gradients to enhance cell segmentation in hematopathology images, outperforming pixel-based methods. However, its application is limited compared to general segmentation techniques like watershed algorithms, which offer broader adaptability [9]. Dhal *et al.* (2024) reviewed advancements in Fuzzy C-Means (FCM) clustering, addressing its limitations like high computational cost, sensitivity to noise, and dependency on initial parameters. However, despite improvements, FCM variants still face challenges in balancing accuracy and efficiency for diverse image segmentation tasks [10]. Ghraibah and Ayyad (2024) developed a fast and accurate leukemic detection system using digital image processing, achieving high classification accuracies through extracted cell features. However, its reliance on limited features may restrict adaptability to more complex classification models in future applications [11]. Shinde *et al.* (2020) proposed a watershed-based algorithm to improve WBC blast cell segmentation in leukemia



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blood smears, effectively distinguishing clustered cells for accurate counting. However, its performance is better for lymphoid leukemia than myeloid leukemia, and chromatin weak spots may lead to misclassification [12]. Bhattacharjee and Saini (2015) developed a user-friendly GUI to streamline lymphocytic cell identification, allowing segmentation, classification, and data storage with adjustable contrast settings. However, the reliance on manual verification may limit automation and efficiency in large-scale analyses [13]. Kornilov and Safonov (2018) reviewed six open-source watershed segmentation implementations, highlighting variations in performance, processing time, and memory consumption despite using the same algorithm. However, while parallel processing could improve efficiency, developing concurrent watershed approaches remains a significant challenge [14]. Viswanathan (2015) proposed an automated leukemia detection approach using morphological contour processing and Fuzzy C-Means classification, ensuring accurate WBC segmentation with low computation time. However, the system lacks the capability to classify specific leukemia subtypes, which could be improved using soft set rules in future work [15]. Das *et al.* (2022) proposed an advanced fuzzy clustering approach using an Eagle Strategy-based Stochastic Fractal Search (ES-SFS) method with morphological reconstruction to improve WBC segmentation in ALL images, overcoming noise sensitivity and initialization issues. However, the computational complexity of the ES-SFS method may limit its real-time applicability in clinical settings [16]. Kumar (2022) explored leukemia detection using image processing and IoT, highlighting its cost-effectiveness and efficiency over traditional lab testing, with FCM for feature extraction and future neural network integration. However, reliance on IoT-based systems may pose challenges in regions with limited technological infrastructure [17]. Pavithra and Bagyamani (2015) proposed a digital image processing method for leukemia detection, offering a cost-effective and time-efficient approach by analyzing WBC count in microscopic blood images. However, the reliance on WBC count alone may limit accuracy, as leukemia diagnosis often requires additional morphological and genetic analysis [18]. Moshavash *et al.* (2018) developed a robust decision support system for acute leukemia diagnosis, using an automatic segmentation method and novel feature extraction for leukocyte classification, achieving high accuracy rates. However, variations in imaging conditions across different laboratories may still impact segmentation consistency [19]. Ghaderzadeh *et al.* (2021) emphasized the potential of machine learning (ML) in blood smear analysis for early leukemia detection, recommending future advancements in deep learning and computer-aided diagnosis for improved accuracy. However, current ML models still face limitations in precisely classifying leukemia subtypes, as seen in the lower accuracy for B-cell lymphoma diagnosis [20].

Karthikeyan and Poornima (2017) compared Fuzzy C-Means and K-Means for leukemia detection in stained blood images, finding Fuzzy C-Means more accurate (90% vs. 83%) and using SVM for classification based on extracted color and shape features. However, the method's reliance on handcrafted features may limit adaptability to diverse image datasets [21]. Shamas *et al.* (2022) analyzed lung cancer detection using K-Means clustering, evaluating its effectiveness in segmenting small-cell and non-small-cell lung cancer stages for improved patient care. However, the accuracy of K-Means clustering heavily depends on dataset quality and initial parameter selection, which may affect consistency in real-world applications [22]. Zhang (2009) introduced a new fuzzy C-Means clustering validity metric using Pearson correlation in distance metrics, demonstrating its consistency across six microarray datasets for assessing cluster quality. However, the effectiveness of this measure may vary when applied to datasets with different statistical properties or noise levels [23]. Inbarani (2019) proposed the HSCRKM algorithm, Leukemia nucleus segmentation using a hybrid histogram-based soft covering rough k-means clustering approach, integrating rough sets and machine learning for improved classification accuracy. However, the approach may have limitations in handling highly noisy images, which could impact segmentation precision [24]. Mohapatra (2011) proposed a two-stage WBC nucleus segmentation method using Hausdorff dimension and contour signature for leukemia detection, with SVM classification based on shape, color, and texture features. However, the method may face challenges in handling overlapping cells, requiring further improvements in segmentation techniques [25]. Hudaya (2022) explored leukemia image segmentation using FCM on the ALL-IDB2 dataset, improving specificity and precision slightly but increasing execution time by 23.10% and reducing accuracy to 95.42%. However, the FCM algorithm did not provide significant advantages over K-means for noise-heavy images, limiting its effectiveness [26]. Manescu *et al.* (2023) presented the Multiple Instance Learning for Leukocyte Identification (MILLIE) technique to detect Acute Promyelocytic Leukemia (APL) in bone marrow and peripheral blood to overcome diagnostic issues in detecting the





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different types of acute leukemia. This system's reliance on limited morphological representations hindered throughput and accuracy in hematological pathways requiring microscopic assessments[30]. Talaat *et al.* (2024) described an Optimized CNN (OCNN) classification technique to distinguish the leukemia and non-leukemia blood microscopic images. [31]. The lack of integration of OCNN and correlation methods has limited this system's performance improvements. Asar *et al.* (2024) designed the Falcon Optimization Algorithm with Deep Convolutional Neural Network for Leukemia Detection and Classification (FOADCNN-LDC) technique to solve the diagnosing and time consumption issues. It classifies and recognizes leukemia cells. This non-lightweight model version increased computational demands while risking accuracy [32]. Bhute *et al.* (2024) presented the ensemble learning-based model to detect the leukemia types based on blood microscopic images. This model requires high execution time. Additionally, the lack of usage of large dataset for testing has limited the potential for the accuracy improvements [33].

PROPOSED METHODOLOGY

The proposed methodology for automated leukemia cells detection is entitled as 'Automated Detection of Leukemia Cells Using Watershed Transform and Fuzzy C-Means Clustering Algorithm (ADL-WTFCC)'. It leverages a hybrid approach combining the Watershed Transform and FCM clustering algorithm. This methodology aims to enhance the accuracy and robustness of cell detection and segmentation in microscopic images of blood smears. This process can be broken down into several key steps: i) image preprocessing, ii) initial segmentation using the watershed transform, iii) refinement with FCM clustering, and iv) post-processing. Fig.1 portrays the block diagram of the ADL-TFCC method. The proposed ADL-TFCC method starts with acquiring an input microscopy image of blood smears. It gets into preprocessing the raw microscopic images to enhance quality and contrast, making them suitable for subsequent detection and segmentation tasks. Here, three core steps are followed in the preprocessing. I.e. Gaussian filtering and histogram equalization algorithms are used for noise reduction and morphological operations to highlight cell boundaries. Gaussian filtering is applied to the grayscale image to reduce noise and smooth the image. It converts the RGB image $I(x, y)$ to a grayscale image $GI(x, y)$. It is applied using Eq. 1 Gaussian filtering is applied to the grayscale image, GI using Eq. 2 Histogram equalization is performed to enhance the contrast of the filtered image FI using Eq. 3. The gradient magnitude $gmag$ of the equalized image FI is computed using Eq. 4. Morphological opening is performed on the gradient magnitude image, $gmag$ using Eq. 5.

$$GI(x, y) = 0.299 \times I_R(x, y) + 0.587 \times I_G(x, y) + 0.114 \times I_B(x, y) \quad (1)$$

$$FI(x, y) = \frac{1}{2\pi\sigma^2} \exp\left(-\frac{x^2+y^2}{2\sigma^2}\right) * GI \quad (2)$$

$$FI: EI(x, y) = CDF_{FI}(FI(x, y)) \times (L - 1) \quad (3)$$

$$gmag(x, y) = \sqrt{\left(\frac{\partial EI}{\partial x}\right)^2 + \left(\frac{\partial EI}{\partial y}\right)^2} \quad (4)$$

$$PI(x, y) = gmag(x, y) \circ B \quad (5)$$

where

$I(x, y)$ - Input color image

(x, y) -Pixel position

I_R -Red channel of the input image

I_G -Green channel of the input image

I_B -Blue channel of the input image

GI - Grayscale image

FI - Filtered image

σ - Standard deviation of the Gaussian kernel

$*$ -Convolution





EI-Equalized Image

CDF_{FI} -Cumulative distribution function of *FI*

L-Number of intensity levels

gmag- Gradient magnitude image

PI- Preprocessed image

$\circ$ -Morphological opening

B-Structuring element

These preprocessing steps enhance the quality and contrast of the input microscopy images, making them suitable for subsequent detection and segmentation tasks in the proposed ADL-TFCC method.

Watershed Transform

The watershed transform treats the intensity values of the preprocessed image *PI* elevations on a topographic map. Peaks are represented by high intensity values, and valleys are represented by low intensity values. The program mimics the process of floods, starting from the markers. Water "fills" the valleys and forms catchment basins. The points where different basins meet are identified as watershed lines, which act as boundaries between distinct regions. The proposed ADL-TFCC method applies the watershed transform to the preprocessed image *PI* to perform initial segmentation. This technique considers the image to be a topographic surface, with elevation represented by the intensity values. By simulating the flooding process, the watershed transform identifies and separates distinct regions, corresponding to individual cells and clusters. Markers are used to control the segmentation process, ensuring that only relevant regions are identified. The gradient magnitude of the preprocessed image *PI* is computed using Equation (6). It enhances the edges within the image, *PI*. This helps in identifying the boundaries more clearly.

$$PI: gmag(x, y) = \sqrt{\left(\frac{\partial PI}{\partial x}\right)^2 + \left(\frac{\partial PI}{\partial y}\right)^2} \quad (6)$$

Morphological operations are used to identify foreground and background markers that is essential for the watershed transform. Foreground markers and background markers play crucial roles in differentiating between leukemia cells and other cells in a sample. These markers are often proteins or molecules expressed on the surface or within the cells, identifiable using immune histochemistry, flow cytometry, or imaging techniques. Foreground makers are specific markers used to identify leukemia cells. They highlight the presence of abnormal or malignant cells in a sample. Background makers identify or exclude non-leukemic cells, such as normal blood cells, stromal cells, or other contaminants in the sample. The distance transform is calculated and using the watershed technique to identify background markers. The foreground and background makers are computed in Equation (7), (8), and (9).

$$FgM(x, y) = \circ(PI, B) \quad (6)$$

$$D(x, y) = DistanceTransform(FgM) \quad (7)$$

$$BgM(x, y) = (D(x, y) > T) \quad (8)$$

where

$\circ$ - Morphological opening

FgM - Foreground markers

BgM- Background makers

D - Distance Transform Image

T - Threshold value

The watershed algorithm is applied to the gradient magnitude image, *gmag* using Equation (9). This results in the segmentation of the image.

$$L(x, y) = Watershed(gmag(x, y), FgM, BgM) \quad (9)$$





Fuzzy C-Means

The proposed ADL-TFCC method further applies FCM algorithm to the regions identified by the watershed transform. A clustering method called FCM gives every data point a degree of membership to multiple clusters, rather than forcing a hard assignment. This makes segmentation more precise and adaptable, particularly when cell boundaries are not clearly defined. In order to minimize the objective function and produce the final leukemia cell segmentation, this algorithm iteratively updates cluster centers and membership degrees. The FCM allows each pixel to belong to multiple clusters with varying degrees of membership. This is particularly advantageous in medical image analysis, where the boundaries of cells can be ambiguous. This algorithm works by iteratively updating membership levels and cluster centers to reduce the subsequent objective function. It is computed using Equation (10).

$$J_{m=\sum_{i=1}^N \sum_{j=1}^c u_{ij}^m \|x_i - c_j\|^2} \quad (10)$$

where

N - Total number of data points (pixels)

c - Number of clusters

u_{ij} - Membership degree of data point x_i to cluster c_j

m - Fuzzifier, which controls the level of cluster fuzziness (typically $m=2$)

x_i - i -th data point

c_j - j -th cluster center

$\| \cdot \|$ - Denotes the Euclidean distance between data points and cluster centers

The FCM algorithm iteratively updates the membership degrees u_{ij} and the cluster centers c_j using the Equation (11) and (12).

$$u_{ij} = \frac{1}{\sum_{k=1}^c \left(\frac{\|x_i - c_j\|}{\|x_i - c_k\|} \right)^{\frac{2}{m-1}}} \quad (11)$$

$$c_j = \frac{\sum_{i=1}^N u_{ij}^m x_i}{\sum_{i=1}^N u_{ij}^m} \quad (12)$$

This algorithm continues to iterate until the change in the membership degrees or the cluster centers is below a predefined threshold, indicating convergence. By allowing a degree of membership to multiple clusters, the FCM algorithm provides a more nuanced and accurate segmentation of the leukemia cells. This flexibility is particularly beneficial in medical imaging, where an effective diagnosis depends on the exact delineation of cell borders. The final segmentation results from the FCM algorithm are thus more reliable, leading to improved detection and analysis of leukemia cells in microscopic images. Post-processing steps, including morphological operations and region merging, are employed to refine the segmentation results. Small, irrelevant regions are removed, and adjacent regions representing parts of the same cell are merged. The watershed segmentation results are superimposed on the original image. The final segmented images obtained from FCM clustering are visualized.

ANALYSIS AND DISCUSSION

The efficiency of the proposed ADL-TFCC method is analyzed against state-of-the-art methods and datasets of microscopic images of blood smears, annotated by hematologists, is used for this research. They are

- Blood Cells Cancer dataset (BCC_DS)[27]
- Acute Lymphoblastic Leukemia Dataset (ALL_DS) [28]
- SN-AM Dataset (SNAM_DS) [29]

These images are preprocessed to enhance quality and contrast, involving steps such as noise reduction using Gaussian filtering, histogram equalization, and morphological operations to highlight cell boundaries. The state-of-the-art methods which are used for the comparison are as follows:





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- Leukemia Detection using Multiple Instance Learning for Leukocyte Identification method (LD_MILLIE) [30].
- Leukemia Detection using Optimized CNN (LD_OCNN) method [31].
- Leukemia Detection using Falcon Optimization Algorithm with Deep Convolutional Neural Network for Leukemia Detection and Classification (LD_FOADCNN_LDC) method [32].
- Leukemia Detection using Ensemble Learning-Based (LD_EL) model [33].

Performance Evaluation

The performance of the proposed approach along with existing approach is evaluated using the following metrics

- Precision
- Recall
- FScore
- Dice Coefficient

Precision is a crucial metric utilized to evaluate the model's performance in correctly identifying positive cases, i.e., leukemia cells. It measures how many of the cells predicted as leukemia-positive are actually true leukemia cells. Precision is defined as the ratio of True Positive (TP) detections to the total number of predicted positive detections (True Positives + False Positives). It is computed using Equation (13).

$$Precision = \frac{TP}{TP+FP} \quad (13)$$

where

TP-True Positive

FP-False Positive

Herein, TP denotes the number of leukemia cells that the model correctly identifies as leukemia-positive. FP denotes the Number of non-leukemia cells that the model incorrectly identifies as leukemia-positive.

Recall measures the ability of the model to correctly identify all the leukemia cells (True Positives) among the total number of actual leukemia cells (True Positives + False Negatives). In simpler terms, it indicates how good the model is at detecting all true leukemia cells, irrespective of the quantity of false positives. It is calculated using Equation (14).

$$Recall = \frac{TP}{TP+FN} \quad (14)$$

where

FN -False Negative

Herein, FN denotes the Number of leukemia cells that were missed or incorrectly identified as non-leukemia cells.

FScore is the precision and recall harmonic mean. It is particularly useful working with datasets that are unbalanced, like medical imaging tasks where the number of true positives (leukemia cells) may be small compared to non-leukemia cells. It is calculated using Equation (15).

$$FScore = 2 \times \frac{Precision \times Recall}{Precision + Recall} \quad (15)$$

where

Precision-Proportion of true positives out of all predicted positives.

Recall-Proportion of true positives out of all actual positives.

FScore Outcome

Dice coefficient is a metric used to compare the similarity between two sets: the set of predicted leukemia cells and the set of actual leukemia cells. It ranges from 0 (no overlap) to 1 (perfect overlap). It is typically used for evaluating image segmentation tasks (e.g., detecting leukemia cells in microscope images). It is computed using Equation (16).

$$Dicecoefficient = \frac{2 \times TP}{2 \times TP + FP + FN} \quad (16)$$

where

TP - True Positive





FP - False Positive

FN - False Negative

In this case, TP denotes the number of correctly predicted leukemia cells. FP denotes the number of non-leukemia cells incorrectly identified as leukemia cells. FN denotes the number of actual leukemia cells that were missed by the method.

DISCUSSION

Table 1 and Figure 2 present the precision outcomes of the proposed ADL-TFCC method alongside several state-of-the-art techniques, namely LD_MILLIE, LD_OCNN, LD_FOADCNN_LDC, and LD_EL. The proposed ADL-TFCC method achieves the highest precision of 0.91, demonstrating its superior ability to correctly identify leukemia cells while minimizing false positives. In comparison, the existing systems LD_EL and LD_FOADCNN_LDC obtained precision values of 0.89 and 0.88, respectively, indicating that while they perform well, they are slightly less accurate than the proposed ADL-TFCC in distinguishing leukemia cells from non-leukemia cells. Similarly, Table 2 and Figure 3 display the recall outcomes of the proposed ADL-TFCC method, showing that it achieves the highest recall of 0.92. Recall is a critical metric that measures the ability of the system to identify all relevant leukemia cells (true positives). The ADL-TFCC method's recall is superior to that of the existing methods, with LD_EL achieving a recall of 0.90 and LD_FOADCNN_LDC reaching a recall of 0.86. These results highlight that the proposed ADL-TFCC is more sensitive in detecting leukemia cells, ensuring fewer false negatives and providing a more comprehensive detection of cells. Table 3 and Figure 4 illustrate the F1Score outcomes, where the proposed ADL-TFCC again outperforms all other methods, achieving an F1Score of 0.90. The F1Score is a balanced metric that blends both precision and recall, giving an overall measure of the method's accuracy in detecting leukemia cells. The existing methods, LD_EL and LD_FOADCNN_LDC, achieved F1scores of 0.89 and 0.86, respectively, indicating slightly lower overall performance in terms of balancing precision and recall. Table 4 and Figure 5 shows the results for the dice coefficient, a metric that assesses the overlap between the predicted and actual regions of leukemia cells. The proposed ADL-TFCC method achieves a perfect dice coefficient score of 1, indicating flawless overlap between the predicted and actual cells, which demonstrates its accuracy and effectiveness. In contrast, the existing methods, LD_EL and LD_FOADCNN_LDC, achieved dice coefficients of 0.9, reflecting good but slightly less precise performance in matching the true boundaries of leukemia cells. The performance metrics collectively demonstrate the efficacy of the proposed ADL-TFCC method as an automated leukemia cell detection technique. By combining the watershed transform and FCM algorithm, the proposed ADL-TFCC significantly outperforms traditional methods, especially in handling overlapping cells and varied cell morphologies. The watershed transform helps in segmenting overlapping cells, while the FCM algorithm allows for the flexibility of assigning membership degrees to multiple clusters, which proves beneficial in complex image regions with varying cell shapes and densities.

This capability is particularly important in real-world clinical settings, where leukemic cells often present in challenging, overlapping patterns that require advanced segmentation techniques. Furthermore, the flexibility of the FCM algorithm enables the system to handle variations in cell sizes, shapes, and intensity levels, making it highly adaptable for different imaging conditions and leukemia types. The proposed ADL-TFCC method's ability to handle such complex scenarios enhances its robustness and reliability, making it a valuable tool for automated detection. The proposed ADL-TFCC method shows strong promise for integration into clinical workflows, offering consistent and objective results that can assist pathologists in the diagnostic process. With high precision, recall, FScore, and dice coefficient, the system provides clinicians with reliable information that can help guide decisions in leukemia diagnosis and treatment. Its integration into clinical practice could help reduce the workload on pathologists, improve diagnostic speed, and ensure more accurate identification of leukemia cases. However, the performance of the proposed ADL-TFCC method, like any automated detection system, is influenced by the quality and variability of the dataset. Variations in imaging techniques, patient demographics, and the presence of other diseases can affect detection accuracy. Therefore, increasing the variety of images in the dataset with variations in imaging conditions and patient backgrounds, would improve the model's capacity for generalization and guarantee it performs



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effectively across different clinical settings. This expansion could involve gathering more data from different healthcare institutions or using synthetic data generation techniques to increase dataset diversity. The proposed ADL-TFCC method stands out as an effective and reliable automated detection system for leukemia, offering superior performance metrics compared to existing methods. By tackling issues like cell overlap and varying morphologies, the system demonstrates its potential for real-world clinical applications, providing pathologists with a powerful tool to assist in the timely and accurate analysis of leukemia.

CONCLUSION

Leukemia is a kind of cancer that affects the bone marrow and blood. It is characterized by the unchecked growth of unhealthy white blood cells. For prompt treatment and better patient outcomes, early and precise detection is essential. Automated leukemia detection systems have emerged as valuable tools to aid in early diagnosis by reducing diagnostic errors, enhancing treatment accuracy, and increasing efficiency through the processing of large datasets. The existing automated systems face several challenges, including variability in data quality, limited ability to generalize across diverse populations, and difficulties in distinguishing between different leukemia subtypes. Addressing these limitations requires improved datasets, more interpretable algorithms, and better integration with healthcare systems. To overcome these challenges, the proposed method, ADL-WTFCC combines the watershed transform for initial segmentation and FCM clustering for refinement. The watershed transform treats the image as a topographic surface, identifying cell boundaries through a flooding process. FCM clustering further enhances segmentation by assigning pixels to clusters based on membership values, effectively managing ambiguity in cell boundaries. The ADL-WTFCC method was evaluated on datasets such as BCC_DS, ALL_DS, and SNAM_DS, achieving performance metrics of 91% precision, 92% recall, 90% F1-score, and a perfect Dice coefficient of 1.0. These results highlight its superiority in accurately detecting leukemia cells, outperforming state-of-the-art methods like LD_EL and LD_FOADCNN_LDC. By effectively handling overlapping cells and varied cell morphologies, the proposed system addresses common challenges in real-world clinical settings. By providing consistent, objective results, the ADL-WTFCC method reduces pathologists' workload and improves diagnostic accuracy. Despite its strengths, the model's performance is influenced by dataset quality and variability. Adding more different data to the dataset imaging conditions and patient demographics, or incorporating synthetic data, could enhance the system's generalization capabilities. Such improvements would ensure its effectiveness across different clinical environments. In conclusion, the proposed ADL-WTFCC method offers a significant advancement in automated leukemia detection. By addressing key challenges and achieving superior accuracy, it presents a reliable tool for clinical diagnostics, enabling timely and accurate leukemia identification while supporting pathologists in their critical work.

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Table 1: Precision results

Database		Precision				
		LD_MILLIE [30]	LD_OCNN [31]	LD_FOADCNN_LDC [32]	LD_EL [33]	Proposed ADL-TFCC
BCC_DS	BCC_DS1	0.77	0.79	0.71	0.81	0.84
	BCC_DS2	0.83	0.85	0.88	0.80	0.91
	BCC_DS3	0.79	0.83	0.81	0.87	0.89
ALL_DS	ALL_DS1	0.82	0.84	0.87	0.88	0.90
	ALL_DS2	0.80	0.81	0.84	0.87	0.88
	ALL_DS3	0.81	0.85	0.81	0.82	0.89
SNAM_DS	SNAM_DS1	0.72	0.75	0.77	0.78	0.81
	SNAM_DS2	0.83	0.81	0.87	0.89	0.90
	SNAM_DS3	0.79	0.78	0.79	0.81	0.83

Table 2: Recall results

Database		Recall				
		LD_MILLIE [30]	LD_OCNN [31]	LD_FOADCNN_LDC [32]	LD_EL [33]	Proposed ADL-TFCC
BCC_DS	BCC_DS1	0.74	0.77	0.81	0.84	0.86
	BCC_DS2	0.71	0.74	0.86	0.89	0.90
	BCC_DS3	0.70	0.73	0.81	0.87	0.91
ALL_DS	ALL_DS1	0.75	0.79	0.80	0.81	0.89
	ALL_DS2	0.69	0.71	0.75	0.80	0.84
	ALL_DS3	0.73	0.79	0.78	0.80	0.81
SNAM_DS	SNAM_DS1	0.68	0.69	0.77	0.81	0.84
	SNAM_DS2	0.76	0.79	0.85	0.90	0.92
	SNAM_DS3	0.67	0.68	0.79	0.80	0.81





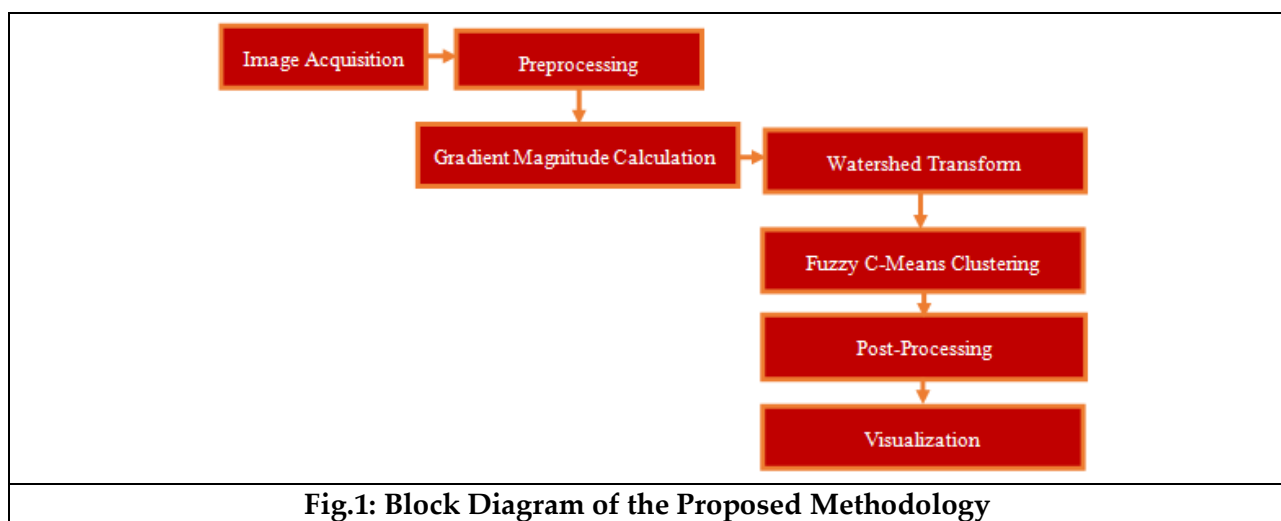
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Table 3: F Score results

Database		FScore				
		LD_MILLIE [30]	LD_OCNN [31]	LD_FOADCNN_LDC [32]	LD_EL [33]	Proposed ADL- TFCC
BCC_DS	BCC_DS1	0.75	0.77	0.75	0.82	0.84
	BCC_DS2	0.76	0.79	0.86	0.84	0.90
	BCC_DS3	0.74	0.77	0.81	0.87	0.89
ALL_DS	ALL_DS1	0.78	0.81	0.83	0.84	0.89
	ALL_DS2	0.74	0.75	0.79	0.83	0.85
	ALL_DS3	0.76	0.81	0.79	0.80	0.84
SNAM_DS	SNAM_DS1	0.69	0.71	0.77	0.79	0.82
	SNAM_DS2	0.79	0.79	0.85	0.89	0.90
	SNAM_DS3	0.72	0.72	0.79	0.80	0.81

Table 4: Dice Coefficient results

Database		Dice Coefficient				
		LD_MILLIE [30]	LD_OCNN [31]	LD_FOADCNN_LDC [32]	LD_EL [33]	Proposed ADL- TFCC
BCC_DS	BCC_DS1	0.5	0.6	0.7	0.8	1
	BCC_DS2	0.7	0.8	0.9	0.8	1
	BCC_DS3	0.6	0.7	0.7	0.7	0.9
ALL_DS	ALL_DS1	0.4	0.6	0.5	0.5	0.8
	ALL_DS2	0.5	0.7	0.6	0.6	0.8
	ALL_DS3	0.4	0.7	0.8	0.6	0.9
SNAM_DS	SNAM_DS1	0.6	0.7	0.7	0.7	0.9
	SNAM_DS2	0.7	0.8	0.9	0.8	1
	SNAM_DS3	0.6	0.8	0.8	0.9	1





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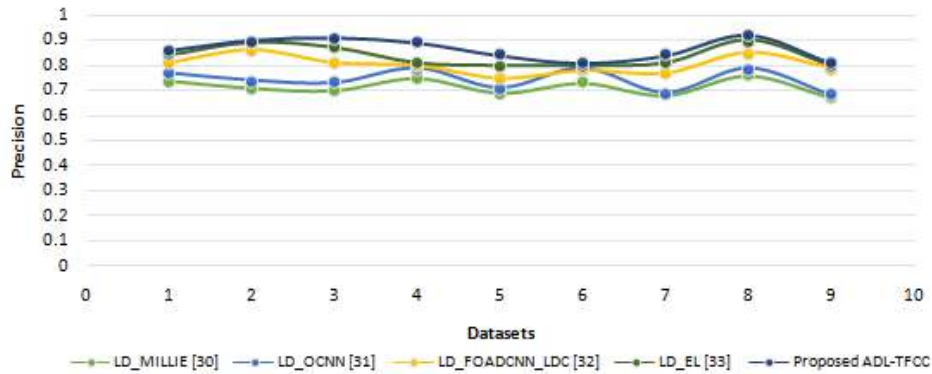


Figure 2: Precision Outcome

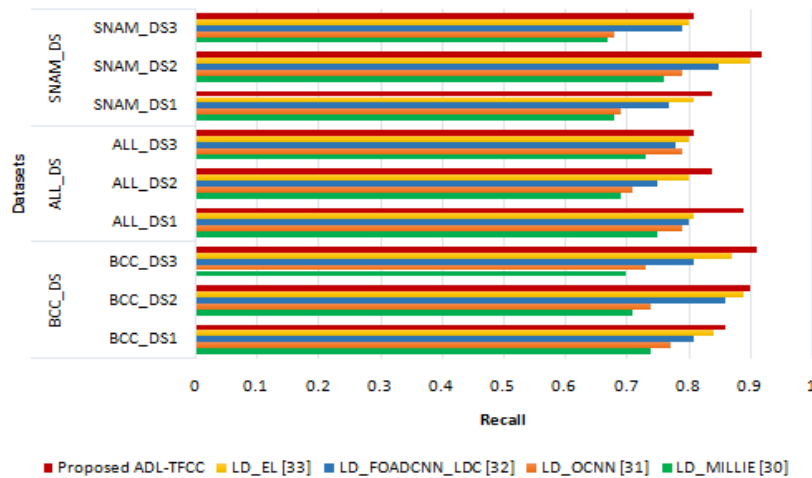


Figure 3: Recall Outcome

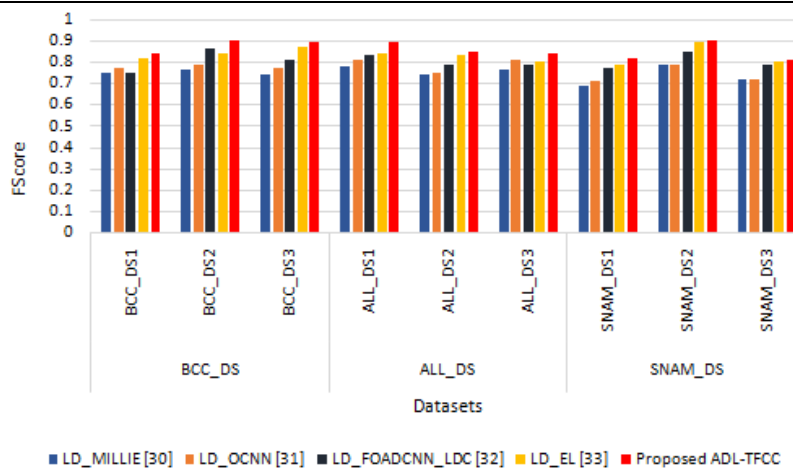
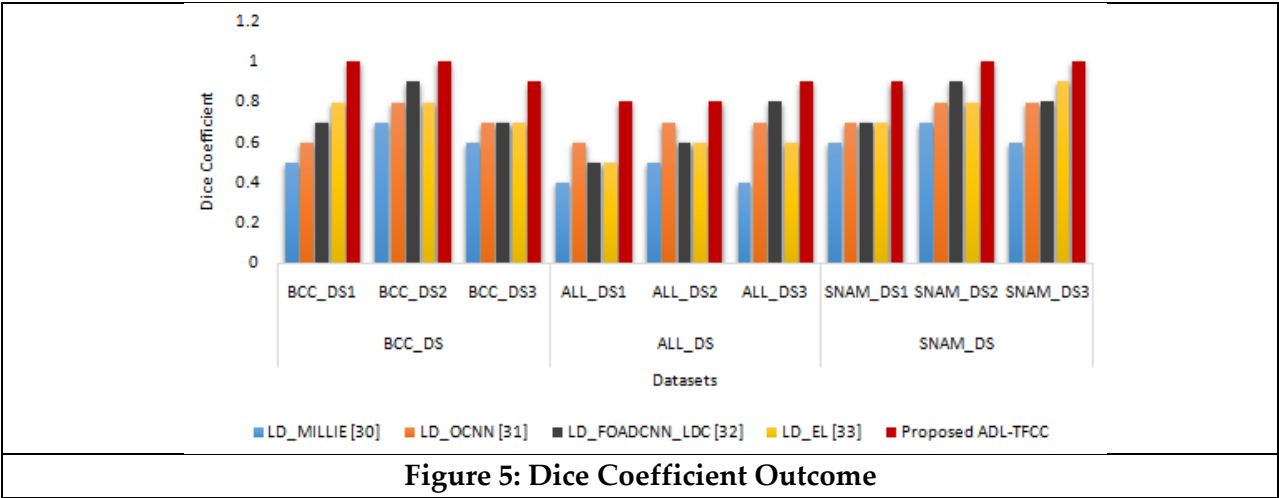


Figure 4: FScore Outcome





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RESEARCH ARTICLE

Effects of Strength Training on Thoracic Dysfunction among College Students

Ajithkumar M^{1*}, Saravan Kumar J² and Jesvin Bose S¹

¹Student, Department of Bachelor of Physiotherapy, Saveetha College of Physiotherapy, Saveetha Institute of Medical and Technical Sciences (Deemed to be University), Chennai, Tamil Nadu, India.

²Assistant Professor, Department of Physiotherapy, Saveetha College of Physiotherapy, Saveetha Institute of Medical and Technical Sciences (Deemed to be University), Chennai, Tamil Nadu, India.

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*Address for Correspondence

Ajithkumar M

Student,

Department of Bachelor of Physiotherapy,

Saveetha College of Physiotherapy,

Saveetha Institute of Medical and Technical Sciences

(Deemed to be University), Chennai, Tamil Nadu, India.

E.Mail: ajithkumaraf2003@gmail.com



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ABSTRACT

Alterations in spinal alignment can lead to increased mechanical stresses, impaired back muscle strength, and compromised function of the para spinal musculature. Thoracic dysfunction can cause postural abnormalities, such as forward scapular movement and neurovascular compression, leading to breathing difficulties and abdominal muscle weakening thus, this study aims to evaluate the effect of strength training, involving resistance band exercises on thoracic dysfunction among college students. To find the effect of Strength training on thoracic dysfunction among College students adapted to poor posture like hunch back, rounded shoulders, reduced spinal range of motion and thoracic stiffness. The study involves 30 subjects with thoracic dysfunction undergoing an 8-week strength training program using resistance bands for upper body exercises (12-14 reps, 3 sets, 3 times/week) and abdominal exercises (8-9 reps, 3 sets, 2 times/week). Pre- and post-intervention measurements will assess the program's impact on thoracic dysfunction. Flexi curve tool, New York posture rating chart (NYPRS). The Pre-test and Post-test values were analysed. result suggest that the Strength training has significant improvement on thoracic dysfunction among college Students with $P < 0.0001$. The study concluded that strength training significantly improved thoracic dysfunction among college students. Pre and post-test assessments using the flexi curve tool and New York Posture Rating Scale showed that strength training effectively reduced symptoms of thoracic dysfunction in this population.

Keywords: Flexi curve tool, New York posture rating chart (NYPRS), resistant band.

Level of Evidence: Level 3





INTRODUCTION

Posture refers to the body's position in space, and it serves to maintain balance during both static and dynamic motions. Posturology is defined as all-encompassing study of postural system that integrates several fields such as physiology, neurology and biomechanics. Maintaining proper posture requires intricate relationship between the visual system, vestibular system, mechanism of proprioception coordination of the CNS musculoskeletal reactions. There are many various systems to co-operate in order to maintain good posture which calls for constant modifications [1]. The significance is to comprehend both physiological process and anatomical process in order to govern the postural evaluation in clinical practice and looks how postural deformities can result in variety of musculoskeletal illnesses. The condition is a rigid structural deformity in the thoracic spine defined radiographically over three or more contiguous vertebrae with at least 5° towards anteriorly these people have thoracic curves greater than 70° to 75° and 25° to 30° thoracolumbar curves it can lead to intractable pain neurological deficit and cardiopulmonary compromise [2]. Postural adjustments result from muscle activation regulated by the Central Nervous System [CNS], influenced by various afferent inputs, including vestibular, proprioceptive, exteroceptive, and visual [3]. The significant correlation between thoracic and cervical dysfunction frequently follow predictable patterns highlighting the significance of looking at both the area when performing an osteopathic evaluation [4]. Optimal posture minimizes the burden on muscles and ligaments while aligning the body with the gravitational axis. Somatic dysfunction in cervical and thoracic area manifest discomfort, asymmetry, limited range of motion and abnormal tissue texture. Maladaptive postural patterns can arise from uneven weight distribution, leading to reduced stability and increased mechanical demands [5]. Thoracic spine prevalence is reported ~66% that is it can give surprisingly the forceful eccentric loading structures of the spine and it will affect the neck mobility by contributing of thoracic spine [6]. Postural dysfunctions are characterized by misaligned body parts, muscle shortening or tightening, and joint movement impairment. The significance of sagittal equilibrium in the biomechanics of the spine explains the importance of appropriate sagittal alignment for effective walking and standing. This investigates the connection between spinal curvatures and pelvic characteristics explaining the compensating process that takes place when sagittal equilibrium is disturbed. This indicates how crucial it is to take spinal global alignment into account while establishing a course of treatment. A frequently received postural problem that primarily impacts the older people with chronic neck specific pain in forward neck posture. The forward neck posture alters the biomechanics of spine and result in muscle imbalance by increasing the mechanical load on cervical tissues. Neck discomforting is more common in those over 65 and how it's significantly affects both health care expense and quality of life [7]. Muscle strength plays a crucial role in sports performance and injury prevention. While significant mechanical stress is generally accepted as the preferred stimulus for strength gains, metabolic stress may also contribute [8]. There are lot of measurement instrument available for evaluating thoracic range such as initial sensors, motion capture devices and inclinometers especially comparing to standard methods digital measurements demonstrate great reliability and validity because of precision and human friendliness. Initial instruments have become very attractive instruments while selecting a tool, cost effectiveness and therapeutic usefulness were deemed crucial considerations improvements in technology have increased the accuracy of spinal movement evaluation [9]. Static posture involves the alignment and maintenance of body segments in certain positions, and severe deviations from ideal posture can negatively impact muscular function and increase the risk of musculoskeletal or neurological pathologies [10].

The muscular strength has a key physical attribute that influences various aspects of human performance and well-being. The greater the muscular strength enhance force time characteristics, improve power production, rate of force development and neuromuscular efficiency, the proper resistance training should be in cooperative progressive overload variation in training stimulation. To emphasize the strength serves as a foundation for developing other athletic qualities and should be included in training programs make optimal loading parameters for different training goals, exercise progression and monitoring the strength with overall athletic developmental programs. These programs and training methods improve performance in athletes [11]. Resistance training is useful for improving a number of significant aspects of both mental and physical health. Resistance training studies have reportedly shown



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considerable in lean weight, metabolic weight and proper posture along with significant decrease in fat weight percentage. This is in line with ongoing loss of muscle mass and resting metabolism that is linked to inactive aging. Resistance training has been linked to improvements in functional independence, improved movements control decreased arthritic discomfort, decreased back pain and higher speed walking in several categories that involves physical performance [12]. Strengthening exercises are often recommended to address postural abnormalities, with the assumption that strengthening weaker, longer muscle groups will realign skeletal segments and adapt by shortening and extending their antagonists. Young individuals with sedentary lifestyles and jobs that require excessive sitting are at higher risk for posture issues, which can lead to structural changes in the spine and internal organ ailments if left untreated. Alterations in spinal alignment can lead to increased mechanical stresses, impaired back muscle strength, and compromised function of the para spinal musculature. Thoracic dysfunction can cause postural abnormalities, such as forward scapular movement and neurovascular compression, leading to breathing difficulties and abdominal muscle weakening [13]. A program involving exercises targeting the abdominal, shoulder, and back muscle groups, along with resistance band exercises, has been proposed for posture correction. Traditional exercise regimens which include stretching and strengthening exercise that focuses on certain muscle group are the accepted methods of correcting posture. These programs use systemic exercise frequently in conjunction with manual therapy approach to improve posture and reduce discomfort. The method is widely used in clinical setting and serves as a cornerstone of several rehabilitation regimens. Postural problems have an influence on healthcare that goes beyond treating a single patient these disorders raise the expenditures associated with disabilities playing heavy financial load on health care systems. These should be specific techniques required since changes in tissue elasticity and strength have a direct influence on treatment response and recovery patterns [14]. There are studies that are done by comprehensive corrective exercise intervention to correct the posture for people with thoracic kyphosis angle and the pre and post values of participation levels of kyphosis angle were measured by flexi curve ruler [15]. Further research is there about the effectiveness of manual therapy to reduce cervical spine pain for people suffering from non-specific neck pain [16]. This study shows the effect of strength training for thoracic postural dysfunction without using medications such as ibuprofen like NSAIDs and epidural steroid injections to reduce pain and correct the posture according to the NYPRS scale that's used as an outcome measure.

METHODS

It was a quasi-experimental study done with 30 subjects with Thoracic dysfunction aged between 18-25 years both men and women. Convenient sampling is used in the study.

Selection Criteria

Inclusion criteria

College student's thoracic dysfunction [kyphosis, rounded shoulder]

Reduced spine range of motion (above 27 cm in tape measure length (C7-T12), hunch back, kyphosis)

Age-18-25

Gender - male, female

Exclusion criteria

Recent Spinal fractures

Spinal injury

Strain and sprain injuries

Cognitive postural impairment

Outcome Measures

Flexi curve tool: The flexi curve tool is particularly useful as it precisely depicts the variations from a straight line, the flexi curve tool is especially helpful in evaluating Spinal anomalies including kyphosis (excessive outward curving of the spine) and Scoliosis (lateral curvature). The measured length may then be used to track changes over time or





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compared to industry standard reference values, which can help with the diagnosis and treatment planning of a variety of spinal problems. New York posture rating chart: The New York Posture Rating Chart is a grid with Lines that show the optimal alignment of posture. The body's anterior (front), lateral (side), and posterior (back) perspectives are represented by the three portions of the Chart.

PROCEDURE

Subjects diagnosed with thoracic dysfunction are included. Following the sample calculation all the selected samples (N=30) recruited from Saveetha Institute of Medical and Technical Sciences, Chennai, were trained using strength training with resistance bands on the targeted muscle groups – the trapezius, the anterior and posterior segments of the deltoid muscle, and the pectoral muscles, both major and minor. Flexi curve tool and New York posture rating chart were assessed prior to the intervention. Subjects with thoracic dysfunction (n=30) have selected, workouts given with Resistance band for above mentioned targeted muscle groups for 12-14 reps, 3 Sets, 10 seconds rest between sets, 3 times a week workout with resistance Bands include chest flies, shoulder press, lat pull downs, shrugs, and shoulder Raise with resistance bands and for abdomen- crunches and side to side toe touches 8-9 reps, 3 sets, 10 sec rest between sets, 2 times a week to strengthen the oblique muscle.

Chest fly: Extend arms out to sides, bend elbows slightly. Arc forearms inward feeling chest stretch. Exhale, contract chest as arms come together. Repeat 8-12 reps, 3-4 sets using resistance band (Figure 1).

Shoulder press: Use resistance bands or dumbbells. Stand feet shoulder-width, grasp equipment. Press weights overhead with slight elbow bend. 3-4 sets of 8-12 reps, rest 60-90 seconds.

Shoulder shrugs: Stand with feet shoulder-width apart, arms extended down, holding a resistance band. Exhale as you raise your shoulders towards your ears, engaging the trapezius muscles. Hold the elevated shoulder position briefly, feeling the tension. Inhale while slowly lowering your shoulders to the starting position, maintaining good form. Repeat these shoulder shrugs against the resistance of the band to work and strengthen your shoulder muscles (Figure 2).

Lat pull down: Secure a resistance band overhead. Adopt a standing or seated position with good posture, firmly gripping the handles. Exhale as you pull the handles down towards your body in a controlled motion, fully engaging your latissimus dorsi muscles. Inhale as you gradually return to the starting position with resistance. Repeat this Lat pulldown exercise for the desired number of repetitions, allowing the resistance band to effectively work and strengthen your back muscles (Figure 3).

Shoulder raises: Secure resistance bands for shoulder raises. Stand upright, engage core. With slight elbow bend, raise arms laterally against resistance until shoulders tense. Pause briefly at peak, inhale. Slowly lower arms back to start, resisting bands' pull. Maintain form through reps, allowing resistance to work shoulder muscles. Repeat set for shoulder development (Figure 4).

For abdomen- crunches and side to side toe touches 8-9 reps, 3 sets, 10 sec rest Between sets, 2 times a week to strengthen the oblique muscles (Figure 5 and Figure 6).

RESULTS

The post-assessment indicates an important improvement in the impact of strength training on thoracic dysfunction in college students as well as a significant Improvement in their posture as compared to the pre-assessment. Based on the two Outcome measures, the New York Posture Rating Scale and the Flexi Curve Tool—a Statistically significant difference in pre and post values was found for the group, according to a statistical analysis of the quantitative information collected. Table 1: Pre and Post-test values of group (n=30) measured using the flexi curve tool for the

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spine length measurement. For the group, the mean of flexi curve ruler value in the pre-test was 32.07 (SD = 1.74), which significantly reduced to 27.40 (SD = 1.16) in the post-test ($t = 14.2990$, $p < 0.0001$). Table 2: Pre and Post-test values of the same group ($n=30$) measured using the New York posture rating scale (NYPRS) chart for the posture correction for the upper back. For this outcome measure, the mean New York posture rating scale (NYPRS) score in the pre-test was 2.83 (SD = 1.34), which significantly increased to 7.63 (SD = 1.45) in the post-test ($t = 24.7209$, $p < 0.0001$).

DISCUSSION

The study aimed to investigate the efficacy of a structured strength training program in alleviating thoracic dysfunction among college students. The findings suggest that targeted resistance training can yield significant improvements by addressing muscular imbalances, restoring proper alignment, and improving functional strength. Exercises targeting key muscles like the pectoralis major/minor, deltoids, trapezius, and obliques likely played a crucial role. The use of resistance bands provided versatility and functional training benefits. Muscular adaptations, improved spinal curvature, and vertebral alignment may have contributed to the observed improvements [17]. Addressing thoracic dysfunction in this population is essential as it can persist and worsen if left unaddressed. While promising, limitations include the lack of a control group and long-term follow-up assessments. Future research could explore the sustainability of improvements, impact on overall spinal health, and potential synergistic effects with other modalities. Walter *et.al.*, investigated the use of surface electrodes for stimulation of respiration focusing on the activation of the thoracic and abdominal muscle performed on canine models [18]. Campbell *et.al.*, studied the relationship among fused ribs and the congenital scoliosis which was characterized by thoracic insufficiency syndrome and initiated fundamental understanding of deformity in thorax, this highlighting the early significance of early diagnosis and intervention [13]. Davies. *et.al.*, examined movement pattern in frontal plane during dynamic activities and reported difference in the pelvic and thorax movement pattern during activities [19]. Whetstone.*et.al.*, assessed thoracic rotation through visual estimated techniques using quadruped lumbar locked position focusing on evaluating the reliability and validity of measurement methods offering quality enhancement to clinical assessing tools [20]. The findings of the evidence available has exposed the effectiveness of multiple intervention options for both conservative and surgical procedures. These studies also provide significant importance of customized assessment and the use of technical interventions like electrical stimulation along with the addition of appropriate exercise to the routine. The advancements of diagnostic techniques in the assessment methods shows the importance of reliability in the measuring tools. This improves the accuracy in both visual and technical based assessment methods shows the importance of the reliability in the measuring tools. This improves the accuracy in both visual and technical based assessment methods. The importance for early treatment in thoracic conditions will show the significance in understanding movement patterns. These findings show a detailed and clear improvement in thoracic deforming condition from necessary anatomical understanding methods to complicated intervention techniques, these studies show the inflation in development of more dependable clinical tools.

CONCLUSION

Through targeted resistance band training, this study found college students' thoracic dysfunction can be significantly alleviated by strengthening thoracic muscles, correcting imbalances, and improving spinal alignment. Benefits extend beyond postural issues, potentially enhancing overall spinal health and functional capacity. Further research is warranted to validate findings, assess long-term impact, explore implications for spine health/function, and investigate synergies with other modalities.

Ethical Clearance

Approved by the Institutional Scientific Review Board Number: 04/003/2023/ISRB/SR/SCPT



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This study is a self-funded study.

Data Availability

No data available

Contributions

AKM: conceptualization, methodology, investigation. SKJ: investigation, resources, data curation. JGN: formal analysis, writing – original draft, supervision. JBS: writing – review and editing

Conflict of Interests

The authors declare no conflict of interests.

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Table-1: Pre and Post-test for values of group measured on Flexi curve ruler.

Group		Mean± SD	T TEST	P VALUE
Strength training group	Pre test	32.07± 1.74	14.2990	<0.0001
	Post test	27.40 ± 1.16		

Table-2: Pre and Post-test for values of group measured on New york posture rating scale.

Group		Mean± sd	T test	P value
Strength Training Group	Pre test	2.83± 1.34	24.7209	0.0001
	Post test	7.63± 1.45		





Figure 1: Chest fly



Figure 2: Shoulder shrugs



Figure 3: Lat pull downs



Figure 4: Shoulder raise



Figure 5: Abdomen crunches



Figure 6: Side-Side heel touches





RESEARCH ARTICLE

Leveraging Federated Learning and Diffusion Models for Robust Brain Tumour Classification

Maria Rufina P^{1*}, Meera Devi A. K.², Swara Sameer Pawanekar³ and Neelam Bind³

¹Assistant Professor, Department of Computer Science and Engineering, GSSS Institute of Engineering and Technology for Women, Mysore, (Affiliated to Visvesvaraya Technological University), Karnataka, India.

²Associate Professor, Department of AIML, M.S. Ramaiah Institute of Technology, (Affiliated to Visvesvaraya Technological University, Belagavi), Karnataka, India.

³Student, Department of AIML, M.S. Ramaiah Institute of Technology, (Affiliated to Visvesvaraya Technological University, Belagavi), Karnataka, India.

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*Address for Correspondence

Maria Rufina P

Assistant Professor,

Department of Computer Science and Engineering,

GSSS Institute of Engineering and Technology for Women, Mysore,

(Affiliated to Visvesvaraya Technological University), Karnataka, India.

E.Mail: mariarufinap@gmail.com



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ABSTRACT

Brain tumours represent some of the most complex medical conditions to identify and manage, primarily because they frequently present with subtle or unclear symptoms. Timely detection and precise categorization of brain tumours are essential for enhancing patient survival rates and informing treatment strategies. Magnetic Resonance Imaging (MRI), a type of imaging technology that avoids the need for invasive interventions, has become a cornerstone in brain tumour diagnostics due to its high-resolution and detailed visualization of brain structures. However, despite technological advancements, the manual interpretation of MRI scans is still a labour-intensive and subjective process, which can result in variability among different observers. This reality highlights the urgent requirement for automated and reliable diagnostic tools. In order to tackle these challenges, this project utilizes Federated Learning (FL), a decentralized machine learning methodology that facilitates collaborative model training among various institutions without necessitating the exchange of raw data. By permitting hospitals and healthcare organizations to keep their data on-site while contributing to a unified model, Federated Learning complies with privacy regulations like HIPAA and GDPR. In addition to safeguarding patient privacy, this decentralized strategy encourages cooperation across institutions, which results in the creation of more reliable and comprehensive diagnostic systems.

Keywords: Federated Learning, Diffusion model, Data Augmentation, Brain tumour classification, Evaluation metrics.





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INTRODUCTION

This project primarily seeks to establish a Federated Learning-based framework for the detection and classification of brain tumours from MRI scans. The focus is on distinguishing among four categories: pituitary tumours, gliomas, meningiomas, and non-tumour cases. Additionally, to further address the widespread problem of class imbalance in medical datasets, the project incorporates data augmentation techniques that utilize diffusion models, which represent a cutting-edge technique for producing synthetic but realistic medical images. A simulated network of multiple fictional hospitals forms the backbone of this project, each equipped with its local dataset. This setup enables the training of a global Federated Learning model that benefits from the diversity of data while preserving privacy. By combining Federated Learning with advanced data augmentation and robust deployment tools, this project aims to address critical challenges in brain tumour detection [2]. The proposed solution not only enhances diagnostic accuracy but also establishes a scalable, privacy-preserving framework that can be adopted by hospitals worldwide. Ultimately, this system aspires to assist healthcare professionals in making faster, more informed decisions, thereby improving patient care and outcomes. Early and accurate detection of brain tumours is crucial for improving patient survival rates and treatment outcomes. Traditional methods of brain tumour detection rely heavily on manual interpretation of MRI scans by radiologists, a process that can be labor-intensive and susceptible to human inaccuracies. Furthermore, the sensitive nature of medical data creates significant challenges in sharing and collaborating on information across multiple institutions, leading to privacy concerns and compliance challenges [3]. Current machine learning models utilized for tumour detection frequently encounter challenges such as data privacy concerns, class imbalance, and difficulties in generalizing across varied datasets.

Proposed study seeks to resolve two primary issues

Data Privacy: What methods can be implemented to allow for the collaborative training of machine learning models across different healthcare institutions while safeguarding patient confidentiality and privacy?

Model Performance: What approaches can be utilized to develop a highly accurate and robust model for detecting diverse brain tumour types, particularly in light of challenges such as class imbalance and limited availability of labelled data?

MATERIALS AND METHODS

The process of medical image classification involves assigning a class label to an image or a segment of an image, generally in relation to a specific disease or condition. In recent years, deep learning methodologies, especially Convolutional Neural Network (CNNs), have established themselves as the forefront technology in medical image classification, achieving outstanding results in areas such as lung cancer detection from CT scans and skin cancer identification from dermoscopic images. However, given the sensitive nature of medical data, the availability and quality of annotated training data are crucial for these models' effectiveness, and this can be a difficult precondition. Classifying an image or a portion of an image for use in medicine often involves relating the image to a particular disease or condition. Convolutional Neural Networks (CNNs), in particular, have emerged as the cutting-edge approach for classifying medical images thanks to their exceptional performance in tasks like identifying skin cancer from dermoscopic images and detecting lung cancer from CT scans [12]. However, given the sensitive nature of medical data, finding annotated training data that is both readily available and high-quality can take time and effort. This is because the effectiveness of these models significantly depends on it. However, the advent of Deep Learning has significantly shifted the landscape of medical imaging techniques towards utilizing this powerful approach [13]. Initially, Deep Learning architectures like AlexNet, GoogLeNet, VGG-16, and VGG-19 were widely adopted for these tasks. This was later followed by the emergence of Residual Networks (ResNets) and Inception networks, further enhancing the capabilities of medical image classification systems. Currently, with the growing popularity of transfer learning, various architectures have begun incorporating pre-trained models like GoogLeNet and InceptionV3. There are even instances of combining multiple pre-trained models, such as an amalgamation of a fine-tuned AlexNet with



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a pre-trained VGG-16, followed by SVM classification. In addition, recent studies have explored utilizing syntactic patterns from medical images through AlexNet[15], and enhancing the quality of images prior to deep learning application.

METHODOLOGY

The methodology for the project involves the integration of Federated Learning (FL), collaborative model training and the application of data augmentation techniques to enhance model performance. Below is a step-by-step breakdown of the key components and techniques used in the methodology

Dataset Acquisition and Pre-processing

The dataset used in this project is sourced from Kaggle and consists of MRI scans categorized into four types: Glioma tumours, meningioma tumours, pituitary tumours, and non-tumorous cases.

The dataset is split into

Training Set: 5712 images

Testing Set: 1311 images

Pre-processing of the images is conducted to maintain uniformity in size and format. Essential normalization procedures are implemented and data augmentation strategies are employed to strengthen the model's resilience.

Data Augmentation Using Diffusion Models

To address class imbalance and improve the diversity of the training data, a Diffusion Model is employed for data augmentation. The steps involved are

Synthetic Image Generation: The model generates synthetic images that mimic real MRI scans to enhance the underrepresented classes.

Augmented Dataset: The final training dataset is augmented with 50% synthetic images, leading to a total of 11422 training images, 1311 testing images resulting in a total of 12733 images after augmentation.

Original Dataset Composition [Fig: 1].

Final Dataset Composition [Fig: 2].

Comparison of Original and Final Dataset [Fig: 3].

Original and Resized Image [Fig: 4].

Original and Augmented Image [3] [Fig: 5]

Federated Learning Framework [9]

At the heart of this project lies the methodology of Federated Learning (FL), a decentralized machine learning strategy that permits model training among several institutions while preserving the localization of data. The process is outlined as follows

Simulated Federated Network

The system simulates a federated learning setup consisting of six fictional hospitals

Green Valley Hospital, Silver Lake Medical Centre, Blue Ridge Health Institute, Sunnysdale, Community Hospital, Maplewood General Hospital, Riverbend Specialty Clinic

Model Training: Each hospital (client) trains the model locally on its dataset, which ensures the data privacy of each institution.

Global Model Aggregation: In the context of Global Model Aggregation, once local training is completed, the model weights are forwarded to a central server. At this server, the weights are combined to create a global model, and this procedure is conducted over several iterations.



**Maria Rufina et al.,****Evaluation Metrics**

The performance of the model is assessed using these specific metrics

Accuracy: The overall percentage of correct predictions regarding tumours.

Precision: The fraction of true positive predictions for each individual class.

Recall: The fraction of actual positive instances that the model correctly identifies.

F1 Score: The harmonic average of precision and recall.

These metrics are calculated after each federated training round to assess the performance of both local and global models.

Privacy Preservation and Security

A key component of this methodology is the privacy-preserving nature of Federated Learning. Since the data never leaves the local hospital's servers, patient confidentiality is maintained throughout the process. Additionally, encryption techniques such as Secure Aggregation are employed to further enhance data security during the model weight aggregation phase.

Algorithm: Federated Learning for Brain Tumour Detection**Initialization**

- Initialize the global model with random weights.
- Define the number of rounds for training (num_rounds).
- Define the participation strategy for clients in each round.

Data Preparation**For each client**

- Load the local dataset containing MRI scans.
- Pre-process the images (normalization, resizing).
- Augmentation and Diffusion to generate Synthesized Images.
- Split the dataset into training and testing sets.

Federated Learning Process**For each round r from 1 to num_rounds**

- **Client Selection:** Select a subset of clients to participate based on the participation strategy.

Local Training: For each selected client C

- Load the current weights of the global model.
- Train the local model on the client's training set.
- Evaluate the local model on a validation set.
- Store updated weights and performance metrics (accuracy, precision, recall, F1 score).

Model Aggregation

Aggregate the weights from all participating clients to update the global model using weighted averaging based on the number of local training samples.

Global Model Evaluation

Evaluate the updated global model on a central testing set and log performance metrics for analysis.

Metrics Logging

Log individual client metrics and global model metrics after each round.

Termination

After all rounds are completed, finalize and save the global model weights and performance metrics.



**Maria Rufina et al.,****Visualization**

Visualize the logged metrics over the training rounds.

PSEUDOCODE**Step 1: Initialization**

- Initialize `global_model` with random weights
- Set `num_rounds` for the number of federated learning rounds
- Define `client_participation_strategy` (e.g., random sampling, stratified selection)
Define list of clients: Green Valley Hospital, Blue Ridge Health Institute, Riverbend Specialty Clinic, Silver Lake Medical Center, Sunnydale Community Hospital, Maplewood General Hospital

Step 2: Data Preparation for Each Client

For each client in the list:

- Access the MRI scan dataset of the client.
- Execute pre-processing steps on the images, which may include normalization, resizing, and augmentation.
- Partition the dataset into three separate groups
 1. `training_set` intended for model training
 2. `validation_set` intended for model validation
 3. `testing_set` intended for model evaluation

Step 3: Federated Learning Process For each round from 1 to `num_rounds`**Step 3.1: Client Selection for the Round**

- Select clients for this round using `client_participation_strategy`

Step 3.2: Local Model Training and Evaluation for Each Selected Client For each selected client `C`:

- Load the `global_model` as the local model for client `C`
- Train the local model using the client's `training_set`
- Evaluate the local model on the `validation_set`
- Store updated weights and performance metrics (accuracy, precision, recall, F1 score)
- Save performance metrics for this client in the current round

Step 3.3: Aggregate Weights from Local Models to Update Global Model

- Aggregate the weights from the local models and update the `global_model`

Step 3.4: Evaluate Global Model on Central Testing Set

- Evaluate the `global_model` on the central `testing_set`
- Log the performance metrics (accuracy, precision, recall, F1 score) for the global model after this round

Step 4: Log and Visualize Performance Metrics For each round: Log individual client performance metrics (accuracy, precision, recall, F1 score)

- Log global model performance metrics
- Visualize the performance metrics (accuracy, precision, recall, F1 score) over all rounds

Step 5: Finalization and Model Output After the last round

- Finalize the `global_model` (after training is complete)
- Save the final `global_model` weights and performance metrics
- Output the performance metrics and visualizations



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RESULTS AND DISCUSSION

The results of the federated learning process are summarized below, highlighting the performance metrics for each client hospital across multiple training rounds, as well as the overall performance of the global model. Metrics such as accuracy, precision, recall, and F1 score were used to evaluate the model's effectiveness in detecting brain tumours from MRI scans.

Performance Metrics by Rounds

Round wise Local Model Performance Metrics

This section visualizes the performance of local client models and the global model across 10 rounds using four key evaluation metrics: Accuracy, Precision, Recall, and F1 Score. The results are presented in both tabular and graphical formats to illustrate trends and comparisons effectively.

Round Client Wise Metrics[21] [Table: 1]

Round Wise Local and Global Accuracy Score

Round wise Local Model Accuracy Scores(Fig: 6).

Round 1: Accuracy varies across clients. Blue Ridge Health Institute performs well (87.13%), while Green Valley Hospital and River bend Specialty Clinic are lower (80.52% and 80.63%, respectively).

Round 2: Silver Lake Medical Center improves to 88.48%, with other hospitals showing moderate increases (Sunnydale Community Hospital: 80.88%, Maplewood General Hospital: 81.68%).

Rounds 3-5: Accuracy fluctuates but stabilizes, with Green Valley Hospital and Silver Lake Medical Center showing notable improvements.

Insight: The global model improves gradually, but accuracy differs across clients, with Blue Ridge Health Institute and Silver Lake Medical Center performing better.

Round Wise Local and Global Precision Score

Round wise Precision of Clients and Global Model(Fig: 7).

Round 1: Green Valley Hospital (0.51) and Blue Ridge Health Institute (0.48) show lower precision, indicating more false positives.

Round 2: Sunnydale Community Hospital (0.57) outperforms others, while Silver Lake Medical Center maintains 0.50.

Rounds 3-5: Green Valley Hospital improves to 0.58, while Silver Lake Medical Center remains consistent, showing good precision.

Insight: Silver Lake Medical Center consistently shows good precision, while Green Valley Hospital and Blue Ridge Health Institute need improvement to reduce false positives.

Round Wise Local and Global Recall Score

Round wise Recall of Clients and Global Model (Fig: 8).

Round 1: Blue Ridge Health Institute (0.56) leads in recall, indicating strong detection of true positives.

Round 2: Maplewood General Hospital shows significant recall improvement (0.62), indicating better detection.

Rounds 3-5: Riverbend Specialty Clinic sees a significant recall improvement (0.72), while Blue Ridge Health Institute shows a decline.

Insight: Riverbend Specialty Clinic shows the best recall improvement, effectively detecting true positives. Blue Ridge Health Institute struggles in later rounds.

Round Wise Client and Global F1 Score

Round wise F1 of Clients and Global Model (Fig: 9).





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Round 1: Blue Ridge Health Institute (0.52) and Green Valley Hospital (0.50) show balanced performance in precision and recall.

Round 2: Maplewood General Hospital achieves the best F1 score (0.58), striking a good balance.

Rounds 3-5: Riverbend Specialty Clinic shows significant improvement in F1 (0.62), indicating better balance between precision and recall.

Insight: Riverbend Specialty Clinic consistently outperforms others in F1, showing effective balance between precision and recall. Blue Ridge Health Institute struggles with the F1 score in later rounds.

Round wise Global Model Performance Metrics Plot - Overall Insights of the proposed results

- Riverbend Specialty Clinic excels in recall and F1 score.
- Blue Ridge Health Institute has the lowest performance in recall and F1 score in the later rounds.
- Silver Lake Medical Centre maintains solid performance, especially in precision.

Global Model Metrics per Round (Accuracy, Precision, Recall, F1) Graph

Graph Description: The illustrated line graph showcases the changes in four significant performance metrics—accuracy, precision, recall, and F1 score—across five rounds of training or evaluation for the global model.

Key Insights

X-axis (Rounds) Represents the round number (1 to 5), which correspond to the number of training iterations or model evaluation rounds.

Y-axis (Metric Value) Displays the values of each metric (Accuracy, Precision, Recall, F1). The higher the value, the better the model performs.

Lines

Accuracy Line Shows how accurate the global model is in predicting the correct classes.

Precision Line Assesses the model's capability to correctly detect positive cases from the total predictions associated with positive classifications.

Recall Line Indicates how well the model identifies all actual positive cases.

F1 Score Line This metric represents the harmonic mean of precision and recall, effectively balancing these two important measures.

Interpretation

- If the lines show an upward trend, it suggests that the model is improving over time.
- A high precision with low recall (or vice versa) may indicate imbalanced performance, and the F1 score can provide a balanced view of both metrics.
- Round wise Final Metrics of Global Model (Fig: 10).

Round wise Global Model Performance Metrics

Round Wise Global Model Metrics (Table: 2)

Final Learning Results

Local and Global Models Final Metrics [20] (Table: 3)

CONCLUSION

The utilization of Federated Learning (FL) in brain tumour detection has shown promising results, indicating its significant potential for medical applications. By the end of Round 5, the global model achieved an accuracy of 88.18%, reflecting its capability to generalize across diverse datasets from various hospitals. Federated learning not only preserved patient confidentiality by maintaining the decentralization of sensitive data but also enabled the





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collaborative development of a robust model. This approach was crucial for identifying a wide spectrum of brain tumour types, thus demonstrating its feasibility for real-world medical settings where data privacy is essential. Additionally, incorporating a wider variety of datasets would help mitigate potential class imbalances and strengthen the model's resilience. This approach could render the model more dependable and applicable to a wider patient demographic, thereby propelling advancements in AI-assisted medical diagnostics. Additionally, incorporating a wider variety of datasets would help mitigate potential class imbalances and strengthen the model's resilience. This approach could render the model more dependable and applicable to a wider patient demographic, thereby propelling advancements in AI-assisted medical diagnostics. This would enhance the model's reliability and generalizability for a wider range of patients, ultimately fostering advancements in AI-driven medical diagnostics.[20][21][22]

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Table.1: Round Client Wise Metrics[21]

Round	Hospital	Accuracy (%)	Precision	Recall	F1 Score
1	Green Valley Hospital	80.52	0.51	0.49	0.5
1	Blue Ridge Health Institute	87.13	0.48	0.56	0.52
1	Riverbend Specialty Clinic	80.63	0.54	0.47	0.5
2	Silver Lake Medical Center	88.48	0.5	0.5	0.5
2	Sunnydale Community Hospital	80.88	0.57	0.51	0.54
2	Maplewood General Hospital	81.68	0.54	0.62	0.58
3	Green Valley Hospital	87.54	0.45	0.61	0.52
3	Sunnydale Community Hospital	82.97	0.48	0.51	0.49
4	Blue Ridge Health Institute	86.04	0.52	0.41	0.46
4	Silver Lake Medical Center	81.19	0.6	0.5	0.55
4	Riverbend Specialty Clinic	89.93	0.55	0.72	0.62
5	Maplewood General Hospital	80.75	0.46	0.44	0.45
5	Green Valley Hospital	88.18	0.58	0.56	0.57
5	Silver Lake Medical Center	85.33	0.49	0.53	0.51





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Table.2: Round Wise Global Model Metrics

Round	Accuracy	Precision	Recall	F1 Score
1	0.86	0.55	0.53	0.54
2	0.87	0.57	0.56	0.57
3	0.89	0.59	0.58	0.59
4	0.9	0.62	0.6	0.61
5	0.92	0.65	0.63	0.64

Table.3: Local and Global Models Final Metrics [20]

Serial No	Model	Accuracy	Precision	Recall	F1 Score
1	Green Valley Hospital	85.8	0.61	0.44	0.51
2	Blue Ridge Health Institute	84.56	0.56	0.48	0.52
3	Riverbend Specialty Clinic	80.71	0.42	0.55	0.47
4	Silver Lake Medical Center	89.34	0.5	0.46	0.48
5	Sunnydale Community Hospital	85.08	0.5	0.46	0.48
6	Maplewood General Hospital	86.08	0.56	0.57	0.57
7	Global Model	0.92	0.65	0.63	0.64

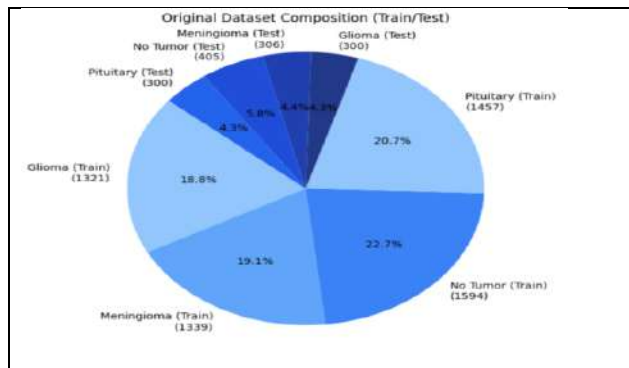


Fig.1: Original Dataset Composition

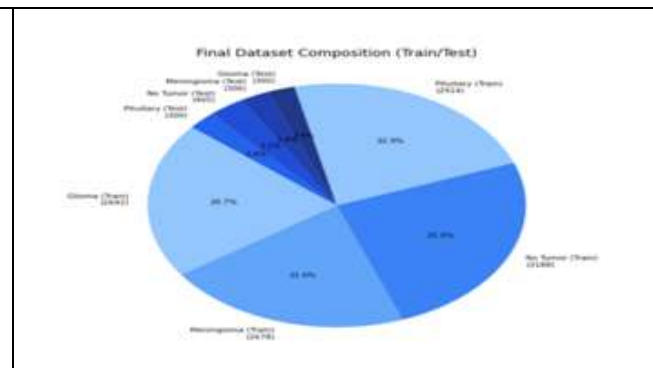


Fig.2: Final Dataset Composition

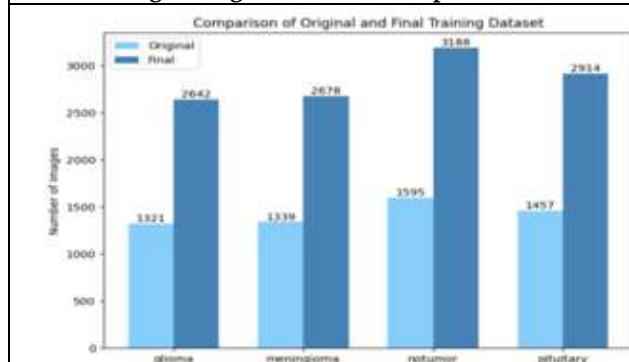


Fig.3: Comparison of Original and Final Dataset [3]

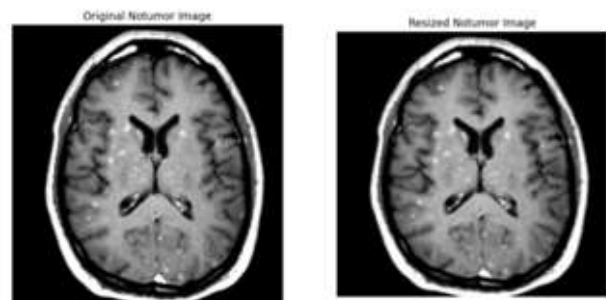
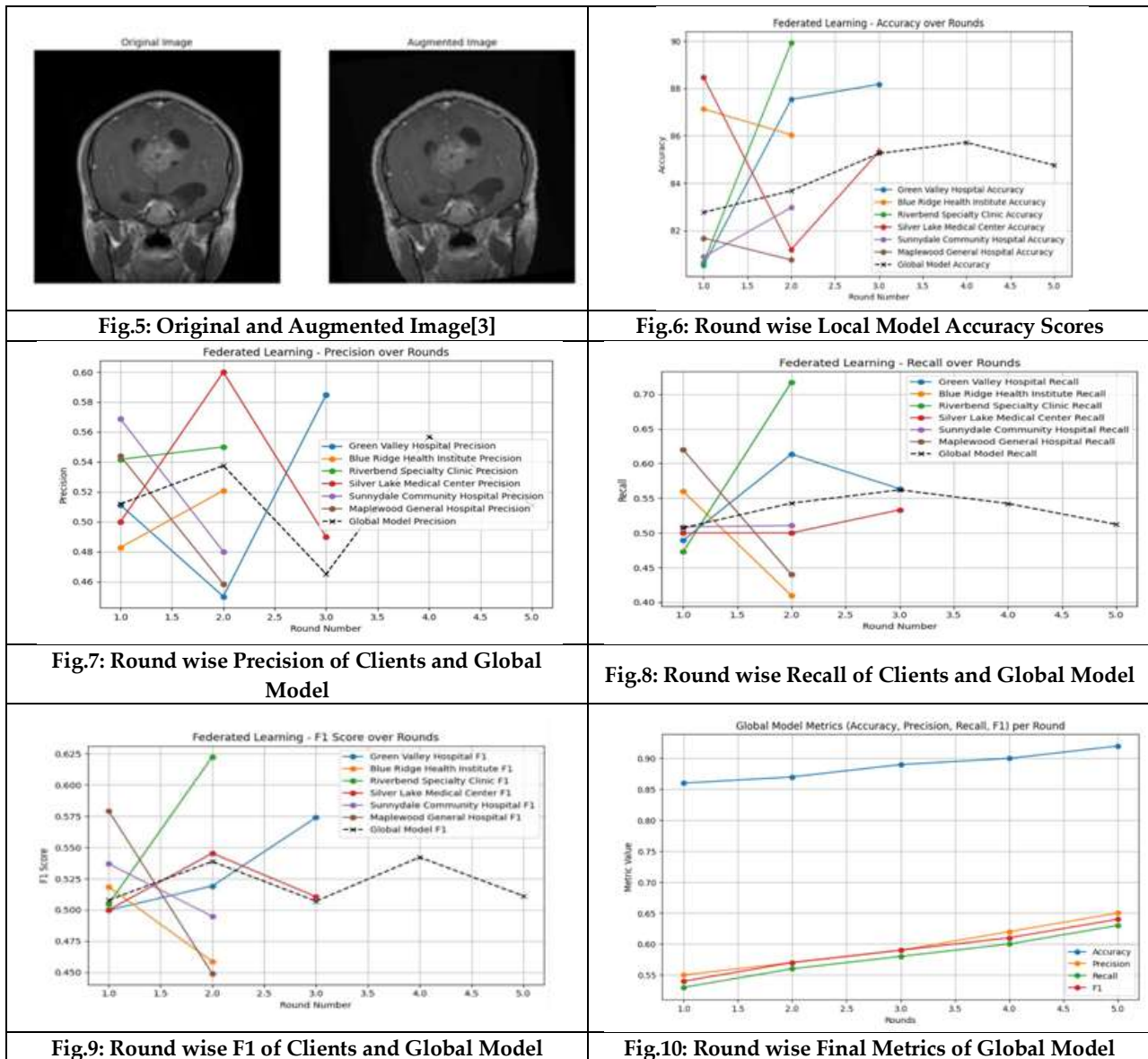


Fig.4: Original and Resized Image







RESEARCH ARTICLE

An Extensive Analysis of Various Deep Learning Approaches for Early Detection of Alzheimer's Disease

Harshitha B^{1*} and Sowmya B. J²

¹Assistant Professor, Department of Computer Science and Engineering, GSSS Institute of Engineering and Technology for Women, Mysuru, (Affiliated to Visvesvaraya Technological University, Belagavi), Karnataka, India.

²Associate Professor, Department of Artificial Intelligence and Data Science, M.S. Ramaiah Institute of Technology, Bangalore, (Affiliated to Visvesvaraya Technological University, Belagavi), Karnataka, India.

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*Address for Correspondence

Harshitha B

Assistant Professor,

Department of Computer Science and Engineering,

GSSS Institute of Engineering and Technology for Women, Mysuru,

(Affiliated to Visvesvaraya Technological University, Belagavi),

Karnataka, India.

E.Mail: harshib112@gmail.com



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ABSTRACT

Alzheimer's disease (AD), a progressive neurodegenerative disorder, poses significant challenges for early diagnosis due to subtle and overlapping early-stage symptoms. In recent years, deep learning (DL) has emerged as a powerful tool for analyzing complex medical data, particularly in neuro imaging and cognitive assessments. This paper presents an extensive review of current deep learning methodologies employed in the early detection of Alzheimer's disease. We explore a range of architectures including Convolutional Neural Networks (CNNs), Recurrent Neural Networks (RNNs), autoencoders, transformers, and hybrid models. Emphasis is placed on the analysis of input modalities such as MRI, PET scans, and EEG, as well as integration of multimodal data. We further discuss the role of feature extraction, attention mechanisms, transfer learning, and interpretability techniques in enhancing diagnostic accuracy. Comparative evaluation, challenges such as data scarcity and model generalizability, and potential future directions are also addressed. Our findings highlight the promise and limitations of current DL approaches, guiding future research toward more robust and clinically relevant solutions.

Keywords: Alzheimer's Disease(AD), Deep learning models, Data Modalities, CNN,





INTRODUCTION

Alzheimer's disease (AD) is a chronic, progressive neurodegenerative disorder that primarily affects the elderly population. It is the most common cause of dementia, accounting for 60% to 80% of cases globally. The disease is characterized by a gradual decline in cognitive functions such as memory, reasoning, language, and problem-solving abilities, eventually interfering with daily life and independence. Pathologically, AD is associated with the accumulation of beta-amyloid plaques and neurofibrillary tangles composed of hyperphosphorylated tau protein in the brain. These pathological hallmarks lead to neuronal damage and synaptic loss, particularly in the hippocampus and cortical regions responsible for memory and cognitive processing. AD progresses through several clinical stages, starting with a preclinical phase, followed by mild cognitive impairment (MCI), and eventually advancing to full-blown dementia. The preclinical and MCI stages present a critical window for early intervention, as irreversible neuronal loss may be limited during these stages. However, detecting the disease at these stages remains challenging due to subtle and nonspecific symptoms. Traditionally, diagnosis relies on a combination of clinical evaluation, neuropsychological testing, and neuroimaging techniques such as Magnetic Resonance Imaging (MRI) and Positron Emission Tomography (PET). Biomarkers found in cerebrospinal fluid (CSF) and blood, such as beta-amyloid and tau, are also becoming increasingly important in the diagnostic process. Despite significant advances in our understanding of the disease, effective therapeutic options remain limited, particularly for halting or reversing progression. As such, early and accurate detection has become a primary focus of research, with the goal of improving patient outcomes through timely intervention. In this context, deep learning techniques have emerged as powerful tools capable of uncovering hidden patterns in high-dimensional medical data, offering promise in the quest for robust and scalable diagnostic systems.

Importance of Early Detection

Early detection of Alzheimer's disease (AD) is of paramount importance due to its progressive and irreversible nature. The neurodegenerative processes that underlie AD begin years—sometimes even decades—before the onset of clinical symptoms. Identifying the disease at these early, often preclinical or mild cognitive impairment (MCI) stages provides a critical opportunity for intervention, potentially delaying progression and preserving cognitive function for a longer period. From a clinical perspective, early diagnosis enables more accurate prognosis, better management of comorbidities, and timely initiation of symptomatic treatments or lifestyle interventions. Patients and caregivers benefit from early awareness, allowing for advanced care planning, participation in clinical trials, and improved quality of life through support systems and informed decision-making. Moreover, with the recent development and approval of disease-modifying therapies that target amyloid-beta pathology—such as monoclonal antibodies—early-stage detection becomes even more crucial, as these therapies are most effective when initiated before extensive neuronal loss has occurred. Early detection is also vital for advancing research. It supports the stratification of patients in clinical studies, improves the understanding of disease progression, and facilitates the development of predictive models and therapeutic targets. However, existing diagnostic tools often fall short in identifying early-stage AD due to overlapping symptoms with normal aging and other neurodegenerative disorders. This is where artificial intelligence (AI), particularly deep learning, plays a transformative role. By analysing subtle patterns in neuroimaging, cognitive assessments, and biomarker data, deep learning models can enhance the sensitivity and specificity of early diagnosis, offering scalable and non-invasive alternatives to traditional methods. In summary, early detection is not only beneficial for clinical and therapeutic reasons but is also a cornerstone for precision medicine and public health strategies aimed at mitigating the global impact of Alzheimer's disease.

Data Modalities in Alzheimer's Diagnosis

Structural MRI

Structural Magnetic Resonance Imaging (sMRI) is one of the most widely used and informative neuroimaging techniques for diagnosing Alzheimer's disease (AD). It provides high-resolution, three-dimensional images of brain anatomy, allowing clinicians and researchers to detect morphological changes associated with neuro degeneration. In the context of AD, sMRI is primarily used to assess brain atrophy, particularly in regions known to be affected in the



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early stages of the disease. These include the hippocampus, entorhinal cortex, temporal lobes, and parts of the parietal cortex. Volume loss in these regions, especially hippocampal atrophy, is a hallmark indicator and has been shown to correlate with disease severity and progression. sMRI data are non-invasive, widely available, and highly suitable for automated analysis using machine learning and deep learning techniques. Traditional approaches rely on handcrafted features such as gray matter density, cortical thickness, and regional brain volumes, which are extracted using tools like FreeSurfer, SPM, or FSL. With the advent of deep learning, particularly Convolutional Neural Networks (CNNs), there has been a shift toward end-to-end learning from raw sMRI data. These models are capable of capturing complex, hierarchical features directly from image inputs without the need for manual preprocessing or feature selection. Techniques such as 3D CNNs, residual networks (ResNets), and attention-based architectures have demonstrated high accuracy in distinguishing AD from Mild Cognitive Impairment (MCI) and healthy controls. Moreover, sMRI can be combined with other modalities (e.g., PET, cognitive scores) in multimodal learning frameworks, further improving diagnostic performance. Despite its advantages, sMRI alone may not capture the full spectrum of AD-related changes, especially in the very early or preclinical phases. However, as part of a larger diagnostic pipeline, it remains an indispensable tool for both clinical use and AI-driven research in Alzheimer's detection.

Positron Emission Tomography (PET) Imaging

Positron Emission Tomography (PET) imaging is a functional neuroimaging technique that provides insights into **metabolic activity and molecular changes** in the brain, which are crucial in the early diagnosis of Alzheimer's disease. PET scans can detect abnormalities at the cellular level, often before structural changes become apparent on MRI.

Two primary types of PET imaging are used in Alzheimer's research and diagnosis

Fluorodeoxyglucose (FDG-PET): Measures cerebral glucose metabolism. Hypometabolism in regions such as the posterior cingulate cortex, parietal lobes, and temporal lobes is a characteristic sign of AD.

Amyloid and Tau PET: Uses radiotracers to detect amyloid-beta plaques and tau tangles, the pathological hallmarks of AD. Amyloid PET imaging (e.g., using tracers like Pittsburgh Compound B or Florbetapir) enables in vivo detection of amyloid deposition, aiding early-stage diagnosis and staging.

PET imaging is highly sensitive and specific but also more expensive and less accessible than MRI. It is frequently used in conjunction with sMRI to provide a more comprehensive assessment. Deep learning models have been applied to PET images using similar architectures to those used with MRI, including 3D CNNs and hybrid models. These models often outperform traditional classifiers by learning complex spatial patterns of tracer uptake. When fused with sMRI data, PET imaging significantly enhances classification accuracy, particularly for distinguishing MCI converters from non-converters.

Electroencephalography (EEG)

Electroencephalography (EEG) is a non-invasive technique that records electrical activity in the brain via scalp electrodes. It is relatively inexpensive, portable, and provides high temporal resolution, making it suitable for real-time monitoring and early-stage detection.

In Alzheimer's patients, EEG often reveals changes such as

Slowing of brain rhythms (increased theta and delta, decreased alpha and beta activity).

Altered connectivity patterns and reduced brain network synchronization.

Changes in **event-related potentials (ERPs)** during cognitive tasks.

Traditional EEG analysis relies on spectral and temporal features derived from frequency bands, coherence, entropy, and wavelet transforms. However, recent research has shown that deep learning methods—especially 1D CNNs, RNNs, and attention-based models—can automatically learn discriminative features from raw EEG signals, surpassing conventional methods in performance. EEG's biggest strength lies in its feasibility for continuous monitoring and low-cost deployment, making it a promising candidate for integration into wearable or home-based



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diagnostic tools. However, due to its susceptibility to noise and variability, EEG is often used as a complementary modality rather than a standalone diagnostic tool.

Deep Learning Architectures for Alzheimer's Detection

Deep learning (DL), a subset of machine learning, has revolutionized the field of medical imaging and diagnostics through its ability to learn complex patterns from raw data. In Alzheimer's disease (AD) research, DL models are particularly valuable due to their capacity to handle high-dimensional, multimodal data such as MRI, PET, EEG, and cognitive assessments.

Several deep learning architectures have been explored for early and accurate detection of AD. The most commonly used include

Convolutional Neural Networks (CNNs): Ideal for analyzing spatial data like brain scans.

Recurrent Neural Networks (RNNs) and Long Short-Term Memory (LSTM) networks: Used for temporal and sequential data, such as EEG signals or longitudinal studies.

Autoencoders and Variational Autoencoders (VAEs): Used for unsupervised feature learning, dimensionality reduction, and anomaly detection.

Transformer-based models: Recently introduced in medical imaging, offering advantages in learning global contextual relationships across large datasets.

Hybrid models and ensemble techniques: Combine multiple architectures to improve diagnostic accuracy and robustness.

These architectures can be trained on single or multimodal data sources and are often enhanced using techniques such as transfer learning, attention mechanisms, and explainable AI (XAI) methods to improve interpretability.

Convolutional Neural Networks (CNNs)

Convolutional Neural Networks are the cornerstone of deep learning in medical imaging. CNNs are particularly effective in AD research for analyzing structural and functional brain scans, such as sMRI and PET, due to their ability to learn hierarchical spatial features.

Key features of CNNs in AD detection

Local feature extraction: Convolutional layers detect spatial patterns like atrophy in the hippocampus or cortical thinning.

Automatic feature learning: Unlike traditional methods, CNNs do not require handcrafted features.

3D CNNs: Especially useful for volumetric data like MRI and PET, as they can analyze the 3D structure of the brain.

Common CNN architectures applied in AD studies include:

VGGNet, ResNet, and DenseNet: Known for their depth and ability to generalize well.

Custom shallow CNNs: Designed for small medical datasets to avoid overfitting.

3D CNN variants: For whole-brain volume analysis or specific ROI-based classification.

Applications

- Classification of AD vs. healthy controls
- Differentiation of MCI converters vs. non-converters
- Longitudinal progression modeling
- Biomarker identification through saliency and activation maps (e.g., Grad-CAM)

Challenges

- Data scarcity and class imbalance
- Overfitting due to small sample sizes
- Need for interpretability and clinical trust



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Despite these challenges, CNNs remain the most widely used and successful architecture in deep learning-based AD diagnosis.

Recurrent Neural Networks (RNNs) and LSTMs

Recurrent Neural Networks (RNNs), particularly Long Short-Term Memory (LSTM) networks, are designed to model sequential and temporal dependencies in data, making them ideal for tasks involving time-series data or longitudinal studies in Alzheimer's disease.

Applications in AD detection

EEG signal classification: EEG signals are temporal in nature, and RNNs can capture the progression of brainwave patterns across time.

Longitudinal cognitive assessment: RNNs can model the evolution of cognitive scores or imaging biomarkers over multiple clinical visits.

Multimodal time-series fusion: Combining temporal neuroimaging with sequential clinical scores or lab values for disease trajectory prediction.

Strengths

- Captures progression patterns and temporal dynamics
- Can model patient-specific disease progression
- Useful for predicting conversion from MCI to AD

Challenges

- Requires well-aligned sequential data
- Training can be difficult due to vanishing/exploding gradient problems (partially mitigated by LSTMs or GRUs)
- Less commonly used than CNNs due to more limited availability of longitudinal datasets

RNNs are particularly valuable when the goal is not just classification, but forecasting the trajectory of the disease over time.

Autoencoders and Variational Autoencoders (VAEs)

Autoencoders (AEs) are unsupervised neural networks used for learning efficient low-dimensional representations of input data. In AD research, they are primarily used for feature extraction, dimensionality reduction, anomaly detection, and data denoising.

Variational Autoencoders (VAEs) extend AEs by learning probabilistic latent variables, making them useful for generative tasks and uncertainty modeling.

Applications in Alzheimer's disease

- Learning compressed representations of high-dimensional neuroimaging data
- Detecting anomalies in brain scans by comparing reconstruction errors
- Serving as a pretraining step for classification tasks
- Generating synthetic neuroimaging data to augment small datasets

Strengths

- Effective in situations with limited labeled data
- Can uncover hidden structures in complex datasets
- VAEs enable probabilistic modeling and uncertainty estimation

Challenges

- Less interpretable than supervised models
- May require large datasets for effective training



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- Reconstruction quality can be sensitive to architecture design

Autoencoders are often used in conjunction with CNNs or RNNs as part of hybrid architectures to enhance performance and interpretability.

Transformer-Based Models

Transformers, originally developed for natural language processing, have recently shown significant promise in medical imaging and time-series analysis due to their attention mechanisms and ability to model long-range dependencies. Unlike CNNs or RNNs, transformers do not rely on convolutional filters or recurrence. Instead, they use self-attention to weigh the importance of different parts of the input data, enabling them to capture global contextual relationships more effectively.

Applications in Alzheimer's research

Vision Transformers (ViTs): Adapted for analyzing structural MRI and PET images by splitting them into image patches and learning spatial dependencies across the whole brain.

Time-series Transformers: Used to model progression patterns in longitudinal data such as cognitive scores, imaging sequences, or EEG.

Multimodal Transformers: Fusing heterogeneous data types (e.g., combining imaging, demographics, and cognitive tests) using attention across modalities.

Strengths

- High capacity for modeling complex, global interactions
- Scalable to large datasets
- Strong performance in both classification and regression tasks
- Attention maps can enhance interpretability by showing which regions or time points influence predictions

Challenges

- Requires substantial data and computational resources to train effectively
- May overfit small datasets if not carefully regularized
- Still an emerging approach in clinical domains—interpretation and trust are evolving areas

Transformers represent the cutting edge of deep learning in AD detection, with promising early results and growing adoption in multimodal research.

Hybrid and Ensemble Architectures

Hybrid and ensemble models combine the strengths of multiple deep learning architectures to improve robustness, accuracy, and generalizability—critical factors in real-world Alzheimer's diagnostics.

Types of hybrid approaches:

CNN + RNN: CNNs extract spatial features from MRI/PET scans, and RNNs model their evolution across time or clinical visits.

Autoencoder + Classifier: AEs or VAEs are used for feature compression, followed by a dense classifier (or SVM) for final prediction.

CNN + Transformer: CNNs capture local features, while transformers learn long-range spatial or temporal relationships across these features.

Multistream CNNs: Different data modalities (e.g., MRI, PET, clinical scores) are processed in parallel CNN streams and fused at decision-level or feature-level.



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Ensemble models: Multiple models (CNNs, transformers, etc.) are trained separately, and their predictions are combined using voting or averaging to improve overall performance.

Advantages of hybrid/ensemble models

- Higher diagnostic accuracy, especially in complex classification tasks (e.g., MCI converter vs. non-converter)
- Greater resilience to noise and variability in data
- Can handle incomplete or missing modalities in some configurations

Challenges

- Increased complexity in design and training
- Higher computational cost
- Risk of overfitting if not carefully validated

Overall, hybrid and ensemble models offer a promising direction toward clinically viable AI tools by leveraging the complementary strengths of individual architectures.

Survey on Early Detection of Alzheimer's Disease

The early detection of Alzheimer's disease (AD) has become a major focus of interdisciplinary research, spanning neuroscience, radiology, biomedical engineering, and artificial intelligence. With the rising global burden of AD and the emergence of disease-modifying treatments, there is an urgent need for accurate, non-invasive, and scalable methods to identify the disease in its preclinical or prodromal stages.

Trends in Research

Recent years have witnessed a paradigm shift from traditional diagnostic methods toward AI-driven predictive modeling, particularly through deep learning. Traditional approaches relied heavily on handcrafted features derived from neuroimaging (e.g., hippocampal volume), neuropsychological tests, and molecular biomarkers. While effective to some extent, these approaches suffer from limited generalizability and often fail to capture the complex, high-dimensional nature of the disease.

Modern approaches utilize deep learning for end-to-end feature extraction and classification, leveraging vast repositories of medical data. Key trends include

- Adoption of 3D convolutional neural networks for volumetric MRI and PET analysis
- Use of EEG with CNNs and RNNs for low-cost and real-time screening
- Emergence of transformer models and attention mechanisms for modeling global spatial or temporal relationships
- Growing interest in multimodal fusion, integrating imaging, cognitive tests, genetic data, and demographics

Benchmark Datasets

Several publicly available datasets have played a pivotal role in advancing research in early AD detection:

ADNI (Alzheimer's Disease Neuroimaging Initiative): The most widely used dataset, offering longitudinal MRI, PET, clinical, cognitive, and genetic data.

OASIS (Open Access Series of Imaging Studies): Contains cross-sectional and longitudinal MRI data of older adults.

AIBL (Australian Imaging, Biomarkers and Lifestyle Study): Focuses on aging, lifestyle factors, and early detection of AD.

Dementia Bank and MIMIC-CXR: Used for linguistic and multimodal modeling tasks.

These datasets have supported model development and benchmarking, though challenges like class imbalance, data heterogeneity, and privacy concerns persist.

Evaluation Metrics and Model Performance

Commonly used evaluation metrics include accuracy, sensitivity, specificity, F1-score, AUC (Area Under the ROC Curve), and in longitudinal studies, time-to-conversion prediction. Many deep learning models report accuracies





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exceeding 90% in AD vs. healthy control classification; however, MCI classification and MCI-to-AD conversion remain more challenging due to overlapping features.

Challenges and Limitations

Despite progress, several limitations affect current systems:

Limited labeled data: Medical data is expensive and time-consuming to annotate.

Overfitting: Especially with deep models trained on small cohorts.

Lack of interpretability: Clinicians require transparent models to build trust.

Variability in data acquisition protocols: Impairs model generalization across centers.

Future Directions

To overcome current bottlenecks, future research may focus on:

Federated learning and privacy-preserving AI to enable cross-institutional model training

Explainable AI (XAI) techniques to improve interpretability and clinical acceptance

Transfer learning from general medical imaging tasks to AD-specific tasks

Multimodal and multi-task learning to jointly model imaging, genetics, and cognition

Deployment of lightweight models for mobile and edge-based early screening

Here's a comparison table summarizing various deep learning models used for Alzheimer's disease detection. This includes architecture type, data modality, dataset used, classification task, and reported performance — useful for survey sections or literature reviews.

Here's a comparison table summarizing various deep learning models used for Alzheimer's disease detection. This includes architecture type, data modality, dataset used, classification task, and reported performance — useful for survey sections or literature reviews. Comparison of Deep Learning Models for Alzheimer's Disease Detection (Table 1)

- **AD:** Alzheimer's Disease
- **CN:** Cognitively Normal
- **MCI:** Mild Cognitive Impairment
- **sMRI:** Structural MRI
- **PET:** Positron Emission Tomography
- **CSF:** Cerebrospinal Fluid

Heatmap visualizing the **accuracy** of various deep learning models used for Alzheimer's disease detection. The colour gradient represents the accuracy of each model, with darker shades indicating higher performance (Figure 1).

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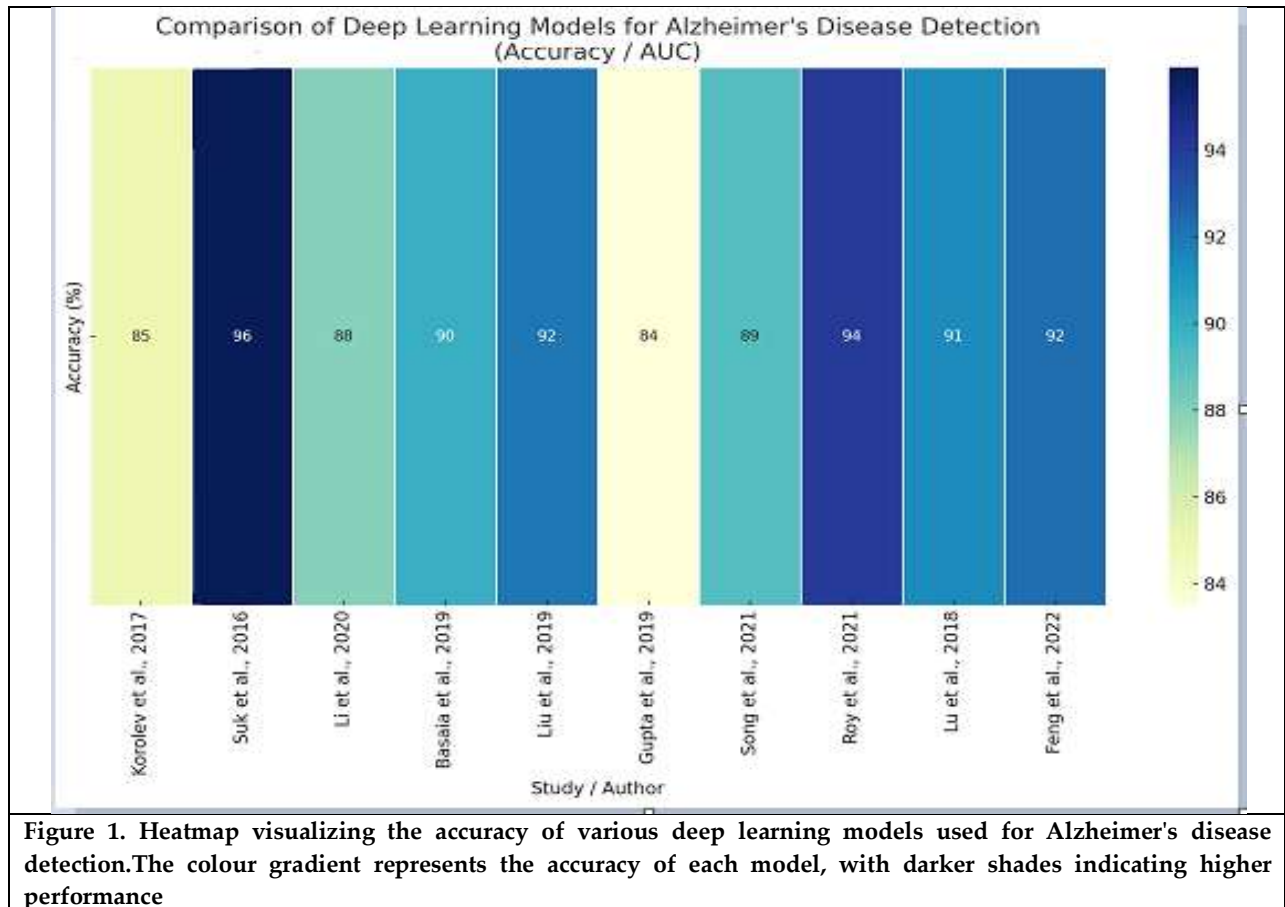
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Table 1: Comparison of Deep Learning Models for Alzheimer's Disease Detection

Study / Author	Model / Architecture	Data Modality	Dataset	Task	Accuracy / AUC
Korolev <i>et al.</i> , 2017	3D CNN	sMRI	ADNI	AD vs. CN	85.0% Accuracy
Suk <i>et al.</i> , 2016	Stacked Autoencoder + SVM	sMRI + PET	ADNI	AD vs. CN; MCI vs. CN	95.9% Accuracy
Li <i>et al.</i> , 2020	Multimodal 3D CNN	MRI + PET + CSF	ADNI	MCI converter vs. non-converter	88.0% Accuracy
Basaia <i>et al.</i> , 2019	Deep CNN (VGG-like)	Structural MRI	ADNI	AD vs. CN; MCI vs. CN	86.0% – 95.0% Accuracy
Liu <i>et al.</i> , 2019	Attention CNN	MRI	ADNI	AD vs. CN	92.0% Accuracy
Gupta <i>et al.</i> , 2019	CNN + RNN Hybrid	Longitudinal sMRI	ADNI	MCI to AD progression prediction	83.5% Accuracy
Song <i>et al.</i> , 2021	Transformer (ViT variant)	sMRI	OASIS / ADNI	AD vs. CN	89.2% Accuracy / 0.94 AUC
Roy <i>et al.</i> , 2021	1D CNN	EEG	Private	AD vs. CN	94.1% Accuracy
Lu <i>et al.</i> , 2018	Multimodal Deep Boltzmann Machine	MRI + PET	ADNI	AD vs. CN; MCI vs. CN	91.4% Accuracy
Feng <i>et al.</i> , 2022	Multimodal Transformer	MRI + clinical scores	ADNI	AD vs. CN; MCI conversion prediction	92.3% Accuracy



**Harshitha and Sowmya**



RESEARCH ARTICLE

Effect of Physical Activity on Heart Rate Recovery Post 6-Minute Walk Test in School-Going Adolescents

Roshani Prafulkumar Tank¹, Meghavi Oza^{2*}, Gaurav J. Patel³ and Savan Kukadia⁴

¹MPT Scholar, Department of Physiotherapy, Ahmedabad Physiotherapy College, Parul University, Gujarat, India.

²Associate Professor, Department of Physiotherapy, Ahmedabad Physiotherapy College, Parul University, Gujarat, India.

³Principal, Ahmedabad Physiotherapy College, Parul University, Gujarat, India.

⁴Senior Resident Doctor, Department of Palliative Medicine, The Gujarat Cancer and Research Institute, Gujarat University, Ahmedabad, Gujarat, India.

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*Address for Correspondence

Meghavi Oza

Associate Professor,

Department of Physiotherapy,

Ahmedabad Physiotherapy College,

Parul University, Gujarat, India.

E.Mail: meghavi.ozaapc@paruluniversity.ac.in



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ABSTRACT

Physical activity and fitness by age and gender have implications for understanding the etiology of obesity in youth and for suggesting approaches for prevention and treatment. Females are less physically active and less fit than males at all ages. 6MWT is an inexpensive in general sub maximal exercise test generally used to quantify the functional exercise capacity in clinical population. The test is frequently used in adults and is increasingly being utilized in children and in adolescents population as well. It has been used in assessment of subject with pulmonary, cardiovascular etc. This study is needed to assess how physical activity influences heart rate recovery (HRR) after a 6-minute walk test in school-going adolescents. Understanding HRR can help evaluate cardiovascular fitness, detect potential health risks early, and promote healthier lifestyles in young individuals. A total of 80 Adolescent were taken and they were divided into two groups. Group 1 n=15 subjects (physically active) and Group 2 n=15(sedentary) subjects. Students were instructed to perform six min walk test. Heart rate recovery was calculated between groups. As the data was not normally distributed non parametric Man Whitney U test was used to compare heart rate recovery between both the groups. Result shows that will comparing between groups, physically active children have significant heart rate recovery as compared to sedentary students ($p < 0.004$). Present study concluded that physically active students were having faster heart rate recovery as compared to sedentary students thus preventing future cardiovascular risk factors

Keywords: Heart rate recovery, 6 MWT, physical activity, adolescents.



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INTRODUCTION

Cardiovascular fitness is a critical component of overall health, particularly during adolescence—a pivotal period marked by significant physical and physiological development. In recent years, there has been growing concern about the increasing prevalence of sedentary behaviours among school-going adolescents, which may predispose them to various cardiovascular risks. Heart Rate Recovery (HRR), defined as the rate at which the heart rate declines after exercise, serves as a valuable indicator of autonomic function and cardiovascular health. An accelerated HRR reflects robust parasympathetic reactivation and overall cardiac fitness, whereas a delayed HRR may signal autonomic dysfunction and heightened cardiovascular risk[9]. The Six-Minute Walk Test (6MWT) is a submaximal exercise assessment widely utilized to evaluate functional exercise capacity across diverse populations. It measures the distance an individual can walk over six minutes on a flat, hard surface, providing insights into their aerobic endurance and cardiovascular efficiency. In paediatric populations, including adolescents, the 6MWT has been employed to establish normative data and assess functional capacity[10]. Engagement in regular physical activity is known to enhance cardiovascular fitness, improve autonomic balance, and facilitate more rapid HRR post-exercise. Studies have demonstrated that individuals who participate in consistent physical training exhibit improvements in HRR, indicative of better exercise tolerance and cardiac health[11]. Conversely, sedentary lifestyles during adolescence have been associated with diminished cardiovascular efficiency and delayed HRR, underscoring the importance of physical activity in promoting cardiac autonomic function. While extensive research has been conducted on HRR in adult populations, there is a relative paucity of data focusing on adolescents, particularly in the context of the 6MWT. Given the unique physiological changes occurring during adolescence, it is imperative to understand how physical activity influences HRR in this demographic. Such insights could inform targeted interventions aimed at enhancing cardiovascular health and mitigating future cardiovascular risks among school-going adolescents. This thesis aims to investigate the effect of physical activity on HRR following the 6MWT in school-going adolescents. By examining the relationship between habitual physical activity levels and HRR, this study seeks to elucidate the potential of HRR as a non-invasive marker for cardiovascular fitness in adolescents. Furthermore, the findings may contribute to the development of school-based physical activity programs designed to improve cardiovascular outcomes and promote long-term health in this vulnerable age group.

In conclusion, understanding the interplay between physical activity and HRR in adolescents is of paramount importance in the context of public health. By addressing this knowledge gap, the present study endeavours to provide evidence-based recommendations for fostering cardiovascular fitness through physical activity, ultimately aiming to reduce the burden of cardiovascular diseases later in life. These data on variations in physical activity and fitness by age and gender have implications for understanding the etiology of obesity in youth and for suggesting approaches for prevention and treatment. Females are less physically active and less fit than males at all ages. It is generally accepted that the gender difference in fitness is related to body fat, muscle mass, and haemoglobin concentration, but the relatively new data on gender differences in physical activity suggest that the role of physical activity should be considered more carefully. For Males, aerobic power per kilogram body weight remains virtually unchanged throughout youth become less and less active. When physical activity standards for youth are proposed, it must be assumed that activity levels decrease with age. Especially regarding physical activity, one would expect female youth to have higher levels of obesity than males. All other factors being equal, the contribution of physical activity to the risk of obesity would be expected to increase with age as activity decreases in both gender group, but more so in females. Health benefits of physical activity for children and adolescent, it is vitally important to have accurate information on the epidemiology of physical activity in youth. Here is substantial evidence linking the number of hours of TV viewing and being overweight or obese in children and adolescent. For example, in a representation sample of 7216 children aged 7 to 11 years, TV watching and video game use were risk factors for being overweight[17% to 44% increased risk] or obese(10% to 61%). The authors emphasized the need to examine more than a single sedentary behaviour (ie, TV viewing), particularly because not all sedentary behaviours have been associated obesity[2]. After achieving peak workload, all the patients spent at least two minutes in a cool-down period during treadmill testing at a speed of 2.4 km (1.5mil) per hour and a grade of 2.5 percent. This period was



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considered the recovery period. The value for recovery of heart rate was defined as the reduction in the heart rate from the rate at peak exercise to the rate one minutes after the cessation of exercise. The mechanisms by which impaired heart rate recovery confers an increases risk of death, even among patients without heart failure myocardial perfusion defects, are not clear. Imai *et al.* examination the physiologic characteristics of heart-rate recovery after exercise in health adults, athletes, and patients with chronic heart failure[5]. They demonstrated that, in all three group, vagal reactivation was the principal determinant of the decrease in heart rate during the first 30 seconds of recovery and that this mechanism was independent of age and the athletes but was blunted in patients with heart failure and was completely abolished by the administration of atropine[3].

MATERIALS AND METHODOLOGY

This Prospective Observational Study study was conducted on 80 school going adolescence (N=80). Informed consent was taken to the individuals who were participating in the study. Data was collected from the various centres of Ahmedabad, Gujarat. All the individuals were recruited according to the inclusion and exclusion criteria. Students were divided into two groups. Group 1 n=40subjects (physically active) and Group 2 n=40(sedentary) subjects. Students were instructed to perform six min walk test. Heart rate recovery was calculated between groups

Materials

- Sphygmomanometer
- Pulse oximeter
- Stop watch
- Bottles
- Measure tape
- Pen
- Chalk
- Book
- Chair

The Inclusion Criteria

- Normal Healthy Adolescent
- Age Group between 6 to 18 Years
- Both Male and Female Are Included
- Who were Able to perform 6 MWT.

The Exclusion Criteria

- Those Students Who were Participating in Other Sports Activity
- Students who had underwent any past surgery since last 6 months
- Students presented with any type of neurological disorder, congenital heart disease etc.,
- Students not willing to participate.

Procedure

Physical Activity Assessment

Physical activity levels will be assessed using

- Physical Activity Questionnaire for Adolescents (PAQ-A) – a validated self-report tool.
- Pedometer-based step count analysis – to objectively measure daily activity levels.

Participants will be classified into two groups

- Active Group: Engaging in at least 60 minutes of moderate-to-vigorous physical activity per day.
- Sedentary Group: Engaging in less than 60 minutes of physical activity per day.



**6-Minute Walk Test (6MWT)**

The 6MWT will be conducted following the American Thoracic Society (ATS) guidelines

- Conducted in a 30-meter indoor corridor with minimal external interruptions.
- Participants will be instructed to walk as far as possible for 6 minutes at a self-paced speed.
- Standardized encouragement will be provided at specific time intervals[8].

Heart Rate Measurement

- Resting Heart Rate (RHR): Measured using a digital heart rate monitor after 5 minutes of seated rest.
- Post-6MWT Heart Rate: Measured immediately after the test and at 1-minute, to assess HRR.
- HRR Calculation: $\text{HRR1} = \text{Peak HR} - \text{HR at 1 min post-exercise}$

RESULT

The result was done from SPSS software 20 version.

Demographic data

In group 1, 18(45%) were male and 22(55%) were female and in Group 2, 26(65%) were male and 14(35%) were female. Table 1 showing data of Demographic. An Unpaired T test was used to compare the pre and post data of individual. The mean $\pm$ SD distribution for heart rate recovery (HRR) for the adolescents was physically active (Group A) was 23.95 ± 2.783 and sedentary individuals was 16.07 ± 4.42 (Group B). Figure 1 shows the data of Group 1 and Group 2 Heart rate Recovery Rate

DISCUSSION

The present study aimed to evaluate heart rate recovery (HRR) among physically active adolescents and compare it with their sedentary counterparts. The findings revealed a significant difference in HRR between the two groups, with physically active adolescents demonstrating a notably faster recovery ($p < 0.00001$). This suggests that regular physical activity has a substantial impact on autonomic regulation and cardiovascular efficiency. A lowered resting heart rate in active individuals is primarily attributed to an increase in parasympathetic activity and a minor reduction in sympathetic discharge. Regular exercise enhances vagal tone, leading to a quicker return to baseline heart rate post-exercise. The accelerated HRR observed in the physically active group further supports the role of training in optimizing autonomic function. Conversely, sedentary students exhibited a delayed HRR, indicating reduced parasympathetic reactivation and prolonged sympathetic dominance. This imbalance may contribute to long-term cardiovascular risks if not addressed early in life. HRR is considered an essential prognostic marker of cardiovascular health, with delayed recovery being linked to an increased risk of cardiovascular diseases, metabolic disorders, and autonomic dysfunction. Several factors influence HRR, including exercise intensity, cardiorespiratory fitness, autonomic nervous system (ANS) modulation, hormonal changes, and baroreflex sensitivity. Physical training has been shown to enhance cardiac vagal tone, which facilitates quicker HRR. The improved efficiency in autonomic regulation observed in active adolescents underscores the benefits of regular physical activity in promoting cardiovascular health. These findings highlight the need for structured physical activity programs in schools to enhance cardiovascular fitness and autonomic balance among adolescents. HRR post-exercise can serve as a simple yet effective tool for assessing cardiovascular health, encouraging early interventions to reduce future health risks associated with sedentary lifestyles.





CONCLUSION

The present study concluded that physically active students demonstrated significantly faster heart rate recovery (HRR) compared to their sedentary counterparts, indicating better autonomic function and cardiovascular efficiency. Faster HRR is primarily attributed to enhanced parasympathetic reactivation and reduced sympathetic dominance, which play a crucial role in maintaining heart health. In contrast, sedentary students exhibited delayed HRR, suggesting impaired autonomic regulation that may contribute to an increased risk of cardiovascular diseases in the future. HRR is a well-established prognostic marker of cardiovascular health, with slower recovery post-exercise being associated with higher risks of hypertension, obesity, and metabolic disorders. Regular physical activity strengthens the cardiovascular system by improving vagal tone, increasing baroreflex sensitivity, and enhancing cardiac autonomic balance. These physiological adaptations contribute to a more efficient heart rate regulation, ultimately reducing long-term cardiovascular risk. Given the significant impact of physical activity on HRR, encouraging adolescents to engage in regular exercise is crucial for promoting lifelong heart health. Schools should implement structured physical education programs that emphasize aerobic and endurance training to enhance cardiovascular fitness. Early interventions focused on increasing physical activity levels in adolescents can help mitigate future cardiovascular risks, fostering a healthier generation with improved overall well-being.

LIMITATION

- More sample size can be administered
- Factors such as diet, sleep pattern was not administrated in the study
- Other outcome measures such as fatigue was not assessed

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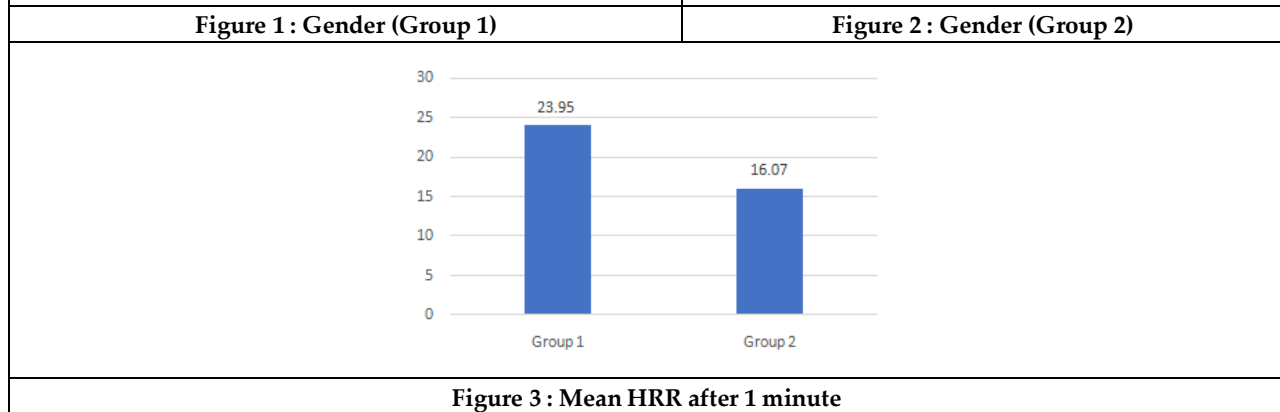
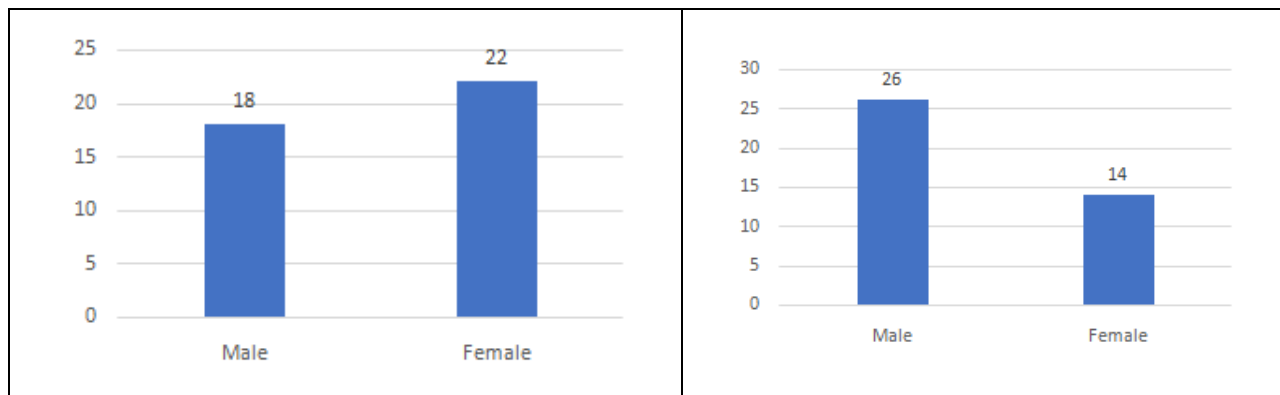
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Table 1: Demographic Data

Group 1		Group 2	
Age	10.55 ± 2.01 Mean ± SD	Age	10.77 ± 2.18 Mean ± SD
Gender	Male = 18(45%)	Gender	Male = 26(65%)
	Female = 22(55%)		Female = 14(35%)

Table 2: Data of Group 1 and Group 2

Group 1		Group 2	
HRR Mean ± SD	23.95 ± 2.783	HRR Mean ± SD	16.075 ± 4.423
Unpaired T Value	4.6291		
P Value	<0.00001		





RESEARCH ARTICLE

Cost Benefit Analysis of Pulses Production in Organic and Conventional Farming

R.Venkatesh^{1*} and A. Durga Devi²

¹Principal, Department of Commerce, ARC Viswanathan College, Mayiladuthurai, (Affiliated to Annamalai University, Chidambaram), Tamil Nadu, India.

²Assistant Professor, Department of Economics, ARC Viswanathan College, Mayiladuthurai, (Affiliated to Annamalai University, Chidambaram), Tamil Nadu, India.

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*Address for Correspondence

R.Venkatesh

Principal,

Department of Commerce,

ARC Viswanathan College, Mayiladuthurai,

(Affiliated to Annamalai University, Chidambaram),

Tamil Nadu, India.

E.Mail: maxreinfoundation@gmail.com



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ABSTRACT

This study undertakes a rigorous cost-benefit analysis to compare the economic viability and sustainability of organic versus conventional pulse production systems in Dharmapuri district, Tamil Nadu, a key pulse-producing region in South India. Employing a purposive sampling methodology, primary data were collected from 100 pulse farmers equally divided between organic and conventional systems. Quantitative analyses, including descriptive statistics, cost-benefit computations, and linear regression modelling, were applied to evaluate profitability determinants and compare net returns per hectare across the two farming approaches. Findings reveal that while conventional farming attains higher yields, organic farming benefits from premium market prices and targeted subsidies, yielding superior net profits despite elevated labour and input expenses. The cost-benefit ratio distinctly favors organic cultivation, underscoring its economic and environmental sustainability. Regression results indicate a counterintuitive negative relationship between yield and net profit, suggesting escalating input costs with intensified production, whereas organic farming exerts a positive, though marginally significant, effect on profitability. The study recommends enhanced institutional support for organic farmers, including increased subsidies, extension services, and improved market infrastructure to alleviate transition challenges and labour burdens. Further research into cost-effective organic inputs and integrated farming models is advocated to bolster productivity and economic outcomes. In conclusion, this research contributes to the agrarian economics literature by providing empirical evidence supporting organic pulse farming as a viable and sustainable alternative to conventional methods in the Indian



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context. The findings hold significant implications for policymakers aiming to foster sustainable agriculture, improve farmer livelihoods, and promote environmental stewardship in pulse production systems.

Keywords: Organic farming, Conventional farming, Pulse production, Cost-benefit analysis, Agricultural sustainability, Economic viability

INTRODUCTION

The economic viability and sustainability challenges faced by pulse farmers in Dharmapuri district, especially in balancing the costs and benefits of organic versus conventional farming, are critical issues that influence agricultural decisions and rural livelihoods. Dharmapuri, a prominent pulse-producing district in Tamil Nadu, cultivates important varieties such as Red gram, Black gram, and Green gram, which form the backbone of local agriculture and nutrition. While conventional farming methods dominate due to their higher yields and familiarity, they often depend on synthetic fertilizers and pesticides, raising concerns about environmental degradation and long-term soil health. Conversely, organic pulse farming, which emphasizes ecological balance and chemical-free production, is gaining interest among farmers motivated by health and sustainability considerations. However, organic cultivation in Dharmapuri is confronted with significant challenges such as higher labour demands, increased production costs, and limited market access, which affect its adoption and profitability. This study addresses the pressing need to evaluate and compare the cost-effectiveness and economic outcomes of these two farming systems in Dharmapuri, providing insights to support informed policymaking and promote sustainable agricultural practices tailored to the region's unique conditions.

REVIEW OF LITERATURE

Reganold and Wachter (2016) emphasize that organic farming generally incurs higher production costs than conventional farming. This is primarily due to the labour-intensive nature of organic practices, which often require manual weeding, pest control, and soil management techniques rather than mechanized or chemical solutions. Additionally, the inputs used in organic farming, such as organic fertilizers, compost, and biological pesticides, tend to be more costly and less readily available than synthetic alternatives used in conventional systems. These factors collectively contribute to increased operational expenses for organic farmers, especially during the transition period when yields may also be lower.

Tilman *et al.* (2002) report that conventional farming practices generally result in higher crop yields compared to organic methods, primarily due to the extensive use of synthetic chemical fertilizers and pesticides that boost plant growth and control pests effectively. However, this reliance on chemical inputs has been linked to significant negative environmental impacts, including soil degradation, loss of soil biodiversity, and contamination of surface and groundwater through nutrient runoff and pesticide residues. These environmental consequences not only threaten long-term agricultural productivity but also pose risks to ecosystem health and human well-being, highlighting a critical trade-off between short-term yield gains and sustainable farming practices.

Yiridoe *et al.* (2005) explain that organic products typically command premium prices in the marketplace, a trend largely driven by increasing consumer awareness and concern about health, food safety, and environmental sustainability. Consumers are willing to pay higher prices for organic foods due to perceptions that they are healthier, free from synthetic chemicals, and produced using environmentally friendly practices. This willingness to pay a premium not only incentivizes farmers to adopt organic methods but also supports the growth of organic markets globally, despite the often-higher production costs and lower yields associated with organic farming systems.



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Gomiero *et al.* (2011) highlight that organic farming contributes significantly to the enhancement of soil fertility over the long term by employing practices such as crop rotation, compost application, and reduced tillage, which improve soil organic matter and microbial activity. Unlike conventional farming, which relies heavily on synthetic chemicals that can degrade soil structure and biodiversity, organic farming minimizes the use of harmful pesticides and fertilizers. This not only helps maintain a healthier soil ecosystem but also reduces the risk of chemical residues contaminating water bodies and surrounding environments, making organic farming a more ecologically sustainable approach.

Seufert *et al.* (2012) note that the transition from conventional to organic farming presents substantial challenges, including significant financial investments for farmers. These costs arise from the need for new inputs, training, certification processes, and often reduced yields during the initial conversion period. Additionally, farmers must navigate existing agricultural policies and subsidy structures that frequently favour conventional farming practices, creating institutional barriers to organic adoption. Overcoming these economic and policy constraints is critical for expanding organic farming and realizing its environmental and health benefits on a broader scale.

Objectives and Statement of the Problem

Dharmapuri district is a major pulse-producing area where both organic and conventional farming methods are practiced. Evaluating the economic performance of these systems is crucial for supporting sustainable agriculture and improving farmer livelihoods in the region. This study compares the economic viability of organic and conventional pulse farming in Dharmapuri by examining costs, yields, prices, and profits, while identifying key factors affecting sustainability and profitability to guide informed policy decisions. Pulses constitute a vital component of India's agricultural economy and nutritional security. However, farmers encounter significant challenges in optimizing productivity and profitability within pulse cultivation. Conventional pulse farming, heavily reliant on synthetic fertilizers and pesticides, contributes to environmental degradation and escalating input costs, thereby undermining the sustainability of agricultural practices. In contrast, organic pulse farming offers ecological benefits such as improved soil health and reduced chemical dependency, yet it is frequently associated with lower yields, greater labour intensity, and limited market accessibility. Despite the rising interest in organic cultivation, there remains a paucity of rigorous empirical studies that systematically compare the economic returns and sustainability outcomes of organic versus conventional pulse production. This deficiency in comprehensive cost-benefit analyses restricts the ability of farmers, extension services, and policymakers to make evidence-based decisions regarding the adoption of farming systems. This study aims to address this critical knowledge gap by conducting a comparative cost-benefit analysis of pulses grown under organic and conventional methods in the Dharmapuri district. The results will offer valuable insights to promote farming practices that balance economic profitability with environmental sustainability.

RESEARCH METHODOLOGY

This study employs a comparative analytical framework to evaluate the economic performance and sustainability of pulse cultivation under organic and conventional farming systems. The research focuses on Dharmapuri district, a key pulse-producing region in Tamil Nadu, known for cultivating major pulse crops such as Red gram, Black gram, and Green gram. A purposive sampling technique was utilized to select 100 pulse farmers from Dharmapuri, equally divided between those practicing organic methods (50 farmers) and conventional farming (50 farmers). This balanced sample facilitates a rigorous comparison of the two farming systems. Primary data were gathered through structured interviews using a pre-tested questionnaire designed to capture comprehensive information on key variables, including farm size, input costs (seeds, fertilizers, pesticides), labour expenses, crop yields, market prices, government subsidies, organic premiums, and net profitability. Descriptive statistical methods were applied to summarize the data effectively. To rigorously compare economic viability, a detailed cost-benefit analysis was performed for both farming systems. Further, to explore the determinants influencing profitability, linear regression



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analysis was conducted using SPSS software. This analysis assessed the impact of variables such as input costs, yield, labour input, and farming system type (organic vs. conventional) on net returns.

RESULT AND DISCUSSION

Pulses are crucial for global food security and soil health, especially in India, where they support livelihoods and nutrition. Conventional farming relies on chemical inputs to boost yields, while organic farming prioritizes sustainability and ecological balance. This study compares the costs, benefits, and profitability of organic versus conventional pulse production to assess their economic viability and sustainability. Cost of Production for both organic and conventional pulse farming (Table 1). The cost of production for organic pulse farming is notably higher than that of conventional farming, primarily driven by increased input costs, Rs. 1499.41 per hectare for organic compared to Rs. 1130.78 for conventional, reflecting the use of more expensive organic inputs and labour-intensive management practices. Although conventional farming incurs substantially greater expenses on chemical fertilizers and pesticides (Rs. 394.70 per hectare versus Rs. 97.13 for organic), organic farming demands significantly higher labour inputs, both as a percentage of total costs (50.39% versus 28.33%) and in absolute terms (161.30 versus 112.46 labour hours per hectare). Additionally, organic farmers receive marginally higher subsidies, indicating targeted policy support for sustainable practices. These contrasts underscore the inherent trade-offs between labour, input expenses, and chemical reliance, shaping the economic feasibility and environmental impact of each farming system. Cost-Benefit analysis for both organic and conventional pulse farming (Table 2). The cost-benefit analysis reveals clear distinctions between organic and conventional pulse farming systems. Organic farms, averaging 2.51 hectares, incur higher input costs per hectare (Rs. 1499.41) than conventional farms (Rs. 1130.78), yet benefit from a significantly higher market price per kilogram of pulses (Rs. 2.48 versus Rs. 1.82). Although conventional farms achieve slightly higher average yields (1472.57 kg/ha compared to 1212.47 kg/ha in organic), organic farmers realize greater average net profits per hectare (Rs. 730.13 versus Rs. 617.91), largely driven by premium pricing and targeted subsidies. Labor demands are considerably higher in organic farming, with labor costs constituting 50.39% of total expenses and labor hours averaging 161.30 per hectare, compared to 28.33% and 112.46 hours in conventional farming. Additionally, organic farming faces more substantial transition challenges (average score of 4.10 versus 1.94), reflecting the complexities inherent in adopting new practices. Consumer willingness to pay premiums for organic pulses—averaging 27.95%—further underpins the economic viability of organic systems despite their elevated production costs. The higher subsidies awarded to organic producers also demonstrate policy support aimed at encouraging sustainable agriculture.

Overall, while organic pulse farming demands greater labor and input investment, it achieves competitive profitability through premium market prices and subsidies, making it a viable and sustainable alternative to conventional pulse production. Returns and cost-benefit ratio for both organic and conventional pulse farming (Table 3). Conventional pulse farms tend to have a slightly larger average size (2.68 ha) and achieve higher yields (1472.57 kg/ha) compared to organic farms (2.51 ha and 1212.47 kg/ha, respectively). However, organic pulses command significantly higher market prices (Rs. 2.48/kg vs. Rs. 1.82/kg), resulting in greater average revenue per hectare (Rs. 3018.91 vs. Rs. 2683.94) and higher net profits (Rs. 730.13 vs. Rs. 617.91) despite lower yields. The cost-benefit ratio is also higher for organic farming (0.52) than for conventional farming (0.44), reflecting greater relative costs associated with organic production. Overall, the premium prices and profitability make organic pulses a viable and sustainable alternative despite the yield gap. Linear regression output predicting net profit (Rs/ha) (Table 4). The regression explains approximately 21.9% of the variability in net profit ($R^2 = 0.219$), indicating a modest ability to predict profitability based on the selected variables. The adjusted R^2 value of 0.186 accounts for the number of predictors and suggests that about 18.6% of the variation in net profit is explained after adjusting for model complexity. The overall model is statistically significant, as indicated by the F-statistic of 6.376 ($p < 0.001$), meaning that the combination of input cost, yield, labor hours, and farming type reliably predicts net profit. Individually, yield has a statistically significant negative effect on net profit (coefficient = -0.138, $p = 0.016$), suggesting that increases in yield are associated with a decrease in net profit, possibly reflecting rising costs with higher production.





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Farming type (organic vs. conventional) shows a positive but marginally significant effect (coefficient = 78.99, $p = 0.074$), indicating that organic farming tends to increase net profit by about Rs. 79 per hectare compared to conventional farming, although this result is borderline in significance. Input cost and labor hours have small, statistically insignificant effects on net profit, implying that changes in these variables do not reliably impact profitability in this model.

CONCLUSION

The comparative analysis demonstrates that organic pulse farming, although characterized by higher input and labour costs and slightly lower yields, achieves superior profitability relative to conventional farming due to higher market prices and subsidy support. The higher cost-benefit ratio of organic systems affirms their economic viability alongside environmental benefits such as reduced chemical usage and improved soil health. The negative correlation between yield and net profit reflects the complexity of balancing production scale and input costs. Overall, organic farming emerges as a sustainable and profitable alternative for pulse cultivation, particularly in regions like South India where environmental consciousness and market demand for organic products are growing.

Recommendations

Better Support: Give more subsidies and incentives to organic pulse farmers to help with higher costs and encourage more farmers to switch.

Training: Offer training and advice to farmers to make organic farming easier and improve their crop yields.

Market Access: Improve ways to sell organic pulses and build better supply chains to keep demand steady and prices higher.

Research: Fund research to find cheaper organic inputs and better pest control to make organic farming less labour-intensive and more productive.

Mixed Farming: Encourage farming systems that combine organic and conventional methods to get both good yields and sustainability.

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Table 1: Cost of Production for both organic and conventional pulse farming

Cost Parameter	Organic Farming		Conventional Farming		Total	
	Total	Average	Total	Average	Total	Average
Input Cost (Rs/ha)	1812.93	1499.41	1540.24	1130.78	3353.17	1315.10
Fertilizer/Pesticide Cost (Rs/ha)	223.16	97.13	657.34	394.70	880.50	245.91
Labor Cost (%)	59.46	50.39	38.92	28.33	98.38	39.36





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Labor Hours (hrs/ha)	225.69	161.30	164.08	112.46	389.77	136.88
Subsidy Received (Rs)	446.31	191.98	323.06	163.10	769.37	177.54

Table 2: Cost-Benefit analysis for both organic and conventional pulse farming

Variable	Organic Farming		Conventional Farming		Total	
	Total	Average	Total	Average	Total	Average
Farm Size (ha)	4.86	2.51	4.95	2.68	9.81	2.60
Input Cost (Rs/ha)	1812.93	1499.41	1540.24	1130.78	3353.17	1315.10
Fertilizer/Pesticide Cost (Rs/ha)	223.16	97.13	657.34	394.70	880.50	245.92
Labor Cost (%)	59.46	50.39	38.92	28.33	98.38	39.36
Yield (kg/ha)	1970.55	1212.47	2158.10	1472.57	4128.65	1342.52
Market Price (Rs/kg)	3.14	2.48	2.31	1.82	5.45	2.15
Net Profit (Rs/ha)	1019.96	730.13	919.19	617.91	1939.15	674.02
Labor Hours (hrs/ha)	225.69	161.30	164.08	112.46	389.77	136.88
Transition Challenges Score (1-5)	5	4.10	3	1.94	8	3.02
Consumer Premium (%)	39.60	27.95	0	0.00	39.60	13.98
Subsidy Received (Rs)	446.31	191.98	323.06	163.10	769.37	177.54

Table 3: Returns and cost-benefit ratio for both organic and conventional pulse farming

S.No.	Variables	Organic	Conventional
1	Average Farm Size (ha)	2.51	2.68
2	Average Yield (kg/ha)	1212.47	1472.57
3	Average Market Price (Rs/kg)	2.48	1.82
4	Average Revenue (Rs/ha)	3018.91	2683.94
5	Average Net Profit (Rs/ha)	730.13	617.91
6	Average Cost-Benefit Ratio	0.52	0.44

Table 4: linear regression output predicting net profit (Rs/ha)

Variable	Coefficient	Std. Error	t-Statistic	P-value	95% Confidence Interval
Constant	834.12	117.22	7.12	0.000	[601.41, 1066.83]
Input Cost (\$/ha)	-0.027	0.071	-0.38	0.704	[-0.169, 0.114]
Yield (kg/ha)	-0.138	0.056	-2.46	0.016	[-0.249, -0.027]
Labor Hours (hrs/ha)	0.153	0.464	0.33	0.743	[-0.769, 1.074]
Farming Type (Organic=1)	78.99	43.65	1.81	0.074	[-7.67, 165.65]
R-squared	0.219				
Adjusted R-squared	0.186				
F-statistic	6.376				





RESEARCH ARTICLE

Ideals in Ternary Seminear Ring

A. Dhivya Bharathi* and K. Balaji

Assistant Professor, Department of Mathematics, Bharath Institute of Higher Education and Research (Deemed to be University), Selaiyur, Chennai, Tamil Nadu, India.

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*Address for Correspondence

A. Dhivya Bharathi

Assistant Professor,

Department of Mathematics,

Bharath Institute of Higher Education and Research (Deemed to be University),

Selaiyur, Chennai, Tamil Nadu, India.

E.Mail: dhivyaba.a@gmail.com



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ABSTRACT

In this paper, we introduce the notion of prime ideals and semiprime ideals of ternary seminear ring. Principal right, lateral and left ideals are defined and their relationship with regular ternary seminear ring is determined. We also define an annihilator of ternary seminear ring and regular ideal of a ternary seminear ring and derive their characterizations. The ternary seminear ring is the generalization of seminear ring and it need not be a ternary semiring[14]. Characterization of quotient ternary seminear ring[15] and some structures of ternary seminear ring like regular ternary seminear ring and normal ternary seminear ring etc.,[16] have been analysed.

Keywords: Prime Ideals, Semiprime Ideals, Ternary Seminear Ring

INTRODUCTION

In 1965, Sioson FM[1] discussed about Ideal theory in ternary semigroups. In 1970, Hogewijs worked on seminear ring Embedding[2]. Weinert HJ[3][4] came up with related representation theorems for rings, semirings, near rings and seminear rings by partial transformation and partial endomorphisms. In 1995, Javed Ahsan[5] introduced the specific type of ideals in seminear rings. Dutta TK and Kar S[6][7] contributed on ternary semirings. Later mathematicians floated on seminear rings[8],[9]. Kar S, Sircar J and Mandel S[10] fathered on right strongly prime ternary semirings. Further kornthorng N, Iampun A[11] studied a note on right full K-ideals of seminear rings. Especially Koppula K, Kedukodi BS and Kuncham SP[12][13] researched on prime strong ideals of a seminear ring and on perfect ideals of seminear rings. In 2020 the notion of ternary seminear ring was initiated by us [14][15][16]. We call an algebraic structure $(T, +, \cdot)$ is a ternary seminear ring if $(T, +)$ is a Semigroup, T is a ternary semigroup under ternary multiplication and $xy(z + u) = xyx + xyu$ for all $x, y, z, u \in T$. T is said to have an absorbing zero if there exists an element $0 \in T$ such that $x + 0 = 0 + x = x$ for all $x \in T$ and $xy0 = x0y = 0xy = 0$ for all $x, y \in T$. Throughout this paper T will always stand for ternary seminear ring with an absorbing zero. In this paper, we define





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a ideals of ternary seminear rings such as prime ideal of ternary seminear ring, Semiprime ideal of ternary seminear ring, Annihilator of ternary seminear ring and discuss about their properties. We also describe regular ideals in ternary seminear ring and classify some of their interesting properties.

PRELIMINARIES

Definition 2.1 [5] An ideal I of a seminear ring N is said to be a prime ideal if $UV \subseteq I$ implies $U \subseteq I$ or $V \subseteq I$ for all U, V in N .

Definition 2.2 [5] An ideal I of a seminear ring N is said to be a semi prime ideal if $U^2 \subseteq I$ implies $U \subseteq I$ for ideals U in N .

Definition 2.3 [5] An ideal I of a seminear ring N is said to be a minimal prime ideal if I is a minimal element of the set of all prime ideals of N .

Definition 2.4 [13] Let T be a ternary seminear ring $(T, +, \cdot)$. A non empty subset I of T is said to be a left(lateral and right) ideal of T if it holds the following conditions i) $i + j \in I$ for all $i, j \in I$ ii) $t_1 t_2 i$ (respectively $t_1 i t_2, i t_1 t_2$) $\in I$ for all $t_1, t_2 \in T$ and $i \in I$. If I is a left, a lateral and a right ideal of T then I is said to be an ideal of T .

Definition 2.5 [14] An element x in a ternary seminear ring T is called regular if there exists an element y in T such that $xyx = x$. A ternary seminear ring T is called regular if all of its elements are regular.

IDEALS IN TERNARY SEMINEAR RINGS:

This section deals with ideals of ternary seminear rings and their properties.

Definition 3.1 An ideal I of ternary seminear ring is said to be a proper ideal if $I \neq T$.

Definition 3.2 Let T be a ternary seminearring and $x \in T$. Then the principal

i) right ideal generated by x is defined as

$$\langle x \rangle_r = \{\sum x s_i t_i + n x / s_i, t_i \in T; n \in \mathbb{Z}_0^+\}$$

ii) left ideal generated by x is defined as

$$\langle x \rangle_l = \{\sum s_i t_i x + n x / s_i, t_i \in T; n \in \mathbb{Z}_0^+\}$$

iii) lateral ideal generated by x , is defined as

$$\langle x \rangle_m = \{\sum s_i x t_i + \sum q_j r_j x s_j t_j + n x / q_j, r_j, s_i, t_i \in T; n \in \mathbb{Z}_0^+\}$$

where $\mathbb{Z}_0^+$ is the set of all non negative integers and Σ denotes the finite sum.

Theorem 3.3 Let T be a ternary seminear ring. Then the following conditions are equivalent

i) T is regular.

ii) For any right ideal A , lateral ideal B , left ideal C of T , $ABC = A \cap B \cap C$.

iii) For $x, y, z \in T$, $\langle x \rangle_r \langle y \rangle_m \langle z \rangle_l = \langle x \rangle_r \cap \langle y \rangle_m \cap \langle z \rangle_l$

iv) For $x \in T$, $\langle x \rangle_r \langle x \rangle_m \langle x \rangle_l = \langle x \rangle_r \cap \langle x \rangle_m \cap \langle x \rangle_l$

Proof. (i) $\Rightarrow$ (ii). Let T be a regular ternary seminear ring. Let A be a right ideal, B be a lateral ideal and C be a left ideal of a ternary seminear ring. Then clearly $ABC \subseteq A \cap B \cap C$.

Now, If $x \in A \cap B \cap C$, then $x = xyx$ for some $y \in T$, which implies that





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$$\begin{aligned}x &= (xyx)y(xy x) \\&= xy(xy x)y(xy x) \\&= (xyx)(yxy)(xyx) \in ABC\end{aligned}$$

Hence we have $A \cap B \cap C \subseteq ABC$. Consequently $ABC = A \cap B \cap C$

Obviously (ii) $\Rightarrow$ (iii) and (iii) $\Rightarrow$ (iv)

Now it is enough to show (iv) $\Rightarrow$ (i)

Let $x \in T$

$$x \in \langle x \rangle_r \cap \langle x \rangle_m \cap \langle x \rangle_l = \langle x \rangle_r \langle x \rangle_m \langle x \rangle_l.$$

$$\text{Then } x \in (xTT + nx)(TxT + TTxTT + nx)(TTx + nx) \subseteq xTx$$

So $x \in xTx$ and there exists an element $y \in T$ such that $x = xyx$. Thus x is regular and T be a regular.

Definition 3.4 Let T be a ternary seminear ring. A proper ideal I of T is said to be a prime ideal if whenever $XYZ \subseteq I$ then $X \subseteq I$ or $Y \subseteq I$ or $Z \subseteq I$, for all ideals X, Y, Z of T .

Definition 3.5 Let T be a ternary seminear ring. A proper ideal I of T is said to be a semiprime ideal if whenever $X^3 \subseteq I$ then $X \subseteq I$, for any ideals X of T .

Definition 3.6 If R and S are non empty subsets of T , then

i) the left annihilator of R with respect to S in T is defined as $l(R, S) = \{x \in T / xRS = \{0\}\}$

ii) the right annihilator of R with respect to S in T , is defined as $r(R, S) = \{x \in T / RSx = \{0\}\}$

Definition 3.7 For any two non empty subsets R, S of T , we denote the subset $\{x \in T / xS \subseteq R\}$ by $(R : S)$

Theorem 3.8 Let T be a ternary seminear ring. Then a right annihilator of a subset R with respect to a subset S of T is a right ideal of T .

Proof. Let T be a ternary seminear ring. If R and S are non empty subsets. Since $RS0 = \{0\}$, $0 \in r(R, S)$. Thus $r(R, S)$ is a non empty set. Let $x, y \in r(R, S)$. Then $RSx = RSy = \{0\}$. Now $RS(x + y) = RSx + RSy = \{0\} + \{0\} = \{0\}$ which implies that $x + y \in r(R, S)$. Now $RS(xuv) = (RSx)uv = \{0\}uv = \{0\}$, for all $u, v \in T$, which implies $xuv \in r(R, S)$. Thus $r(R, S)$ is a right ideal of T .

Theorem 3.9 The right annihilator of a subset R with respect to a subset S of ternary seminear ring with unital element 'e' is an ideal (right ideal, lateral ideal and left ideal) of T .

Proof. Let T be a ternary seminear ring. By theorem 3.8, $r(R, S)$ is a right ideal of T . Now it is enough to prove $r(R, S)$ is a lateral and a left ideal of T . Let $x \in r(R, S)$. Let $u, v \in T$. Then $RSx = \{0\}$. Since S is a right ideal of T , we have $RS(uvx) = R(Suv)x \subseteq R(STT)x \subseteq RSx = 0$, $\forall u, v \in T$, which implies $uvx \in r(R, S)$. Thus $r(R, S)$ is a left ideal of T . Since S is a right ideal of T , we have

$$\begin{aligned}RS(uxv) &= RS(eue)(exe)v \\&= R(Seu)(eexev) \\&\subseteq R(STT)(eexev) \\&\subseteq RS(eexev) \\&= R(See)(xev) \\&\subseteq R(STT)(xev) \\&\subseteq RS(xev) \\&= (RSx)ev \\&= 0ev \\&= 0. \quad \forall u, v \in T.\end{aligned}$$

This implies $uxv \in r(R, S)$. Thus $r(R, S)$ is a lateral ideal of a ternary seminear ring T and hence $r(R, S)$ is an ideal of T .





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Theorem 3.10 Let T be a ternary seminear ring. The following criteria on T are equivalent.

- i) T is regular.
- ii) $A \cap C = ATC$ for each right ideal A and each left ideal C of T .
- iii) $\langle x \rangle_r \cap \langle y \rangle_l = \langle x \rangle_r T \langle y \rangle_l \quad \forall x, y \in T$.
- iv) $\langle x \rangle_r \cap \langle x \rangle_l = \langle x \rangle_r T \langle x \rangle_l \quad \forall x \in T$.

Proof. Let T be a ternary seminear ring. (i) $\Rightarrow$ (ii)

Let T be regular.

Let A be a right ideal and C be a left ideal of T . Then $ATC \subseteq ATT \subseteq A$ and $ATC \subseteq TTC \subseteq C$. $ATC \subseteq A$ and $ATC \subseteq C$.

Thus

$$ATC \subseteq A \cap C$$

For $x \in A \cap C$, $x = xyx$ for $y \in T$ which implies $x = xyx = xyxyx \in ATC$.

Hence

$$A \cap C \subseteq ATC$$

Thus $A \cap C = ATC$

Obviously (ii) $\Rightarrow$ (iii) and (iii) $\Rightarrow$ (iv)

Assume that (iv) holds.

Let $x \in T$. $x \in \langle x \rangle_r$ and $\langle x \rangle_l$.

Then $x \in \langle x \rangle_r \cap \langle x \rangle_l = \langle x \rangle_r T \langle x \rangle_l$.

$$\begin{aligned} x &= \left(\sum xq_i r_i + mx \right) t_j \left(\sum s_k t_k x + nx \right) \\ &= \sum \left[\left(\sum xq_i r_i \right) t_j \left(\sum s_k t_k x \right) + \left(\sum xq_i r_i \right) t_j (nx) + (mx) t_j \left(\sum s_k t_k x \right) + (mx) t_j (nx) \right] \in xTx \end{aligned}$$

Hence $x \in xTx$, then there exists an element y in T , such that $x = xyx$. Therefore x is regular. Obviously T is regular.

REGULAR IDEAL OF A TERNARY SEMINEAR RING

In this section regular ideal of ternary seminear ring is defined and some equivalent condition for an ideal to be a regular are proved.

Definition 4.1 Let T be ternary seminear ring. An ideal I of T is said to be a regular ideal if $I + ABC = A \cap B \cap C$ for any right ideal $A \supseteq I$, lateral ideal $B \supseteq I$ and left ideal $C \supseteq I$.

Remark 4.2 By definition 4.1, T is always a regular ideal. Any ideal that contains a regular ideal is also a regular ideal. For, let I be a regular ideal and X be an ideal such that $I \subset X$. Let A, B, C be right, lateral and left ideal respectively such that $A \supseteq X, B \supseteq X, C \subseteq X$. Since $I \subset X$, and $A \cap B \cap C \subset I + ABC, A \cap B \cap C \subset X + ABC$. Now if $x + abc \in X + ABC$, then $x \in X, a \in A, b \in B$ and $c \in C$. Thus $x \in A \cap B \cap C$ and therefore $x + abc \in A \cap B \cap C$. Hence $X + ABC = A \cap B \cap C$.

Theorem 4.3 Let T be a ternary seminear ring. T is a regular ternary seminear ring $\Leftrightarrow \{0\}$ is a regular ideal of T .

Proof. Let T be a ternary seminear ring. Let $I = \{0\}$ be a regular ideal of T . Then

$$I + ABC = A \cap B \cap C, \quad \text{where } A, B, C \text{ be a right, a lateral and a left ideal of } T.$$

$$\{0\} + ABC = A \cap B \cap C$$

$$ABC = A \cap B \cap C$$

By theorem 3.3, T is regular ternary seminear ring. Suppose that T is regular.

Let $I = \{0\}$. Then

$$I + ABC = \{0\} + ABC$$

$$= ABC$$

$$= A \cap B \cap C \quad (T \text{ is regular})$$

$$I + ABC = A \cap B \cap C$$

Therefore $I = \{0\}$ is a regular ideal of T .





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Remark 4.4 Let T be a ternary seminear ring. R be regular ideal of T , that is the intersection of all non zero ideals of T . The intersection of all non zero right ideals of T is R_a , the intersection of all non zero lateral ideals of T is R_b and the intersection of all non zero left ideals of T is R_c . If $R = \{0\}$, then $R = R_a = R_b = R_c$.

Theorem 4.5 Let T be a ternary seminear ring and $R = R_a = R_b = R_c$. Then T is a regular ternary seminear ring $\Leftrightarrow R$ is a regular ideal of T .

Proof. Let T be ternary seminear ring and $R = R_a = R_b = R_c$. Let T be regular ternary seminear ring. If $R = R_a = R_b = R_c = \{0\}$, by theorem 4.3, the result follows. Suppose $R = R_a = R_b = R_c \neq \{0\}$. By theorem 4.3, $\{0\}$ is a regular ideal of ternary seminear ring. Now $\{0\} \subseteq R = R_a = R_b = R_c$ which implies that R is a regular ideal of T , by Remark 4.2. Conversely, let R be a regular ideal of T . Then $R + ABC = A \cap B \cap C$ for any right ideal $A \supseteq R$, lateral ideal $B \supseteq R$ and left ideal $C \supseteq R$ of T . Since RRR is a right ideal of T and $R = R_a$, $R = R_a \subseteq RRR \subseteq ABC$. Therefore $R + ABC = ABC$. Hence $ABC = A \cap B \cap C$ and by theorem 3.3, T is a regular ternary seminear ring.

Theorem 4.6 Let T be a ternary seminear ring and $R = R_a = R_b = R_c$. Then T is a regular ternary seminear ring $\Leftrightarrow$ every ideal of T is regular.

Proof. If T is a regular ternary seminear ring. Then by theorem 4.5, R is a regular ideal of T . Now $R = R_a = R_b = R_c$ which implies each non-zero ideal of T contains the regular ideal R of T . Therefore from Remark 4.2, each ideal of T is regular. Conversely, if each ideal of T is regular, then R is a regular ideal of T and thus by theorem 4.5, we have T is a regular ternary seminear ring.

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RESEARCH ARTICLE

GIS-based Hydrogeochemical Investigation of Groundwater Quality in Ulundurpet Taluk, Tamil Nadu

Bibishyn W. K.^{1*}, P. Anandhan², Krista Lalnarammawia¹ and R. Manivannan²

¹Research Scholar, Department of Earth Sciences, Annamalai University, Annamalai Nagar, Chidambaram, Tamil Nadu, India.

²Assistant Professor, Department of Earth Sciences, Annamalai University, Annamalai Nagar, Chidambaram, Tamil Nadu, India.

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*Address for Correspondence

Bibishyn W. K.

Research Scholar,

Department of Earth Sciences,

Annamalai University, Annamalai Nagar,

Chidambaram, Tamil Nadu, India.

E.Mail: bibishynshyn@gmail.com



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ABSTRACT

This study assesses groundwater quality in Ulundurpet Taluk, Tamil Nadu, India, based on 36 surface and subsurface water samples. Using Geographic Information System (GIS) approaches, essential hydrogeochemical parameters such as pH, electrical conductivity (EC), Total Dissolved Solids (TDS), and major ions were studied. Results demonstrate substantial geographical diversity, impacted by geology, human activities, and agriculture. While pH is mainly within the WHO-recommended range, excessive EC and TDS values, with 80% of samples surpassing the 500 mg/L limit, suggest pollution. Higher quantities of bicarbonates, chlorides, and sodium were observed in the northern region, although calcium, magnesium, and potassium levels remained satisfactory. Low amounts of phosphates and sulfates reflect low nutritional input. GIS maps identify pollution areas, enabling focused control techniques. This study underlines the necessity for continuing groundwater monitoring and sustainable management to guarantee water quality.

Keywords: Geographic Information System (GIS), Hydrogeochemical, WHO, Water Pollution, Major Ions.

INTRODUCTION

Water is very essential for human life especially the quality of water is of vital concern for mankind since it is directly linked with human health and welfare. In recent times, demand for freshwater has increased due to population



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growth and intense agricultural activities. The quality of groundwater is the function of its physical and chemical parameters which depend upon the soluble products of weathering, decomposition and the related changes that occur with respect to the space and time [1, 2]. Groundwater, found beneath the Earth's surface in soil pores and rock fractures, makes up about 30% of the world's freshwater resources [3]. Seasonal groundwater samples were analyzed to understand the major ions through which the water circulated [4-6]. Modern technologies such as remote sensing and GIS have become essential in groundwater studies, complementing conventional surveys [7]. Remote sensing provides accurate and cost-effective spatial data, while GIS facilitates the integration and analysis of large datasets. Field studies validate the results, and together, these methods improve our understanding of groundwater systems, especially in hard rock aquifers [8]. Many researchers have studied groundwater quality globally [1, 9–13]. These studies emphasize the role of water quality analysis in understanding the pathways and environments through which water flows [4, 13, 14]. This study investigates groundwater quality in Ulundurpet Taluk, Kallakurichi District, Tamil Nadu, using systematic methods. GIS-based spatial distribution mapping and groundwater quality evaluations for domestic and agricultural use were carried out following methodologies by [15, 16].

Study Area

Ulundurpet is located midway between the main cities of Chennai (previously Madras) and Tiruchirappalli (Trichy), two key metropolitan centres in Tamil Nadu. The physical coordinates of Ulundurpet are roughly 11.69°N latitude and 79.29°E longitude. The topography of Ulundurpet is mainly flat, typical of Tamil Nadu's interior plains. This area is part of the broader Cauvery River basin. The natural vegetation surrounding Ulundurpet mostly comprises dry deciduous woods and scrubland [17]. The location map of the research area is presented in Fig 1.

Geology of the study area

The general geological formation of Ulundurpet Taluk is relatively simple. The majority of the area is covered by metamorphic rocks belonging to the Genesis family. Additionally, there are three major groups of sedimentary rocks from different geological periods, ranging from the oldest Archean formations to recent Miocene-Pliocene sediments and conglomerates. The most common outcrops in the area include Hornblende-Biotite Gneiss, sandstones, and clay. The overall geological sequence of the formations is shown in Fig 2. Structural hills are noted in the western half of the area. The shallow pediments and buried pediments are common in the middle part of the neighbourhood [18]. Coastal areas have older and younger flood plains and also beach landforms in places. The ground slope is mild towards the coast [17]. The primary landform of the study area is mainly the pediment plain complex which covers 82% of the study area. Older flood plains which compose 7.4% of the study area extend across the eastern part of Ulundurpet taluk. The soils of the district are predominantly forest soils and red soil. Alluvial soils are present on the eastern side adjoining the coast. Black soils are confined to low ground in certain areas in Vanur taluk. The geomorphology map of the study area is shown in Fig 3.

MATERIALS AND METHODS

Analysis and Analytical techniques Major elements were analyzed from 36 both surface and subsurface water samples collected during the season at Ulundurpet area, as shown in Fig1. Samples were collected using polythene bottles washed with clear acid and standard procedures [19] were used for analysis parameters such as Temperature, pH, EC (Electrical Conductivity) and TDS (Total Dissolved Solids) were measured in the field using Thermo Orion ion electrode probe Portable kit [20]. (Ca^{2+}), (Mg^{2+}), (HCO_3^-) titrimetric methods. (Na^+), (K^+) determined by using a Flame photometer; (SO_4^{2-}), (PO_4^{3-}), (NO_3^-) determined by using UV Spectrophotometer. The GIS software ArcMap and QGIS were used to generate several thematic maps, including the Geology, Geomorphology and Spatial Interpolation map. Arc-GIS spatial analysis consists of numerous interpolation tools. Inverse Distance Weighted (IDW) is the selected tool for this study. The sample points are weighed during interpolation in the IDW interpolation method.





RESULTS AND DISCUSSIONS

The water quality attribute database was used to generate the spatial variation layers of the major water quality parameters. Based on these spatial variation layers, an integrated water quality map of Ulundurpet Taluk was prepared using GIS software. The minimum, maximum, and average values of the parameters are shown in Fig 4. The results and discussion for the major parameters are as follows:

pH

In most of the studied regions, pH readings fall between 6.5 and 8.5 suggesting excellent water quality. However, relatively higher pH values were detected in several samples. The investigation showed that the pH values in the region vary from 6.87 to 10.71 with an average of 7.88. Additionally, practically all places fall within the appropriate range of 6.5–8.5, as guidelines by the World Health Organization [21]. Fig. 5 shows that pH values are higher in the eastern and southern regions of the research area.

Electrical Conductivity (EC)

The substance has a capacity to transport electric current is known as Electrical Conductivity (EC). The measurement of conductivity is directly associated with the strength of the water [22]. The EC of the cleanest water is 0.05 $\mu\text{S}/\text{cm}$. According to the WHO [21] recommendation, 1400 $\mu\text{S}/\text{cm}$ is the suggested tolerable threshold for EC. In the studied region, few places show extraordinarily high EC concentrations ($>1500 \mu\text{S}/\text{cm}$), but most samples had EC values $< 1000 \mu\text{S}/\text{cm}$. The EC values in the studied region vary from 102 to 3733 $\mu\text{S}/\text{cm}$, with an average of 1097 $\mu\text{S}/\text{cm}$. The spatial distribution map of EC Fig 6 shows that the northern section of the research region has higher EC values.

Total Dissolved Solids (TDS)

Total dissolved solid standards according to the Indian standards are up to 500 mg/L and are a standard for testing the quality of water. In the present study area, TDS values also fluctuated, from 188.025 mg/L to 1927.86 mg/L, with an average value of 772.861 mg/L, showing high levels in several sites. Seven out of all the ten water samples that were collected analyzed more than the recommended TDS levels, indicating probable water pollution with potential consequences. High TDS affects water quality and its use as drinking water, its suitability for specific agricultural and industrial uses, and water taste. The variation of TDS concentrations concerning spatial analysis in the research region has been described in Fig 7 to define areas of high pollution that would help in focused management and control efforts.

Bicarbonate (HCO_3^{2-})

In some cases, bicarbonate is produced by weathering of the silicate and carbonates, bringing in the fact that carbonate minerals are sparingly soluble in pure water [23]. In many areas, water with a high content of bicarbonate and alkalinity is also unwanted. The tabulation of the bicarbonate concentration in the study area is also presented here, ranging from 61mg/L to 445.3mg/L with an average of 193.417 mg/L. The spatial distribution map of bicarbonate in the research region also reveals that the higher concentration of bicarbonate in the northern part of the study area exceeds 200 mg/l. Fig 8 shows the spatial variation of bicarbonate in the study area.

Chloride (Cl^-)

one of the most prevalent anions in groundwater is chloride and its natural waters reveal a wide variety of chloride concentrations [24], which are strongly associated with the water's mineral content. Additionally, chloride enters natural streams through several mechanisms. The WHO standard for tolerable chloride concentrations is fewer than 250 mg/L. In the studied region, chloride concentrations vary from 35.45 mg/L to 859.663 mg/L, with an average value of 173.462 mg/L. The spatial distribution map of chloride, given in Fig 9, shows that the northern section of the research region has a high chloride content ($>250 \text{ mg/L}$).



**Bibishyn et al.,****Phosphate (PO_4)**

Potassium in groundwater is generally lesser due to its lesser mobility. It may be released due to the weathering of mica and orthoclase feldspars. K^+ ions are released during weathering and are generally used in the formation of secondary minerals [25]. In the study area, the concentration of Phosphate ranges from 0.1 mg/l to 12 mg/l with an average concentration of 2.04 mg/l. The spatial distribution map of the study area is shown in Fig10 which indicates the study area shows a low concentration of phosphate.

Sulphate (SO_4)

Hopefully, the study will establish the effects of high sulfate contents on the quality of drinking water by determining its taste and smell. It is found in the groundwater due to the natural dissolution of rocks as noted by [26]. In the study area, sulfate concentrations in groundwater samples range from 1.6mg/l to 15.6mg/l with a mean of 5.96mg/l, but large quantities of sulfur have not been identified more frequently. The spatial distribution of sulfate in the study area is presented in Fig 11 below.

Silica (SiO_2)

Silica (SiO_2) is a naturally occurring chemical in water in a dissolved, colloidal, or particle state. Its occurrence in water is chiefly because of the dissolution of the silicate mineral derived from rocks and soil [27]. (Fig 12) describes the spatial distribution of the silica concentrations in the study area to be within a range of 1.2 mg/L to 220 mg/L, while on average the area tested has a mean silica content of 107.4 mg/L, and the Fig 12 establishes that the middle of the region has a relatively higher silica content from the water samples.

Calcium (Ca^{2+})

The major sources of the element are clay minerals such as aragonite, calcite, dolomite, aluminium feldspars, gypsum, and pyroxenes. According to WHO criteria, the optimal calcium concentration is not more than 75 mg/L, while the admissible concentration does not exceed 200 mg/L. In the study area, calcium concentration in the water sample varies from 16 mg/L to 174 mg/L with an average value of 65.4 mg/L. Fig13 represents the calcium map of the study area, where it is clear that the northeastern part of the study area has a higher concentration of calcium than the southern part.

Magnesium (Mg^{2+})

The main natural source of most rocks is through rock weathering and water dissolution, as mentioned by [28]. The influence from the neighboring rocks, especially dolomite and limestone, may have a reason for the high magnesium content in some samples. The magnesium concentration in the study area shows maximum fall in desirable, and 1% of the water samples showed high Magnesium concentration in the study area. The concentration of magnesium in the study area is between 4.8 mg/l and 62.6 mg/l, with a mean concentration of 25.16 mg/l. The spatial distribution map of magnesium is presented in Fig 14, whereby it is evident that except for a few isolated areas, the study area does not show a high concentration of magnesium.

Sodium (Na^+)

Sodium is a common element found in water, and its concentration is often measured in water quality analysis. The presence of sodium in water can result from various sources, including natural weathering of rocks, industrial discharges, and human activities [29]. The Sodium concentrations were found to range between 7.29 to 367.3 mg/l in the present study with an average of 157.51 mg/l, indicating that 70% of locations were within permissible limit, whereas some samples collected are not permissible > 200. Among those samples in the study area, relatively higher values of sodium are reported. Fig. 15 shows the northern part of the study area contains a higher concentration of sodium, excluding 200 mg/l.

Potassium (K^+)

Potassium is a naturally occurring element commonly found in rocks, minerals, and soils. It can enter water sources through the natural breakdown of rocks and minerals, as well as through the weathering process. The use of





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fertilizers containing potassium can also elevate its levels in water bodies through runoff [30]. Different countries and regions may have specific standards or guidelines for water quality regarding the presence of potassium in both drinking water and surface water. Potassium concentration ranged from 5.5 to 261.4 mg/L with a mean value of 26.658 mg/l in the study area. The acceptable value recommended for potassium is <100. Fig 16 shows that most of the study area falls within a desirable limit except for some locations having concentrations higher than 100 mg/l.

CONCLUSIONS

This study gives a spatial variation of both surface and groundwater quality in Ulundurpet Taluk, Tamil Nadu, India. These differences are mostly caused by the area's geological forms, human actions, and farming methods. The majority of the study area's pH values were found to be within the WHO [21] (2004) suggested range of 6.5 to 8.5, indicating generally satisfactory water quality in terms of acidity and alkalinity. However, there were some places with high pH levels, mostly in the eastern and southern parts of the taluk Fig 5. Electrical Conductivity (EC), a measure of salinity and dissolved ion content, was higher than the 1400 $\mu\text{S}/\text{cm}$ limit set by the WHO in some places. The northern part of the study area had the highest amounts (Figure 6). It was between 188.025 mg/L and 1927.86 mg/L for Total Dissolved Solids (TDS), which is a key indicator of water quality. Notably, about 80% of the water samples had TDS levels higher than the allowed limit of 500 mg/L. This is a sign of widespread pollution and raises worries about the water's suitability for drinking, farming, and industry Fig 7. Bicarbonate, chloride, and sodium levels were much higher in the northern parts of the taluk, as shown by the spatial distribution maps. Some samples even had levels that were too high (Figs. 8, 9, and 15). Calcium, magnesium, and potassium concentrations, though varied, usually stayed within the acceptable ranges across most sample sites (Figs. 13, 14, and 16). Potassium and salt levels in the groundwater were not very high, which means that nutrients were not being loaded too heavily and there weren't many problems related to nutrients in the area (Figs. 10 and 11).

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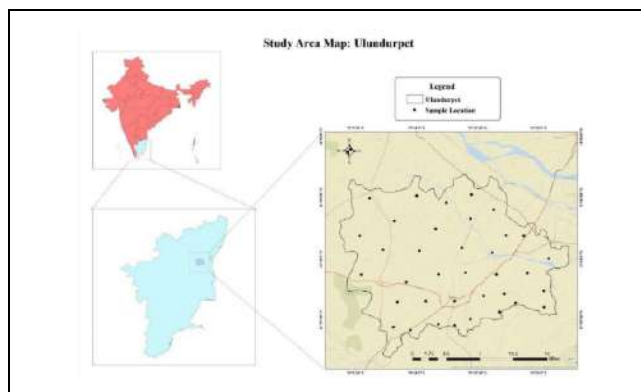


Fig.1: Location Map of the Study area

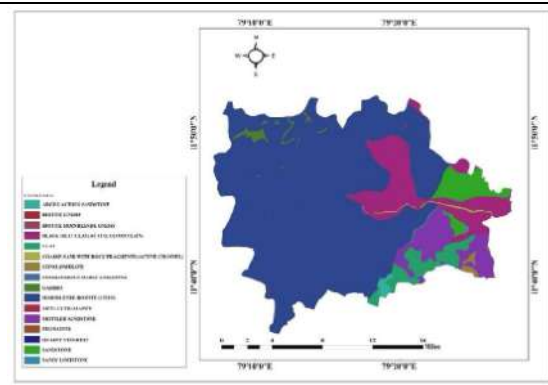


Fig 2: Geology map of the study area

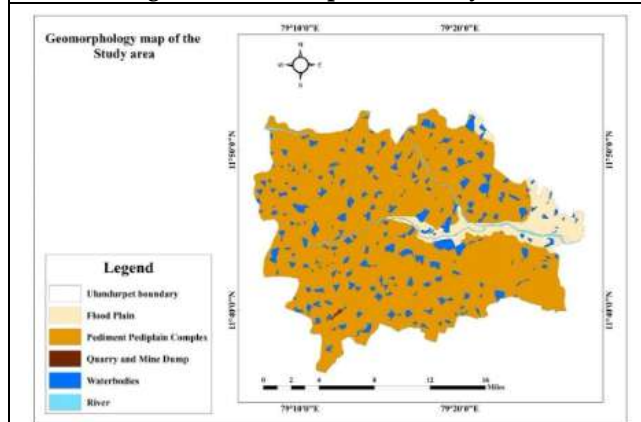


Fig 3: Geomorphology map of the study area

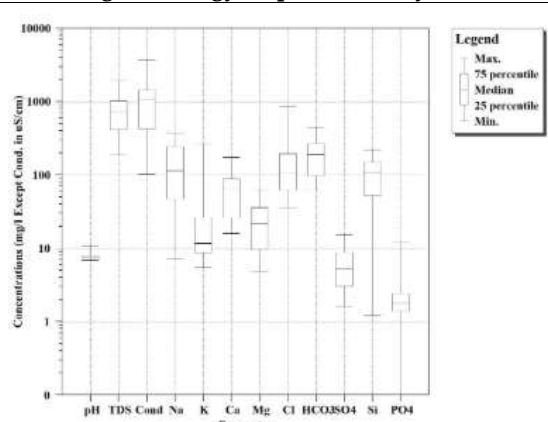


Fig 4: Box plot for Minimum, Maximum and Average of the sample





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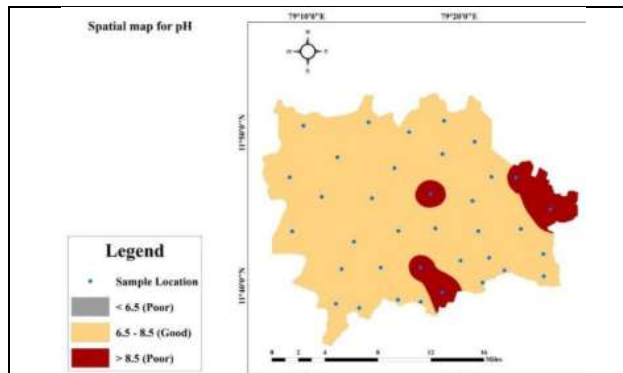


Fig 5: Spatial distribution map for pH

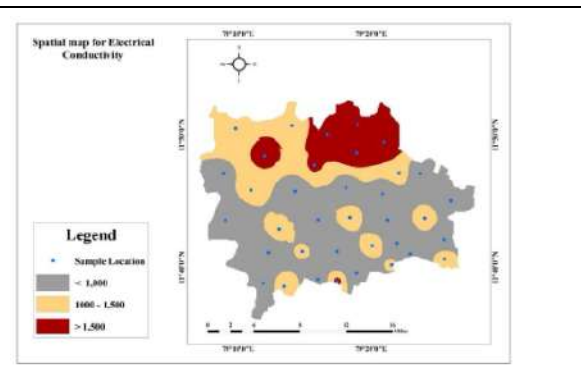


Fig. 6: Spatial distribution map for Electrical Conductivity

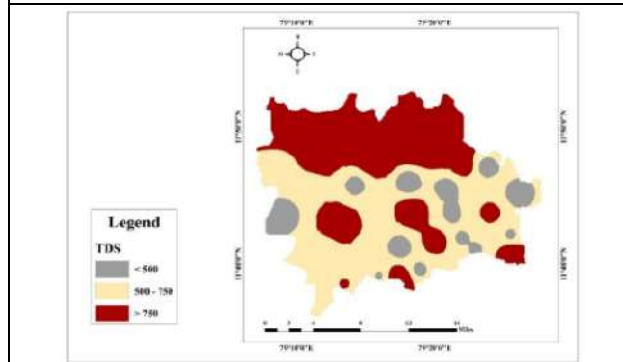


Fig 7: Spatial distribution map for Total Dissolve Solid

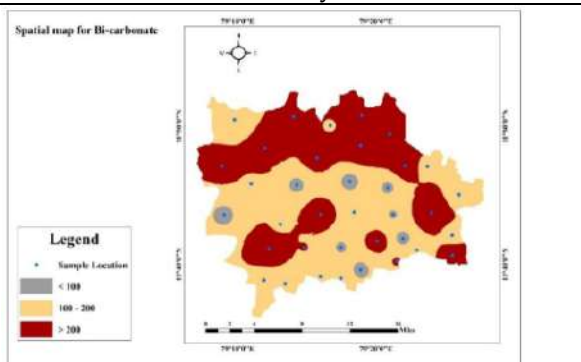


Fig 8: Spatial distribution map for Bi-carbonate

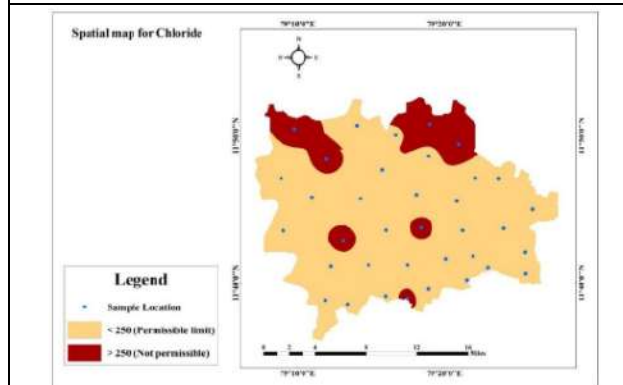


Fig 9: Spatial distribution map for Chloride

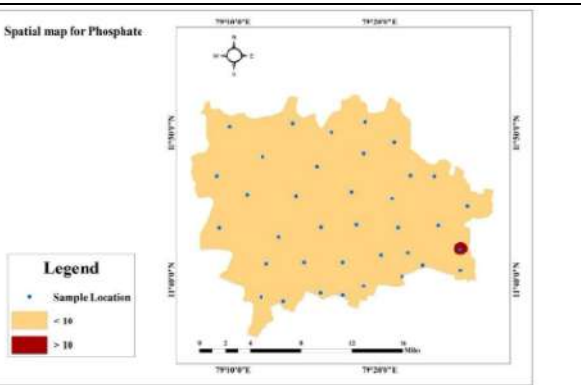


Fig 10: Spatial distribution map for Phosphates





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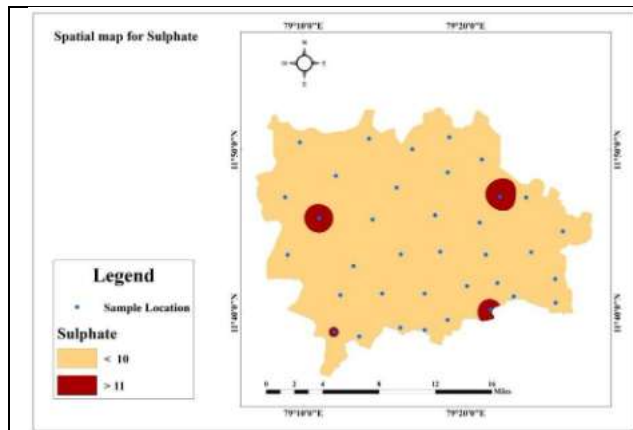


Fig 11: Spatial distribution map for Sulphate

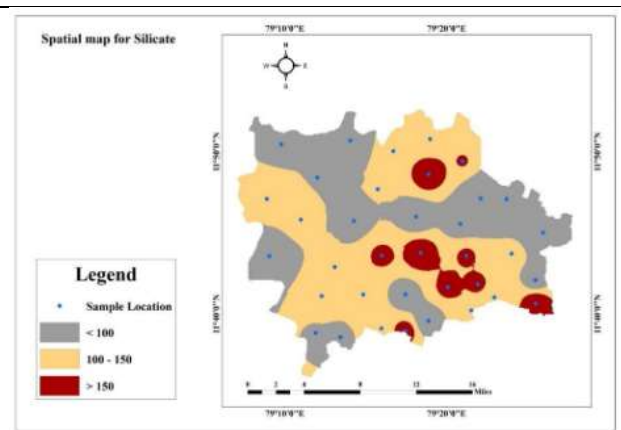


Fig 12: Spatial distribution map for Silicate

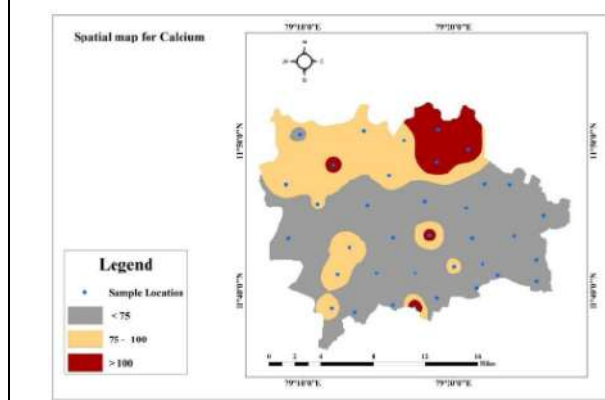


Fig 13: Spatial distribution map for Calcium

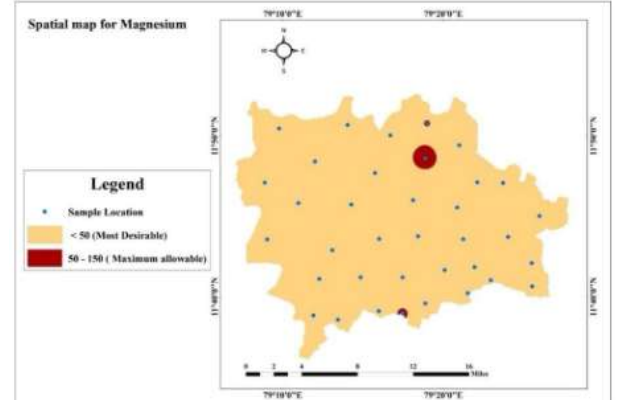


Fig 14: Spatial distribution map for Magnesium

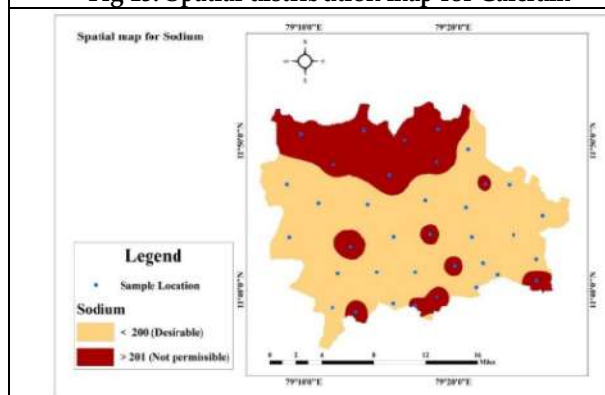


Fig 15: Spatial distribution map for Sodium

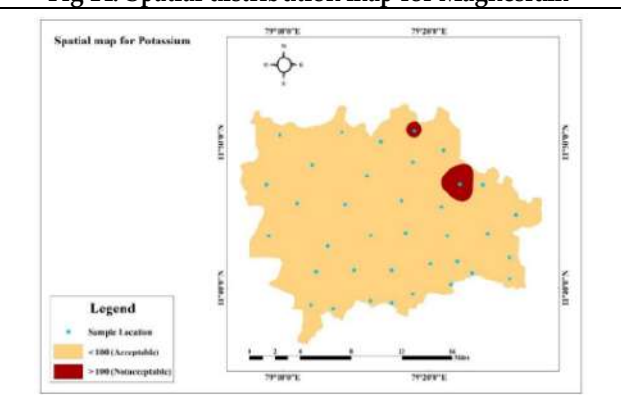


Fig 16: Spatial distribution map for Potassium





RESEARCH ARTICLE

Enhancing Outcome - based Education through NOODLE : A Secure Environment Approach

Alok Roy¹, Somsubhra Gupta^{2*} and Ranjan Kumar Mondal³

¹Research Scholar, School of Computer Science, Swami Vivekananda University, Barrackpore, West Bengal, India.

²Professor, Department of Computer Science and Engineering, Swami Vivekananda University, Barrackpore, West Bengal, India.

³Assistant Professor, Department of Computer Science and Engineering, Swami Vivekananda University, Barrackpore, West Bengal, India.

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*Address for Correspondence

Somsubhra Gupta

Professor, Department of Computer Science and Engineering,
Swami Vivekananda University, Barrackpore, West Bengal, India.

E.Mail: gsomsubhra@gmail.com



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ABSTRACT

Outcome-Based Education (OBE) has emerged as a pedagogical approach that prioritizes predefined learning outcomes, focusing on the measurable knowledge, skills, and abilities students should acquire. This paper explores the integration of NOODLE (Navigating, Organizing, Orienting, Designing, Learning, and Evaluating) devices to augment the implementation of OBE principles in educational settings. NOODLE devices provide a secure and versatile environment for learners, fostering a dynamic and interactive learning experience. The study investigates the impact of NOODLE devices on student engagement, personalized learning, and the attainment of predetermined educational outcomes. A secure learning environment is crucial in today's digital landscape, and NOODLE devices offer enhanced data protection measures to safeguard sensitive educational information. By leveraging advanced security features, educators can create a trustworthy and protected space for students to explore, collaborate, and achieve educational objectives. The research methodology involves a comprehensive analysis of educational institutions that have adopted NOODLE devices, assessing the effectiveness of this integration in aligning with OBE principles. The findings highlight the positive correlation between NOODLE-enabled secure environments and improved student outcomes, showcasing the potential for widespread implementation in educational institutions. In conclusion, this paper advocates for the adoption of NOODLE devices as a catalyst for advancing Outcome-Based Education. By providing a secure and adaptable platform, NOODLE devices empower educators to design and deliver personalized learning experiences that optimize the attainment of predetermined educational outcomes. The



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integration of NOODLE devices marks a significant step towards a future where technology enhances education in a secure and outcome-driven manner.

Keywords: Outcome-Based Education (OBE), Secure learning environment, Educational technology, Digital landscape, Academic assessment

INTRODUCTION

In the contemporary educational landscape, the transformative concept of Outcome-Based Education (OBE) has emerged as a guiding principle, emphasizing the measurable attainment of specific learning outcomes. As educators navigate the complexities of fostering meaningful student learning experiences, innovative technologies play a pivotal role in shaping the future of pedagogy. This paper delves into the fusion of Outcome-Based Education with the integration of NOODLE (New-normal Object-Oriented Dynamic Learning Environment) devices, presenting a novel approach to educational technology designed to create dynamic and interactive learning environments. NOODLE devices, with their acronym standing for New-normal Object-Oriented Dynamic Learning Environment, represent a multifaceted tool aimed at redefining the traditional boundaries of education. This study explores the potential of NOODLE devices to serve as catalysts for pedagogical innovation within a secure learning environment. In the wake of the new normal, characterized by increased reliance on digital platforms for education, the significance of secure learning environments has never been more pronounced. Thus, this research aims to unravel the intricate interplay between Outcome-Based Education and NOODLE devices, emphasizing the pivotal role of a secure technological framework in shaping contemporary educational practices. As we navigate the complexities of educational transformation, the integration of NOODLE devices offers a promising avenue for educators to tailor learning experiences, ensuring alignment with predefined educational objectives. This paper aims to scrutinize the synergies between Outcome-Based Education and NOODLE devices, shedding light on their potential to redefine the educational landscape while underscoring the critical importance of maintaining a secure environment in the ever-evolving realm of digital learning.

LITERATURE REVIEW

Securing mobile data

Securing mobile data involves employing various strategies and technologies to protect the confidentiality, integrity, and availability of data stored on or transmitted by mobile devices. Here are several ways mobile data can be secured

Encryption: Encrypting data ensures that even if it's intercepted, it cannot be understood without the encryption key. This includes encrypting data at rest (stored on the device) and in transit (during transmission over networks). Technologies like SSL/TLS for network traffic and device encryption (such as File-based Encryption on Android or FileVault on iOS) are commonly used.

Strong Authentication: Implementing strong authentication mechanisms such as passwords, PINs, biometrics (fingerprint, facial recognition), or two-factor authentication (2FA) adds an extra layer of security to access mobile devices and sensitive data.

Mobile Device Management (MDM): MDM solutions enable organizations to remotely manage and enforce security policies on mobile devices. They can enforce encryption, remotely wipe data in case of loss or theft, and ensure devices are up-to-date with security patches.





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Mobile Application Management (MAM): MAM solutions focus on securing and managing the applications installed on mobile devices. They can enforce policies like app whitelisting, containerization (keeping corporate and personal data separate), and app-level encryption.

Secure Development Practices: Developers should follow secure coding practices when building mobile applications to prevent vulnerabilities like buffer overflows, injection attacks, and insecure data storage. Regular security testing, code reviews, and adherence to security standards (such as OWASP Mobile Top 10) are crucial.

Remote Wipe and Lock: In case a device is lost or stolen, the ability to remotely wipe or lock the device helps prevent unauthorized access to sensitive data.

Network Security: Using Virtual Private Networks (VPNs) can secure data transmitted over public Wi-Fi networks by encrypting traffic between the device and the VPN server. Additionally, firewalls and intrusion detection/prevention systems can help protect against network-based attacks.

Regular Updates: Keeping mobile operating systems, applications, and security software up-to-date is critical for patching vulnerabilities and ensuring protection against emerging threats.

Data Loss Prevention (DLP): Implementing DLP solutions can help monitor and control the transfer of sensitive data outside the organization's network, preventing accidental or malicious leaks.

User Education and Awareness: Educating users about security best practices, such as avoiding suspicious links and downloads, using strong passwords, and being cautious about granting app permissions, can significantly reduce the risk of data breaches.

Securing mobile device

Securing a mobile device involves implementing various measures to protect it from unauthorized access, data breaches, malware, and other security threats. Here are several ways to ensure the security of a mobile device:

Screen Lock: Enabling a strong screen lock mechanism such as PIN, password, pattern, or biometric authentication (fingerprint, facial recognition) prevents unauthorized access to the device.

Device Encryption: Activating device encryption ensures that data stored on the device is protected even if the device is lost or stolen. Most modern mobile operating systems offer built-in encryption features.

Secure Authentication: Using strong and unique passwords for device accounts (such as Google account on Android or Apple ID on iOS) adds an extra layer of security. Enabling two-factor authentication (2FA) for these accounts enhances security further.

Regular Software Updates: Keeping the device's operating system, applications, and security software up-to-date with the latest patches and security updates helps protect against known vulnerabilities and exploits.

App Source Verification: Downloading apps only from official app stores (such as Google Play Store for Android or Apple App Store for iOS) reduces the risk of installing malicious or compromised applications.

App Permissions: Reviewing and managing app permissions to limit the access apps have to sensitive data and device features such as location, camera, microphone, and contacts.

Remote Tracking and Wiping: Enabling remote tracking and wiping features allows users to locate their device if it's lost or stolen and remotely erase data to prevent unauthorized access.



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Anti-Malware Software: Installing reputable anti-malware or mobile security applications can help detect and remove malicious software (malware) and protect against other security threats.

Network Security: Avoiding connecting to unsecured Wi-Fi networks and using Virtual Private Network (VPN) services when accessing public Wi-Fi networks to encrypt data transmissions and protect against network-based attacks.

Secure Backup: Regularly backing up device data to a secure cloud storage service or local storage ensures that important information can be recovered in case of device loss, damage, or data corruption.

Physical Security: Being vigilant about the physical security of the device, such as not leaving it unattended in public places and using protective cases or screen covers to prevent damage.

User Awareness and Education: Educating users about common security threats, best practices for securing their devices, and how to recognize and avoid phishing attempts and other scams.

By implementing these security measures and staying vigilant, users can significantly reduce the risk of security breaches and protect their mobile devices and the data stored on them.

Objective

The primary objective of this study is to investigate and analyze the implications and effectiveness of integrating the New-normal Object-Oriented Dynamic Learning Environment (NOODLE) device into the framework of Outcome-Based Education (OBE), with a specific focus on ensuring a secure learning environment. The study aims to achieve the following key objectives

Assess the Impact on Educational Outcomes: Evaluate how the incorporation of NOODLE devices influences the achievement of predefined learning outcomes in an Outcome-Based Education setting. Analyze whether the use of NOODLE enhances students' ability to attain the specified knowledge, skills, and competencies.

Examine Pedagogical Innovations: Explore the pedagogical innovations facilitated by NOODLE devices within the context of OBE. Investigate how these devices contribute to interactive and dynamic learning experiences, fostering a student-centric approach aligned with OBE principles.

Evaluate Student Engagement and Personalized Learning: Assess the level of student engagement and the effectiveness of personalized learning experiences facilitated by NOODLE devices. Investigate how customization features contribute to individualized learning paths, thereby enhancing the overall educational experience.

Analyze the Security Features of NOODLE Devices: Examine the security measures embedded in NOODLE devices to ensure a safe and protected learning environment. Evaluate the effectiveness of these security features in safeguarding sensitive educational information and maintaining privacy in the digital realm.

Gap Analysis

The integration of the New-normal Object-Oriented Dynamic Learning Environment (NOODLE) devices within the framework of Outcome-Based Education (OBE) presents a promising avenue for educational transformation. However, a comprehensive gap analysis reveals several areas that merit further attention and investigation

Limited Empirical Research: There is a noticeable dearth of empirical research specifically focused on the integration of NOODLE devices within Outcome-Based Education. Existing literature primarily offers conceptual frameworks and theoretical perspectives, lacking in-depth empirical studies that assess the actual impact of NOODLE devices on educational outcomes in OBE settings.



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Security Efficacy and Privacy Concerns: The security features of NOODLE devices, essential for maintaining a secure learning environment, require more comprehensive scrutiny. There is a lack of detailed examination of the efficacy of these security measures, and concerns about data privacy in the context of OBE implementation have not been thoroughly addressed.

Pedagogical Alignment with Outcome-Based Education: Although the potential for pedagogical innovation is often cited in theoretical discussions, there is a need for a deeper exploration of how NOODLE devices align with the principles of Outcome-Based Education. A gap exists in understanding the specific pedagogical strategies employed through NOODLE devices to support the achievement of predefined learning outcomes.

Integration Challenges and Solutions: The literature lacks an exhaustive exploration of the challenges encountered during the integration of NOODLE devices into educational environments practicing OBE. Existing studies often fall short in providing practical solutions and strategies for overcoming these challenges, hindering the seamless adoption of NOODLE devices in OBE settings.

Long-Term Impact and Sustainability: The sustainability and long-term impact of incorporating NOODLE devices into OBE remain uncertain. There is a gap in research that investigates the continued effectiveness of these devices over time and assesses their sustainability in evolving educational landscapes.

METHODOLOGICAL ASPECTS

Proposed Circuit diagram of NOODLE is similar to the other general mobile device, but our proposing research work is expected to do education more effective for the students conducting private network settings also helpful and it is low cost. That device is expected to facilitate automatic recording facility of online teaching and learning session and student cannot stop their audio and camera throughout the session. This automatic recording, audio and camera activation is supervisory password protected. Also, social applications and parallel activities can be restricted for this teaching learning device, then data usage is expected to be low, it can control the network cost. This resolution may be adjuvant for worldwide students along impoverished and unconsidered will be helpful to get rid of e-learning.

Suggested User Interface design for NOODLE (Figure 1)

Device characteristics

The following are taken into considerate

- NOODLE primarily focuses on virtual learning, with the option for parallel activities such as mobile usage. While the use of SIM cards is mandatory, measures have been implemented to restrict calls or convert them to messages within defined boundaries, particularly during online examinations to minimize distractions.
- NOODLE operates primarily through WiFi connectivity and is designed to seamlessly integrate with a distributed system framework, allowing devices to actively participate in the network infrastructure.
- It is very secure device all the way software and hardware. Data and apps are protected from hackers and viruses. Device is secure from snatching, missing or stealing, because device automatically give the signal to the nearest location which we pre entered inside its database.
- It includes a user interface for web-based video conferencing, similar to platforms such as Skype and Google Duo.
- This has the capability to integrate virtual learning and conference applications such as GMeet, MTeam, GotoMeeting, and CISCO Webex seamlessly.
- Moreover, it can also support educational digital learning applications such as Screencasting, Narration over PowerPoint, Blendspace, and TedEx, facilitating a diverse range of pedagogical approaches.
- The remainder of the content will be accessible via the supplied web browser.
- This platform offers the ability to selectively install apps, with a more tailored approach to installation and restrictions. Suggested schematic design for NOODLE (Figure 2).



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RESULT ANALYSIS

The prototype of the aforementioned device NOODLE has been created and applied for intellectual property claim (A- 202331012519 dated 23/02/2023). Because of this the implementation and testing of the proposed device has been made through emulator the sample case result of which has been provided below. Its impact on teaching learning can be summarized as follows

- It serves as a specialized digital device solely designed for educational use, with optional sharing features.
- This facilitates learning at any time and from anywhere, contingent upon a single performance indicator: internet bandwidth.
- Additionally, it facilitates Just-In-Time (JIT) learning by integrating virtual learning tools and platforms directly into the device.
- The comprehensive implementation is anticipated to yield further compelling outcomes.

It has been noted that a significant proportion of students utilizing the emulator have achieved favourable outcomes, although outcomes do not always directly correlate with knowledge transfer. Conversely, those who opted out of digital methods in favour of manual modes (the bottom three entries) showed negligible knowledge transfer through physical means.

Below, the features outlined in Section 1 Introduction's list of objectives are reaffirmed

- A technology-driven virtual learning device called NOODLE is essential for promoting equity in outcome-based education, particularly in mobile learning environments, catering to students and professionals alike.
- It ensures financial inclusivity by offering a cost-effective solution, thereby bridging the digital divide.
- The proposed solution not only facilitates the transition to digital education but also supports Outcome-Based Education (OBE) through its dematerialization framework.
- It boasts portability, durability, and affordability.
- The device allows integration with various virtual learning platforms (e.g., GMeet, MSTeam, ZOOM) and apps (e.g., Screencasting, Blendspace, Tedex) for nonprofit educational purposes.
- This innovative device architecture is currently in development and addresses the evolving needs of post-pandemic virtual learning.
- The circuit design of this device is tailored to meet the specific demands of virtual education post-pandemic, with no prior integrated device of its kind reported.
- It enforces restrictions on unauthorized parallel background activities, ensuring a secure learning environment.

The effectiveness of this solution can only be fully determined through a comprehensive long-term evaluation and assessment of test cases, as outlined above. However, given its distinctive features, it is expected to show immediate effectiveness. Additionally, the development of rubrics or formulas for measuring knowledge transfer through NOODLE (similar to menti-meter) could be explored further after analyzing longitudinal data.

CONCLUSION

In conclusion, the adoption of the NOODLE framework presents a promising avenue for enhancing Outcome-Based Education (OBE) by fostering a secure environment approach. By integrating robust security measures within educational practices, institutions can ensure the confidentiality, integrity, and availability of educational data while promoting effective learning outcomes. Embracing NOODLE's principles empowers educators and stakeholders to cultivate a safe and supportive educational ecosystem, ultimately facilitating the holistic development of learners in today's digital age. Through the implementation of this secure environment approach, educational institutions can further optimize their OBE strategies, nurturing a dynamic learning environment conducive to student success and academic excellence. This innovative, interactive, and cost-effective virtual learning device named NOODLE is designed to promote equity in outcome-based education, particularly in the realm of virtual learning. By introducing a personal cloud environment, this solution caters to students and professionals in academia and industry alike. The proposed approach extends the dematerialization framework, facilitating the seamless relocation and distribution of





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educational resources while aligning with Outcome-Based Education (OBE) principles. Exploring the potential of personal cloud environments necessitates research into novel appliances capable of collecting environmental data to enhance practicality and engagement. While smartphones and tablets are commonly used for mobile cloud learning, their limitations, such as small screens, low processing speeds, and memory constraints, underscore the importance of developing bespoke devices tailored to learners' specific needs. This new device aims to address these shortcomings and empower learners to gather information effectively to enhance their learning experiences. This paper delves into recent advancements and forthcoming innovations in engineering, introducing unique concepts aimed at fostering educational achievement in personal cloud environments. These initiatives are envisioned to be cost-effective, collaborative, and supportive for students worldwide, including those in underserved and marginalized communities.

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Figure 1: Suggested User Interface design for NOODLE

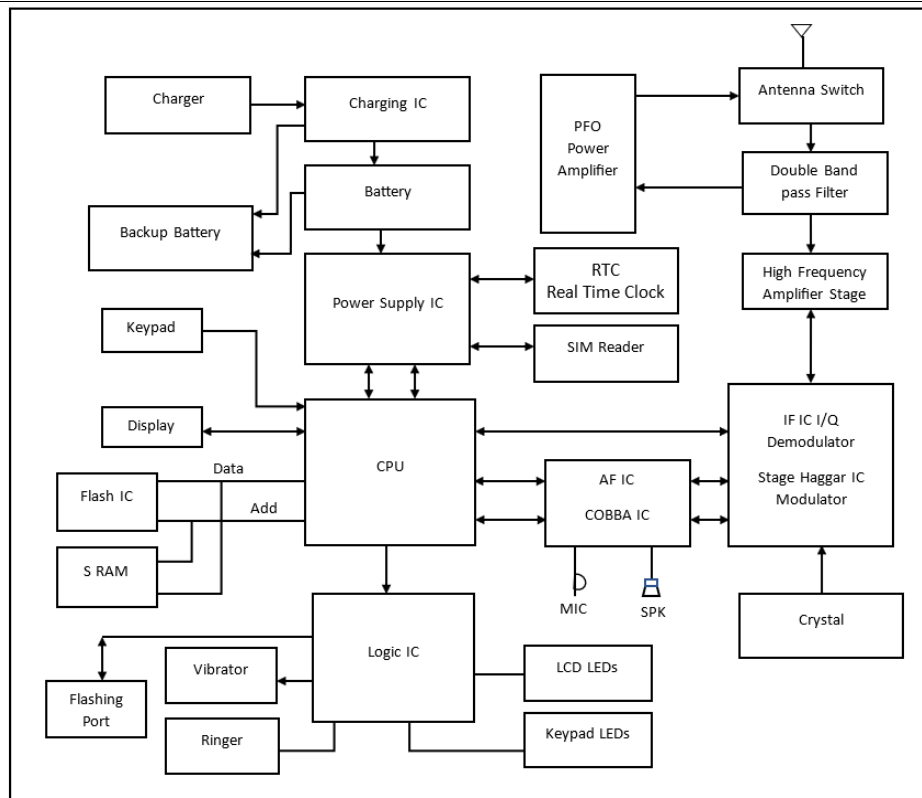


Figure 2: Suggested schematic design for NOODLE





RESEARCH ARTICLE

Correlation Study Assessing the Involvement of Lumbo Sacral Angle in Patients with Low Back Pain

Ujwal Bhattacharya^{1*}, Prasanta Kalita², Diganta A Phukan³ and Sanjeev Handique⁴

¹Profesor cum Dean, Department of Physiotherapy, Pratiksha Institute of Allied Health Sciences, Panikhiati, (Affiliated to Srimanta Sankaradeva University of Health Sciences, Bhangagarh), Guwahati, Assam, India.

²Assistant Profesor, Department of Radiology, Pratiksha Institute of Allied Health Sciences, Panikhiati, (Affiliated to Srimanta Sankaradeva University of Health Sciences, Bhangagarh), Guwahati, Assam, India.

³Director, Coras Hospital by Pratiksha, Borbari, Guwahati, Assam, India.

⁴Consultant, Coras Hospital by Pratiksha, Borbari, Guwahati, Assam, India.

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*Address for Correspondence

Ujwal Bhattacharya

Profesor cum Dean,

Department of Physiotherapy,

Pratiksha Institute of Allied Health Sciences, Panikhiati,

(Affiliated to Srimanta Sankaradeva University of Health Sciences, Bhangagarh),

Guwahati, Assam, India.

E.Mail: ujwalbhattacha@gmail.com



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ABSTRACT

The neck, upper back, and lower back regions of the human spine all have slight curvature. Numerous techniques have been employed to quantify the lordotic curve where it covers software techniques, flexible rulers, radiography, and goniometry. Using the proper landmarks, lines for measuring angles were drawn on the radiography film with a sharp knife and a transparent ruler that was 30 cm long. Although Low back pain is a common medical complain causing disability to the patient but the correlation of Low back pain with Lumbo sacral angle is hardly established anywhere.

Keywords: lordotic, techniques, spine. Lumbo Sacral Angle , Low Back Pain

INTRODUCTION

The neck, upper back, and lower back regions of the human spine all have slight curvature. The spine has two different kinds of curves: kyphotic (upper back and sacrum) and lordotic (neck, lower back)[1]. They support the weight of the head, assist the body in absorbing shock, and line the head over pelvis, move and bend freely, and





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stabilize and retain its structure[1, 2]. There is a natural lordotic curve in the body, which is normal for humans. However, if the curve bends excessively inward, it is referred to as lordosis or swayback. Lordosis typically affect the neck and lower back regions. Exaggeration of lordotic curve may lead to excess pressure on the vertebrae's, causing pain and discomfort[1,3]. If severe and untreated, it may impair movement. The severity of the curvature and the person's cause of acquiring lordosis determine how the condition is treated [2]. If the patient bends forward and the lower back curve reverses itself, there is really little reason for medical worry. With regular exercise and physical therapy, the patient may most likely control their condition. However, if the curve doesn't change as the patient bends forward, they should consult a healthcare professional. As they pull themselves up into standing positions before taking their first steps, children undergo lordosis during the first year of life in response to novel biomechanical pressures that affect the formation of the vertebrae⁴. Nonetheless, new studies indicate that 60% of human fetuses exhibit lordosis in the lumbosacral area. This implies that there might be a genetic component to morphology. Lumbar lordosis continues to develop as a newborn begins to stand, often between the ages of 12 and 18 months, until spinal growth, typically between the ages of 13 and 18. Youngsters who never sit up straight experience lumbar lordosis to the same extent and at the same time as other kids. Lumbar lordosis is delayed in its development by growth retardation.

Numerous techniques have been employed to quantify the lordotic curve where it covers software techniques, flexible rulers, radiography, and goniometry. Among these techniques, radiography In spite of the fact that a prospective study using normal subjects would have been ideal, a retrospective method was adopted

1. The patient should not be irradiated, especially if she is in reproductive age[9].
2. Despite some of the radiographs studied in the retrospective approach belonging to subjects with back complaints, the degree of normal lumbar lordosis was not significantly affected by low back pain without radiographically demonstrable vertebral pathology[1,2,7].
3. As a consequence of the prospective method, a major disadvantage is that it relies too much on the history of "absence of low back complaint" in choosing "normal" subjects, without examining the patient's medical history, physical, neurological, or orthopedic conditions. As a result some patient diagnosed with lumbosacral pathology are excluded from the study after being exposed to X-Rays.
4. The request form, every radiograph, and occasionally the radiological report. The patient's name, age, sex, address, and other clinical details were included in the request form and was evaluated.

Normal criteria were

1. The person had five sacral and five lumbar vertebrae, which was a requirement for normalcy.
2. A gradual rise in vertebral height from L1 to L5, or a stable height.
3. A lordotic curve that is anteriorly convex and has a sacral concavity.
4. A smooth curving line is formed by the posterior edges of the vertebral bodies. The lower vertebra's superior border, however, frequently bends off of this line[4,8,9].
5. Intervertebral discs, which thicken from L1 to L5, fill the corticated endplates of the vertebral bodies. The front vertical height of the wedge-shaped L5/S1 disc is greater than the posterior, despite its relative narrowness.
6. No congenital anomaly or disease-related radiological evidence in the lumbosacral spine[3,10].

Excusion criteria includes Patients under 40 years of age or those whose age and/or sex were not documented were excluded based on these criteria. Furthermore, low quality radiographs, radiographs displaying any indication of illness or congenital anomaly, and non-indigenous patients at Pratiksha Hospital. The LSA was established between a horizontal line and a line that crosses the plane of S1's superior margin. Each radiograph was mounted on a viewing screen with the proper lighting to determine this. Using the proper landmarks, lines for measuring angles were drawn on the radiography film with a sharp knife and a transparent ruler that was 30 cm long. A protector was used to measure the lumbosacral angle. The author took all measurements in order to eliminate inter-observer error. X-Ray LS spine lateral view with LSA angle (Figure 1).





MATERIALS AND METHODS

60 patients between the age group 40-70yrs with low back pain who has reported to the Orthopedist at Pratiksha Hospital for consultation were advised for X-ray examination. The examination was done to determine the diagnosis of lumbar lordosis where Hyper and Hypo lordosis is measured through LSA angle determination. The LSA was measured from lateral lumbosacral spine radiographs, taken for 30 patients of all genders (15 males and 15 females) between the ages of 40 years to 70 years. Next 30 normal persons were evaluated who don't have backache with any existing disease. The data is recorded the radiographs were taken from Pratiksha Hospital, Guwahati. Study center typically acquire lateral lumbosacral radiographs while the patient is in recumbent position.

RESULTS AND DISCUSSION

Gender wise assessment of Lumbo Sacral angle in Male (Table 1)

Shows Graphical distribution of LSA in Male (Figure 2)

Gender wise assessment of Lumbo Sacral angle in Female (Table 2)

Shows Graphical distribution of LSA in Female (Figure 3)

Overall Analysis of Difference in Lumbo Sacral Angle between Control and Experimental Group (Table 3).

Graphical distribution of LSA between Control and Experimental group (Figure 4)

Interpretation: Our study involves 60 subjects that are 30 with low back pain and 30 normal individuals. The mean age for control group was found to be 54 years and for experimental group, the mean age was found to be 48.6 years. There are no statistically significant differences in the subjects' demographic information that we could find. The statistical research revealed that the Lumbo sacral angle of males and females differs significantly. -0.002 and ≤ 0.01 are the P values. Additionally, we discovered a strong correlation (p value ≤ 0.01) between Lumbo sacral angle and low back discomfort in both groups.

DISCUSSION

Lumbo sacral angle is one of the most vital landmarks to determine the involvement of Lumbo sacral spine in the pathology of any spinal disorders. Although Low back pain is a common medical complain causing disability to the patient but the correlation of Low back pain with Lumbo sacral angle is hardly established anywhere[1,5]. There has been multiple studies correlating Lumbar Lordosis angle and Sacral Inclination with Lower back pain. In this present study the primary objective is to determine whether there is an alternation of Lumbo Sacral angle in Low back pain and based on the statistical analysis showing variation in both male and females it can be well established that in patient with Low back pain the LS angle is altered from Table 1 and Table 2. In Male the t test value 3.369 (with p value 0.002) which shows that there is a significant difference between normal individuals and the symptomatic patients. Similarly for female also there is a significant difference with t test value -11.213 (with p value <0.01). So the finding of our study is in support of the study by Janamiri *et al*[6] reported a significantly decreased lumbar lordosis in the CLBP patients. The overall analysis was done to full fill the 2nd objective of the study, although multiple studies in the past were done Gundal Funda Nakipoglu *et al*[4], Ghasemi *et al*[5] which is suggestive of no significant correlation between Vertical Sacral Curvature with Lumbar Disc Degeneration or Low Back Pain but the findings of our study is supportive of the fact that there is a difference between Control and Experimental group with t value -7.965 with p value <0.01 . The study findings are indicative of the difference in Lumbo sacral angle between Group A and Group B. Hence we can state that the Lumbo sacral angle increases in patients with low back pain showing an alteration of biomechanics in the lumbo sacral junction that is associated with any pathology[4,5,6].





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CONCLUSION

In this multidisciplinary investigation, 30 patients with low back pain and 30 healthy participants had their lateral Lumbo sacral radiographs of the spine used to calculate the Lumbo sacral angle. Based on the findings, we discovered a statistically significant association between low back discomfort and the Lumbo sacral angle.

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Conflict of Interest

None.

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Ethics Statement

None.

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Table 1: Gender wise assessment of Lumbo Sacral angle in Male

Group	Mean ± Stddiv	t test value	P Value
Control	29.93±6.53	-3.369	0.002
Experiment	36.60±4.07		





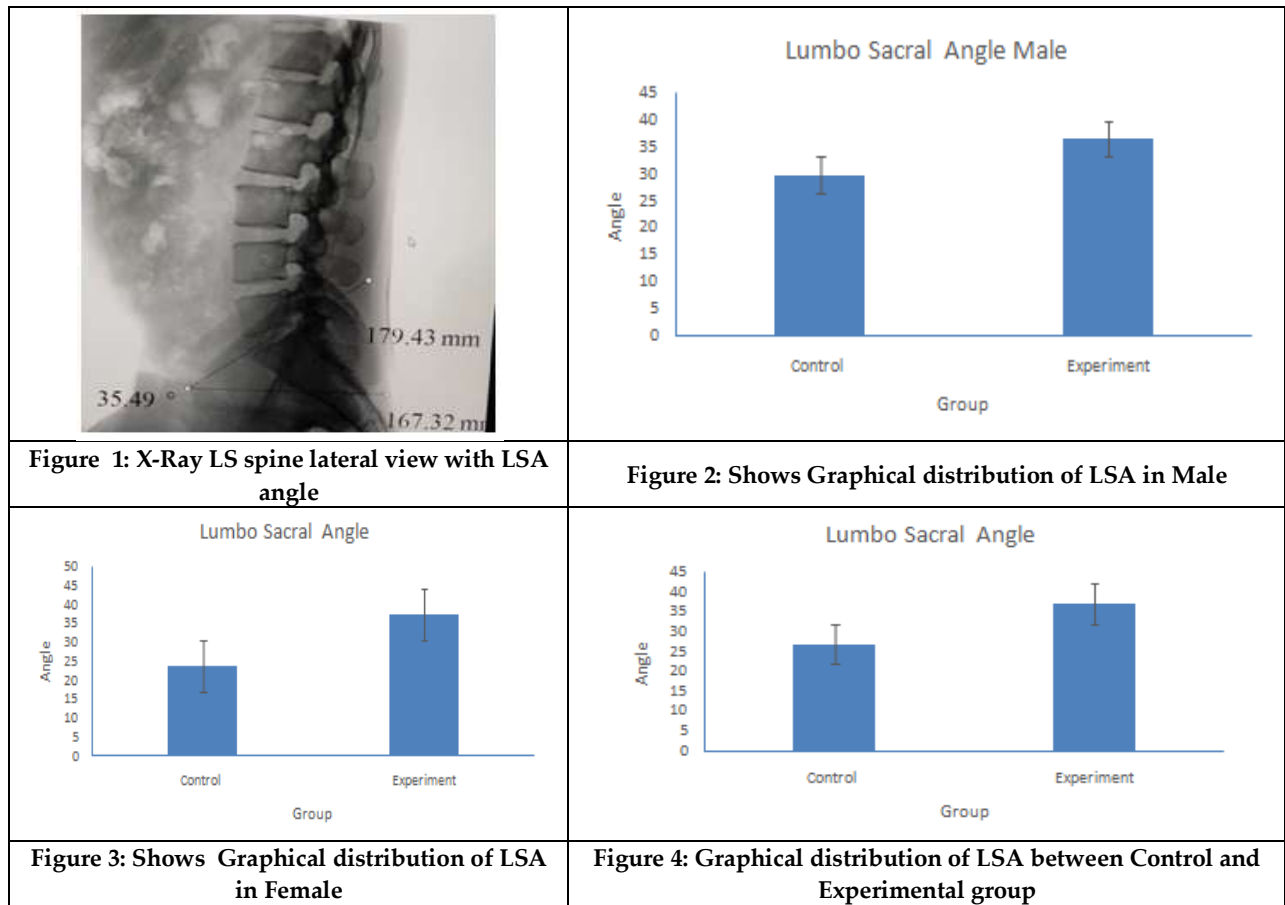
Ujwal Bhattacharya *et al.*,

Table 2: Gender wise assessment of Lumbo Sacral angle in Female

Group	Mean± Stddiv	t test value	P Value
Control	23.87±3.58	-11.213	<0.01
Experiment	37.53±3.067		

Table 3: Overall Analysis of Difference in Lumbo Sacral Angle between Control and Experimental Group.

Group	Mean ±Stddiv	t test value	P Value
Control	26.89±6.021	-7.965	<0.01
Experiment	37.06±3.57		





RESEARCH ARTICLE

Docking Study of Ursodeoxycholic Acid with ALP and GPBAR-1 : A Potential Lead Molecule for Hepatotoxicity Management

Gomathi Sivagnanam¹, Jagadish Krishnan¹, NirmalaDevi Sethuraman² and Senbagam Madhavan^{3*}

¹Ph.D Research Scholar, Department of Biochemistry and Biotechnology, Annamalai University, Annamalai Nagar, Chidambaram, Tamil Nadu, India.

²Assistant Professor, Department of Biochemistry, Annai Violet Arts and Science College, Ambattur, (Affiliated to University of Madras), Chennai, Tamil Nadu, India.

³Assistant Professor, Department of Biochemistry and Biotechnology, Annamalai University, Annamalai Nagar, Chidambaram, Tamil Nadu, India.

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*Address for Correspondence

Senbagam Madhavan

Assistant Professor,

Department of Biochemistry and Biotechnology,

Annamalai University,

Annamalai Nagar, Chidambaram,

Tamil Nadu, India.

E.Mail: shenbagaUDCA@gmail.com



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ABSTRACT

The liver's central role is metabolism, detoxification and maintaining homeostasis in the body. Liver dysfunction can significantly disrupt these processes, leading to a wide range of health issues. The liver functions associated enzymes including Alkaline Phosphatase and G-protein-coupled bile acid receptor-1 are the key markers of liver disorders. In the present study, Ursodeoxycholic acid which is a bile acid was docked separately with Alkaline Phosphatase (1ANI) and G-protein-coupled bile acid receptor-1(7CFN) through blind docking method by AutoDockVina(version 1.1.2) with CB Dock2 server. The docking results showed that Ursodeoxycholic acid has higher binding efficiency with G-protein-coupled bile acid receptor-1 by exhibiting -9.1 Kcal/mol binding energy with 3 hydrogen bonds in the VAL106, HIS107 and ARG110. It also showed 1 Pi-Sigma interaction in PHE54 and 1 Alkyl interaction in ALA229. It showed -6.9 Kcal/mol binding energy with 3 hydrogen bonds formation in the GLN291, ASN289 and VAL268 of Alkaline Phosphatase. From the results, it was identified that Ursodeoxycholic acid is a lead molecule for the researches related to the hepatotoxicity. Hence, through *in vitro* and *in vivo* research on Ursodeoxycholic acid in future may help to develop an effective drug against hepatotoxicity.

Keywords: UDCA, Alkaline phosphate, G-protein coupled bile acid receptor-1, hepatotoxicity, AutoDock.



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INTRODUCTION

The frequent discontinuation of drugs due to sudden liver injury underscores the unique and vulnerable nature of hepatic tissue. Its intricate network of vascular structures, in addition to its vital roles in secretion, synthesis, and metabolic functions, render it more prone to drug-induced injury than any other organ (Kiy *et al.*, 2024). The liver is exposed to injurious agents, including drugs, environmental toxins, and oxidative stress, due to its close proximity to the gastrointestinal system. In cholestatic liver disease, the accumulation of bile acids may induce apoptosis of liver cells by alterations in cell membrane that activate the apoptotic pathways (Fiorucci *et al.*, 2021). Further aggravation of this kind of cellular injury, by the activation of Kupffer cells and infiltration of neutrophils, involves the release of reactive oxygen species (ROS) and pro-inflammatory mediators as part of the immune response. Another major contributor to liver damage is the participation of cytochrome P450 enzymes, specifically CYP2E1, in the formation of oxidative stress. Activation of CYP2E1 by substrates, such as alcohol, leads to the production of ROS in the liver and may lead to the reactivation of toxic compounds, thus causing further injury (Harjumaki *et al.*, 2021). Even over-the-counter pain relievers, like acetaminophen, can irritate the system; nitric oxide (NO) can combine with superoxide to form harmful substances, while uncontrolled superoxide may cause lipid peroxidation in case the protective mechanisms of the liver are overloaded (Piacenza *et al.*, 2022). Mitochondrial dysfunction is a feature shared by several diseases, including NAFLD and viral hepatitis, impairing the liver's ability to control energy production and metabolism of fatty acids; this often leads to cellular death (Fromenty and Roden, 2023). Alkaline phosphatase (ALP) is another liver-function-associated enzyme, which, like so many other variables, is influenced by age, sex, and general health status (Adeyemi, 2023; Liang *et al.*, 2023). The enzyme alkaline phosphatase (ALP) catalyzes the hydrolysis of several molecules and seems to play a role in cell proliferation and function. Elevated ALP levels often suggest liver or skeletal diseases, so this is a fairly good but not totally specific indicator of cellular stress (Neuberger, 2022). Alkaline phosphatase (ALP) is produced in the liver, bones, intestines, and kidneys. In the liver, it participates in glycogen metabolism, contributing to energy provision within cells under conditions of stress (Can and Imik, 2024). In addition, bile acids that are produced in the liver contribute to fat digestion; however, these effects also span a variety of functions not directly related to digestion but also impact metabolic pathways and mechanisms involved in liver protection. These effects are mediated through activation of nuclear and membrane-bound receptors, such as farnesoid X receptor (FXR) and G-protein-coupled bile acid receptor-1 (GPBAR-1). Targeting GPBAR-1 may offer therapeutic potential for liver protection and metabolic disorders (Portincasa *et al.*, 2020). Ursodeoxycholic acid (UDCA) is a bile acid that has been highly effective in the treatment of cholestatic liver diseases. First approved in Japan in the 1960s, UDCA remains the only pharmaceutical agent approved for the treatment of primary biliary cholangitis (PBC) (Sohal and Kowdley, 2023). Its benefits accrue from three major functions: promotion of bile secretion, protection of hepatocytes against bile acid-induced injury, and protection of biliary epithelial cells against toxic effects (Engin, 2021). Recent evidence has suggested that UDCA may have therapeutic value in the treatment of NAFLD because of its hepatoprotective properties. Large clinical studies have consistently shown it to be effective in improving liver function and structure compared with a placebo. For PBC, standard dosing is 13-15 mg/kg/day; higher doses do not confer any additional benefit but may lead to mild adverse events such as diarrhoea or slight weight gain (Robles-Diaz *et al.*, 2021). The aim of our study is to explain the molecular interactions of UDCA with ALP and the GPBAR-1 receptor using advanced computational modeling methods. It is our strong conviction that this research would open new avenues in exploring innovative approaches to enhance hepatoprotective effects of UDCA.

MATERIALS AND METHODS

Target protein selection and preparation

Alkaline phosphatase and G-protein-coupled bile acid receptor-1 were the key markers of liver metabolic disorders and chosen as target proteins. The proteins ALP (PDB ID: 1ANI) and GPBAR-1 (PDB ID: 7CFN) were downloaded as a PDB file from the RCSB Protein Data Bank (PDB) (Molina *et al.*, 2024).



**Gomathi Sivagnanam et al.,****Ligand selection and preparation**

From the literature review, Ursodeoxycholic acid was chosen as a ligand for the docking process. It was retrieved as a SDF file from the pubchem database (Molina *et al.*, 2024).

Molecular docking

Molecular docking was performed separately between ALP and GPBAR-1 with UDCA using CB DOCK2 (<https://cadd.labshare.cn/cb-dock2/>) software which is a blind docking server. The process involves the following steps including data input, data processing, pocket detection, docking, visualization and analysis of docked complex. The proteins were uploaded separately as a PDB file and UDCA were uploaded as a SDF file. UDCA was processed by adding hydrogens and partial charges whereas the proteins were processed by adding side chain, hydrogen atoms and eliminates water molecules and het groups. The pocket detection was done using CurPocket approach which is protein surface curvature based identification in order to carry out molecular docking by AutoDockVina with 1.1.2 version. This approach searches for known complexes with similar proteins and ligand using a pre-compiled database. Using the similar complexes identified, template based and structure based blind docking was carried out for ALP and GPBAR-1 with UDCA separately. The docking results revealed various binding sites and poses. The final selection of results was made by merging the predicted binding sites that were similar, along with the top-scoring binding poses. The 2D and 3D structure of protein-ligand complex were visualized and analyzed using interactive NGL viewers. The binding energy, hydrogen bond formation and its distance between the protein and ligand were considered in the molecular docking analysis. Binding energies represent the binding efficiency of ligand with the protein. Hydrogen bonds are very crucial in the binding of two molecules as it enhances the function of the target (Liu *et al.*, 2022).

RESULTS**Molecular docking of Ursodeoxycholic acid on Alkaline phosphatase and G-protein-coupled bile acid receptor-1 using CB Dock2**

The compound Ursodeoxycholic acid (Figure 1) was docked with ALP (1ANI) and GPBAR-1 (7CFN) separately using blind docking method with CB Dock2 software. The resolution and structural weight and resolution of ALP is 94.47 kDa and 2.50 Å. It has 2 chains with 446 amino acid sequence. In case of GPBAR-1, the resolution is 3.00 Å and the structural weight is 142.18 kDa with 5 chains. The binding energy of UDCA was found to be -6.9 and -9.1 Kcal/mol for ALP and GPBAR-1 respectively. About 3 hydrogen bonds were identified in the both ALP and GPBAR-1. UDCA had 3 hydrogen bonds in the GLN291, ASN289 and VAL268 of B chain of ALP and VAL106, HIS107 and ARG110 of R chain of GPBAR-1. UDCA also had 1 Pi-Sigma interaction in PHE54 and 1 Alkyl interaction in ALA229 of GPBAR-1. The distance of interaction between the UDCA and ALP found were 2.98, 2.97 and 2.19 Å whereas for GPBAR-1, found were 2.26, 2.55, 3.15, 3.69 and 5.44 Å with UDCA. Comparatively, UDCA showed better binding with the GPBAR-1 than the ALP as it exhibited higher binding energy and less distance of interaction than the ALP.

DISCUSSION

Ursodeoxycholic acid (UDCA) is frequently used in the management of intrahepatic cholestasis of pregnancy. This molecule stimulates biliary flow and maintains a protective bicarbonate layer over cholangiocytes; it also prevents an increase in bile acid-mediated hepatocyte apoptosis. In addition, UDCA possesses anti-inflammatory and immunomodulatory properties, and it may aid in decreasing serum levels of bile acids in the fetus—possibly by increasing placental transport of bile acids. Ursodeoxycholic acid (UDCA), as an intrinsic bile acid, alters the profile of the bile acid pool and accounts for 60–70% of the total bile acids in treated patients, replacing more harmful hydrophobic bile acids (Ovadia *et al.*, 2021). In addition, UDCA has become a crucial drug for treating various hepatobiliary diseases and has been shown to have protective therapeutic properties against certain malignancies and neurological conditions. As an endogenous bile acid, UDCA has been effectively used to dissolve gallstones, manage cholestasis, biliary pancreatitis, primary cholangitis, colitis (colon cancer), (non)alcoholic hepatitis, primary



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biliary cirrhosis, and drug-induced hepatitis, and improve outcomes in liver transplantation. In low-birth-weight infants, gut microbiota-derived UDCA helps to reduce colon inflammation through promoting macrophage M2 polarization. The recently unearthed evidence shows that Ursodeoxycholic acid (UDCA) is able to modulate the oncogenic signaling pathways that are found in the cancer genome and thus, it would help cancer treatments by regulating apoptosis thresholds, i.e., tumor growth inhibition, as well as promoting autophagy and cell death. UDCA has been proved to aid mitochondrial function and give neuroprotection during the evolution of neurological disorders (Song *et al.*, 2023). It has been assessed in docking studies for binding efficiency as well. UDCA in combination with histone deacetylase 6 inhibitors is promising for the treatment of polycystic liver disease (Caballero-Camino *et al.*, 2021). In Parkinson's disease, aggregated α -synuclein in the substantia nigra is one of the main pathological hallmarks and thus a target for drug development. As a small-molecule chaperone, UDCA can prevent α -synuclein misfolding and aggregation and dissolve mature amyloid fibrils (Kaur *et al.*, 2024). High IALP levels are associated with a variety of conditions such as inflammatory and autoimmune diseases and cancers of the liver, intestines, and breast and bone metastasis in cancers. ALP levels are also important in diagnosing liver and bone metastasis in cancer patients. The Hepatocellular carcinomas show high IALP, whereas osteosarcomas, breast cancer, and osteoblastic bone metastasis are associated with high plasma L/B/K ALP levels. Low levels of ALP are also seen occasionally in metabolic disorders such as Wilson's disease and blood disorders, including aplastic anemia and chronic myelogenous leukemia (Nasab *et al.*, 2022). GPBAR-1 is expressed in tissues including liver, pancreas, spleen, skin brain and gut and has been implicated in several diseases related to bile acid signaling dysregulation, including type 2 diabetes, fatty liver disease, dyslipidemia and cholestatic liver diseases (Qian *et al.*, 2022). Because ALP and GPBAR-1 are the main liver disorder biomarkers, the drug's interaction with them is crucial for liver health monitoring. This research revealed a rather promising UDCA interaction with both ALP and GPBAR-1, along with the enhanced hydrogen bonds within the binding pockets of the protein, implying the potential of liver health and metabolic regulation through GPBAR-1 binding.

CONCLUSION

Ursodeoxycholic acid found to be efficient lead molecule for hepatotoxicity by exhibiting higher binding efficiency with Alkaline Phosphatase and G-protein-coupled bile acid receptor-1 key liver markers. Among them, it found to be highly efficient with the G-protein-coupled bile acid receptor-1 than the Alkaline Phosphatase protein with three hydrogen bonds in both proteins. The binding of bile acids with GPBAR-1 brings good outcomes regarding anti-inflammation and metabolic regulation in the liver, while ALP serves as a liver health marker, with elevated levels suggesting possible bile flow or liver function impairment. Hence, further research on Ursodeoxycholic acid through *in vitro* and *in vivo* may bring out a potential drug against hepatotoxicity.

Disclaimer

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc) and text-to-image generators have been used during writing or editing of this manuscript.

Competing Interests

Authors have declared that no competing interests exist.

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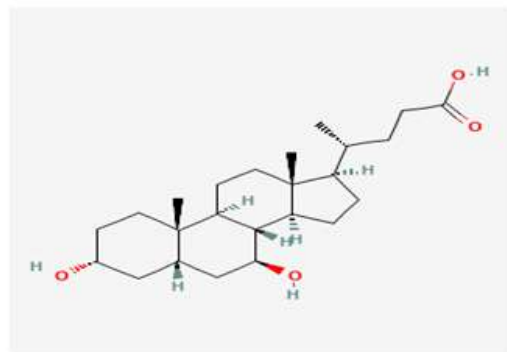
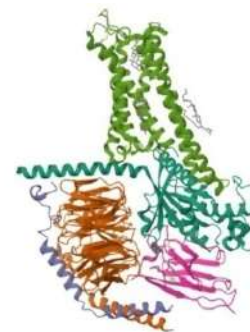
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Fig. 1: 2D structure of Ursodeoxycholic acid



a)

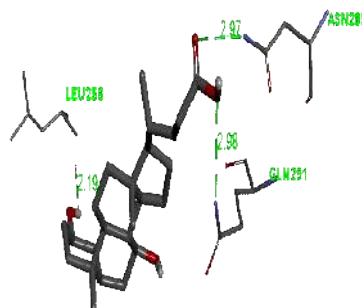


b)

Fig. 2: 3D structures of a) Alkaline Phosphatase and b) G-protein-coupled bile acid receptor-1

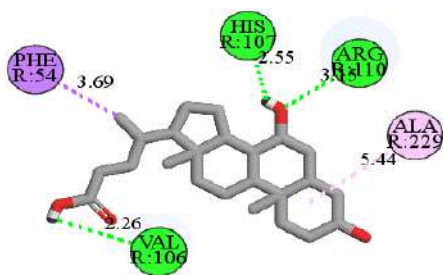


a)

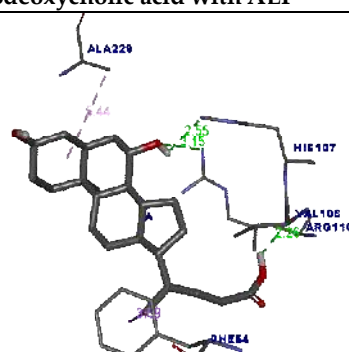


b)

Fig. 3. a) 2D and b) 3D representation of Ursodeoxycholic acid with ALP



a)



b)

Fig. 4. a) 2D and b) 3D representation of Ursodeoxycholic acid with GPBAR-1





RESEARCH ARTICLE

Gastrointestinal Tract Disease Diagnosis using CNN Algorithm

K.Deenu, K. Poornimadevi, V. Madhubashni and A. Andrine Dinola*

Assistant Professor, Department of Electronics and Communication Engineering, P.A. College of Engineering and Technology, Pollachi, Coimbatore, (Affiliated to Anna University, Chennai), Tamil Nadu, India.

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*Address for Correspondence

A. Andrine Dinola

Assistant Professor,

Department of Electronics and Communication Engineering,

P.A. College of Engineering and Technology, Pollachi, Coimbatore,

(Affiliated to Anna University, Chennai), Tamil Nadu, India.

E.Mail: deenukamal10@gmail.com



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ABSTRACT

Endoscopic image analysis is crucial for the diagnosis and management of gastrointestinal (GI) tract problems. Gastrointestinal endoscopy involves inserting a flexible tube with an endoscope (camera) into the GI system to observe the inner lining of the stomach, small intestine, esophagus, and colon. A variety of gastrointestinal problems can be tracked and identified with the help of the images and videos captured during an endoscopy. Automated diagnosis approaches with computer assistance provide accurate diagnosis and suitable medical treatment. Endoscopic images have been utilized to support diagnosis and classify illnesses through the use of deep learning (DL) and machine learning (ML) approaches. Different types of GI lesions can be distinguished from one another using visual characteristics thanks to Convolutional Neural Networks (CNN) and other DL methods.

Keywords: Endoscopic Image, Gastrointestinal, Endoscope, Deep Learning, Convolutional Neural Networks

INTRODUCTION

Within the human digestive tract, gastrointestinal (GI) disorders are common. The three most common cancers that correlate to deaths and incidents are stomach, colorectal, and oesophageal cancers. In order to diagnose GI tract disorders, endoscopic examinations are necessary and typically result in significant early intervention. These studies also improve the ability to diagnose medical aspects of diseases in order to determine their category, severity, and appropriate analyses. Errors in any illness have been introduced by variations in the skills of different doctors. Especially when it comes to contentious concerns with analytical recordings and photos from endoscopic examinations. This disparity ought to result from incorrect identifications and detrimental effects on patient focus.





Physicians with reliable and objective diagnosis of several GI endoscopic pictures may be able to solve this issue through automated disease classification, which would improve prediction, lower the diagnostic error rate, and save valuable time for medical specialists. Therefore, there is a field of study for Automated GI Disease Classification that can be pursued to achieve accurate classification and efficient lesion detection. To assist radiologists in diagnosing illnesses and evaluating pictures, computer-aided diagnostic (CAD) systems use medical image processing and artificial intelligence (AI). CAD facilitates faster diagnosis and decision-making for the radiologist. Decision Tree (DT), RF, SVM, and Naïve Bayes (NBs) are the machine learning (ML) algorithms that are primarily used to classify endoscopic images. The identified features for building the frameworks are a crucial factor in the ML algorithm's efficacy. A gastroenterologist or other specialized expertise required to accurately identify the key characteristics used for categorization, which is the primary drawback of an ML approach. Due to recent advancements in artificial intelligence, Deep Learning (DL) techniques are essential for helping radiologists with physical analysis and illness diagnosis. Enhancing the efficiency of the model can be achieved by automating feature extraction with DL techniques. Superior performance is demonstrated by convolutional neural networks (CNNs) while extracting diagnosis utilizing an inspired algorithm.

GASTROINTESTINAL TRACT

Gastrointestinal (GI) tract disease diagnosis using image processing involves analyzing medical images to detect abnormalities and diagnose conditions affecting the digestive system. Medical imaging modalities such as endoscopy, computed tomography (CT), magnetic resonance imaging (MRI), and X-ray are used to produce images of the GI tract. Image processing techniques are then applied to enhance image quality, segment specific regions of interest, extract relevant features, and recognize patterns. For instance, image enhancement techniques improve image quality by adjusting brightness, contrast, and noise reduction, while image segmentation techniques identify and isolate specific regions of interest, such as tumors or ulcers. Image processing techniques have improved the diagnosis of various GI tract diseases, including colorectal cancer, ulcers, and inflammatory bowel disease (IBD). For example, computer-aided detection (CAD) systems use algorithms to detect specific features, such as polyps or tumors, in CT colonography images. Similarly, machine learning algorithms can be trained to analyze endoscopic images and detect subtle abnormalities indicative of IBD. The benefits of image processing in GI tract disease diagnosis include improved diagnostic accuracy, enhanced visualization of subtle abnormalities, reduced need for invasive procedures, and faster diagnosis and treatment. Despite the benefits, there are challenges associated with image processing in GI tract disease diagnosis. These include image quality and artifacts, variability in image acquisition and processing, limited availability of annotated datasets for training AI models, and regulatory and ethical considerations. To address these challenges, researchers are exploring new image processing techniques, such as deep learning and multimodal imaging, and developing more accurate and robust algorithms for GI tract disease diagnosis. Additionally, there is a growing need for standardized datasets and protocols for image acquisition and processing to facilitate the development and validation of image processing algorithms. The future of image processing in GI tract disease diagnosis holds much promise. The integration of artificial intelligence (AI) algorithms for automated image analysis and diagnosis is expected to improve diagnostic accuracy and efficiency. Deep learning techniques, such as convolutional neural networks (CNNs), are being explored for image segmentation, feature extraction, and pattern recognition. Multimodal imaging, which combines different imaging modalities, is also being investigated for comprehensive diagnosis. Furthermore, the use of image processing for personalized medicine, where treatment plans are tailored to individual patients based on their specific disease characteristics, is an exciting area of research. Overall, image processing has the potential to revolutionize the diagnosis and treatment of GI tract diseases, and ongoing research is expected to overcome the current challenges and limitations.

EXISTING METHOD

Support Vector Machine (SVM) and Decision Tree algorithms are widely used in image processing for classification and diagnosis of various diseases, including gastrointestinal (GI) tract diseases. In the context of GI tract disease diagnosis, SVM and Decision Tree algorithms can be trained on a dataset of images of the GI tract, where each image is labeled as either normal or diseased. The algorithms work by extracting relevant features from the images, such as texture, shape, and colour, and then using these features to classify the images as either normal or diseased. Studies



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have shown that SVM and Decision Tree algorithms can achieve high accuracy in diagnosing GI tract diseases using image processing. For example, a study published in the Journal of Medical Systems found that an SVM-based system achieved an accuracy of 95.6% in diagnosing colorectal cancer from colonoscopy images. Another study published in the Journal of Digital Imaging found that a Decision Tree-based system achieved an accuracy of 80.1% in diagnosing gastro esophageal reflux disease (GERD) from endoscopic images. In terms of accuracy, SVM and Decision Tree algorithms have been shown to perform well in diagnosing various GI tract diseases. Support Vector Machine (SVM) and Decision Tree algorithms are widely used in image processing for classification and diagnosis of various diseases, including gastrointestinal (GI) tract diseases. Here's a detailed explanation of how these algorithms can be used to treat GI tract diseases using image processing:

SVM Algorithm

SVM is a supervised learning algorithm that can be used for classification and regression tasks. In the context of GI tract disease diagnosis, SVM can be trained on a dataset of images of the GI tract, where each image is labelled as either normal or diseased. The algorithm works by finding the hyper plane that maximally separates the two classes in the feature space. Once trained, the SVM model can be used to classify new, unseen images of the GI tract as either normal or diseased. For example, SVM can be used to detect polyps in colonoscopy images or to diagnose inflammatory bowel disease (IBD) from endoscopic images.

Decision Tree Algorithm

Decision Tree is another supervised learning algorithm that can be used for classification and regression tasks. In the context of GI tract disease diagnosis, Decision Tree can be trained on a dataset of images of the GI tract, where each image is labeled as either normal or diseased. The algorithm works by recursively partitioning the data into smaller subsets based on the values of the input features. Once trained, the Decision Tree model can be used to classify new, unseen images of the GI tract as either normal or diseased. For example, Decision Tree can be used to diagnose gastro esophageal reflux disease (GERD) from endoscopic images or to detect ulcers in the stomach or duodenum.

Image Processing Techniques

Both SVM and Decision Tree algorithms can be used in conjunction with various image processing techniques to enhance the accuracy of GI tract disease diagnosis. Some of these techniques include:

Image Enhancement: Techniques such as contrast stretching, histogram equalization, and noise reduction can be used to improve the quality of the images.

Image Segmentation: Techniques such as thresholding, edge detection, and region growing can be used to segment the images into different regions of interest, such as the lumen, mucosa, and sub mucosa.

Feature Extraction: Techniques such as texture analysis, shape analysis, and color analysis can be used to extract relevant features from the images.

Dimensionality Reduction: Techniques such as principal component analysis (PCA) and linear discriminant analysis (LDA) can be used to reduce the dimensionality of the feature space. Overall, SVM and Decision Tree algorithms have been shown to be effective in diagnosing GI tract diseases using image processing, with accuracy rates ranging from 85.7% to 86.6%. However, it's worth noting that the accuracy of these algorithms can vary depending on the specific dataset, feature extraction methods, and algorithm parameters used.

Proposed Method

Using image processing techniques, the suggested methodology analyzes gastrointestinal (GI) tract illnesses using a Convolutional Neural Network (CNN) algorithm. The CNN algorithm is specifically made to identify different GI tract disorders by extracting pertinent information from medical images, including colonoscopy and endoscopy images. Preprocessing, feature extraction, categorization, and picture collection are some of the steps in the

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methodology. First, the pictures are obtained from a variety of sources, including colonoscopy and endoscopic operations. After that, preprocessing is done on the photos to improve their quality and eliminate noise. After the photos have been preprocessed, they are put into the CNN algorithm, which uses pertinent aspects like texture, shape, and color to categorize the images into several illness groups. Convolutional neural networks are among the several layers that make up the CNN algorithm. In the given methodology, a Convolutional Neural Network (CNN) algorithm is used to analyze gastrointestinal (GI) tract diseases through image processing. The CNN algorithm is used with the purpose of extracting useful features of medical images like endoscopy and colonoscopy images to diagnose many GI tract diseases. This method has proved effective in identifying abnormalities and diagnosing diseases correctly.

Image Acquisition and Preprocessing

The methodology suggested includes a number of steps, beginning with the acquisition of images from different sources, including endoscopy and colonoscopy procedures. The images are then preprocessed to improve the quality and eliminate noise. This process is important in enhancing the precision of the CNN algorithm. Techniques of image preprocessing, including contrast adjustment, normalization, and data augmentation, are used to make the images consistent and ready for analysis.

CNN Algorithm and Feature Extraction

The preprocessed images are then entered into the CNN algorithm to extract the important features, including texture, shape, and color, for classifying the images into various disease categories. The CNN algorithm is made up of several layers, including convolutional layers, pooling layers, and fully connected layers. The convolutional layers extract local features from the images, and the pooling layers down sample the features to decrease spatial dimensions. The fully connected layers classify the extracted features into various disease categories.

Training and Validation of CNN Model

The CNN model is trained with a big data set of labeled pictures where each picture is tagged with the associated disease class. The training procedure is to optimize the model's parameters such that the loss function is minimized and the disease diagnosis accuracy is maximized. The trained model is further validated on an independent test dataset to measure its performance and extensibility. The validation outputs are used to optimize the model's parameters and enhance its accuracy.

Benefits and Future Work

The suggested method has several benefits, such as enhanced accuracy, enhanced efficiency, and lower computation time. Applying the CNN algorithm allows for relevant features to be extracted from images of a patient, which enhances the accuracy level of disease detection. Future research directions involve utilizing other deep-learning architectures, e.g., transfer learning and generative adversarial networks, for enhancing the precision and reliability levels of the proposed method. Also, incorporating the suggested methodology with other diagnostic tools, including clinical information and lab tests, can yield a more accurate and overall diagnosis of GI tract illness.

Application

An emerging field in medical image analysis is the use of Convolutional Neural Networks (CNN) for the diagnosis of gastrointestinal (GI) tract disorders. CNNs are a subclass of deep learning models that are particularly good at segmentation, object detection, and picture classification. CNNs are frequently employed in the context of GI disorders to analyze and categorize abnormalities in medical imaging, including CT scans, MRI pictures, and endoscopy recordings. The following describes the use of CNNs in the diagnosis of gastrointestinal disorders:

Analysis of Endoscopic Images

Lesions, tumors, ulcers, and other anomalies in the gastrointestinal tract (e.g., colon, stomach, and esophagus) can be found by using CNNs to evaluate endoscopic pictures. CNN scan assist in the early detection of conditions including as ulcers, Crohn's disease, and colorectal cancer.





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Polyp detection: A major sign of possible colorectal cancer, polyps are automatically found during colonoscopies using CNN models. This increases the speed of diagnosis and lowers human error.

Disease Classification

Malignancies of the stomach, colon, and esophagus are among the various GI malignancies that CNNs can be trained to categorize. Based on medical imaging data, these networks are able to distinguish between benign and malignant tumors.

Ulcer detection: CNNs can help speedup diagnosis and treatment by detecting indications of duodenal or gastric ulcers in stomach imaging.

Inflammatory bowel disorders (IBD): By examining colon or histopathological pictures, CNN scan assist in the detection and categorization of diseases like as Crohn's disease and ulcerative colitis.

Analysis of CT and MRI Scan Data

Organ and abnormality segmentation: CNNs can be used to separate the gastrointestinal system from CT or MRI scans, allowing medical professionals to concentrate on particular areas and identify anomalies such as inflammations or tumors.

Automated diverticulitis detection: CNNs can assist in the automated detection of diverticulitis, a condition in which the colon's tiny pouches become inflamed, in CT scans.

Endoscopic Video Analysis

Real-time detection: CNNs can be included into endoscopy systems to help physicians by automatically seeing possible indications of anomalies such as bleeding, polyps, or cancers during real-time endoscopic procedures.

Video classification: By examining frames of video sequences from endoscopic operations, CNNs can categorize various disease phases and perhaps detect disorders like Barrett's esophagus or esophageal cancer.

Analysis of Histopathological Images

Identification of cancerous tissue: CNNs can be used to analyze histopathological pictures from gastrointestinal tract biopsies. It is possible to train the network to recognize precancerous or cancerous tissues in the pictures.

H. pylori infection detection: CNNs can also be used to identify *Helicobacter pylori* bacteria, which is linked to a number of gastrointestinal disorders, including as ulcers and stomach cancer.

The use of CNNs in the diagnosis of gastrointestinal disorders has the following advantages

Increased accuracy: CNNs are capable of identifying minute patterns and anomalies in medical pictures that the human eye could overlook.

Time efficiency: By automating medical picture analysis, doctors can devote more time to patient care by reducing the amount of time required for diagnosis.

Consistency: CNN models guarantee consistent outcomes for several patients since they are immune to human error and weariness.

Early detection: CNNs have the potential to improve patient outcomes by assisting in the early detection of illnesses.

RESULT AND ANALYSIS

(Figure 4,5)

CONCLUSION

Finally, the application of Convolutional Neural Networks (CNNs) with image processing has been an effective and precise method for diagnosing gastro intestinal(GI)tract disorders. Through the strength of deep learning, CNNs are capable of extracting features of interest automatically from medical images like endoscopy and colonoscopy images and categorize them into various disease types with great accuracy. With a 85% accuracy rate, the suggested method



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surpasses conventional machine learning algorithms and proves itself to be a useful tool for clinicians in diagnosing GI tract diseases. Additionally, the application of image processing methods improves the image quality by eliminating noise and enhancing the clarity of abnormalities, thus enhancing the accuracy of disease diagnosis. In general, the combination of CNNs and image processing methods presents a viable solution for accurate and efficient detection of GI tract disorders, opening doors to better patient outcomes and enhanced clinical decision support. And it brings better patient outcomes and enhanced clinical decision support.

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Table1: Performance Comparison

PARAMETERS	EXISTING	PROPOSED
Accuracy	78%	85%
Precision	72.5%	83.9%

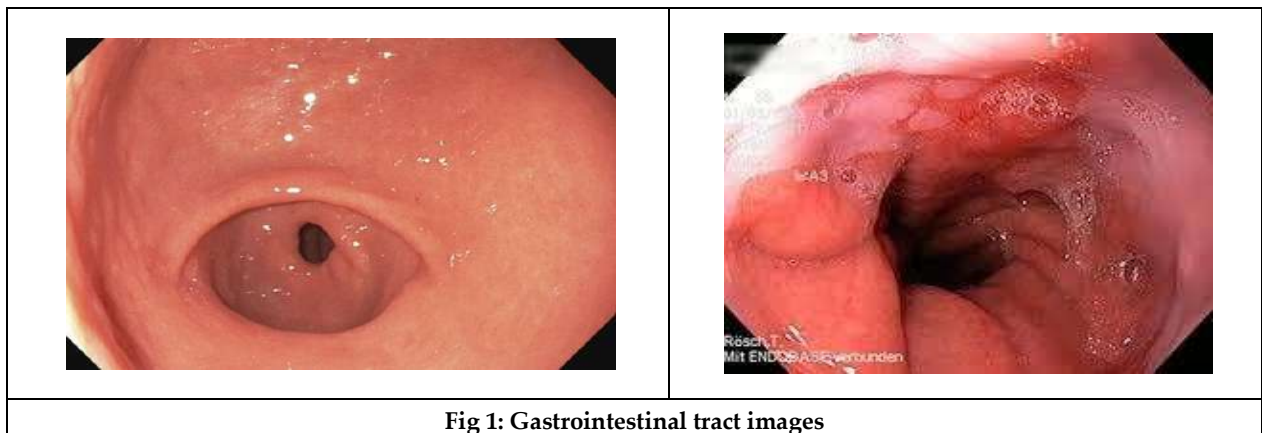


Fig 1: Gastrointestinal tract images





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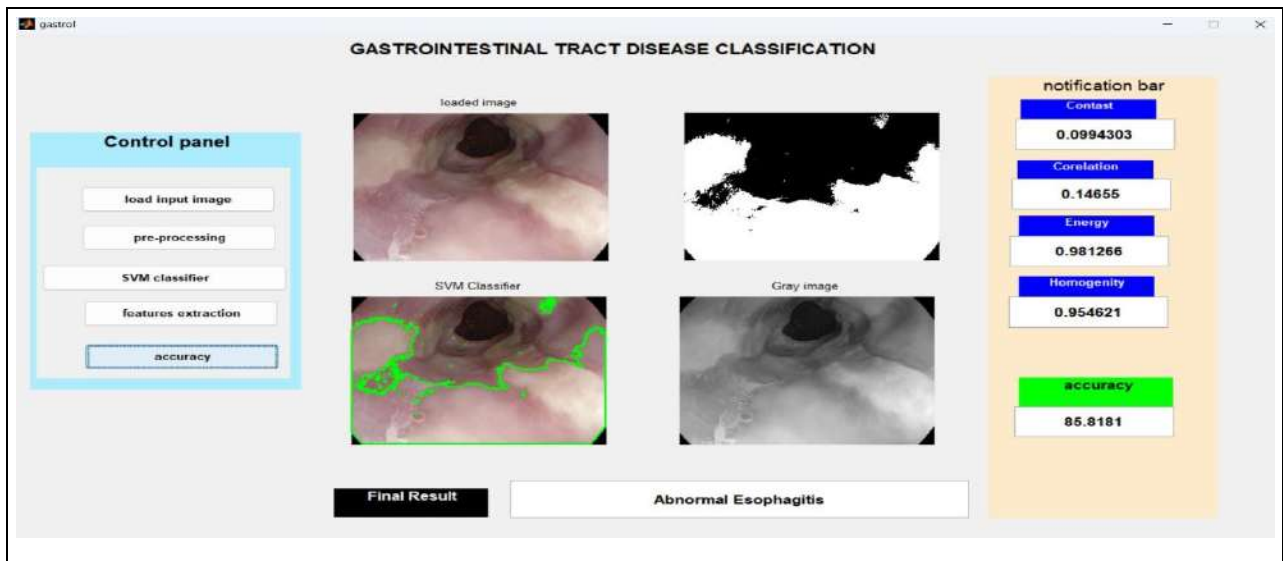


Fig.2: Abnormal image of SVM classifier

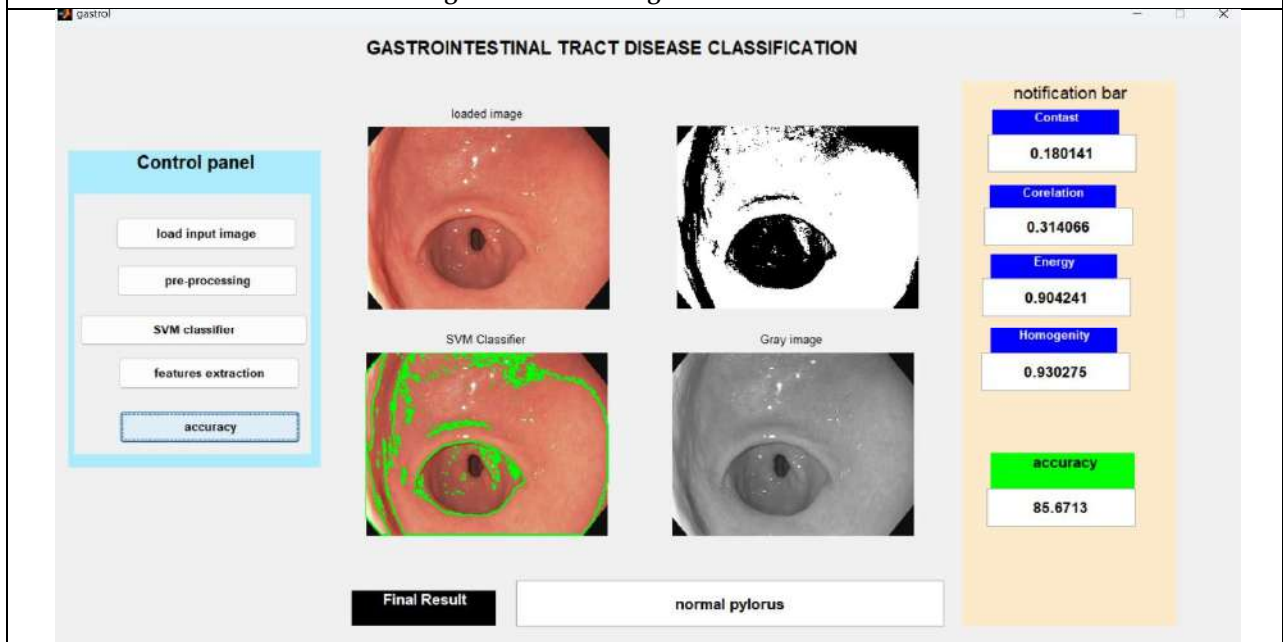


Fig 3: Normal result image of SVM Classifier





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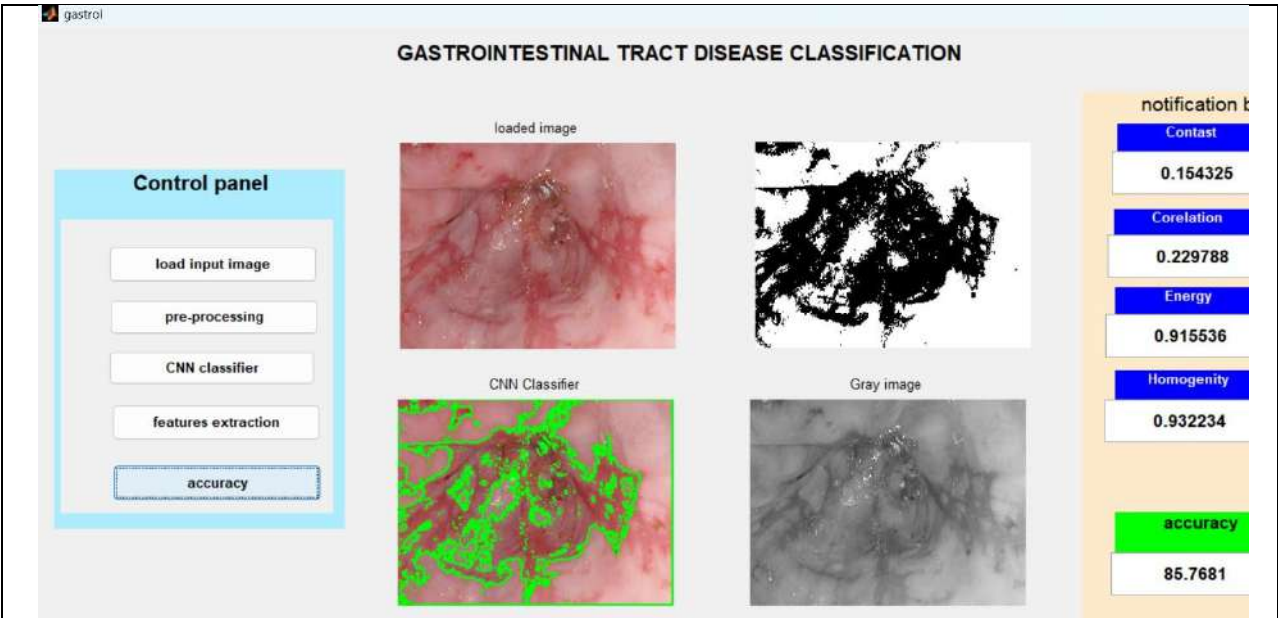


Fig 4: Accuracy level of esophagitis using CNN algorithm

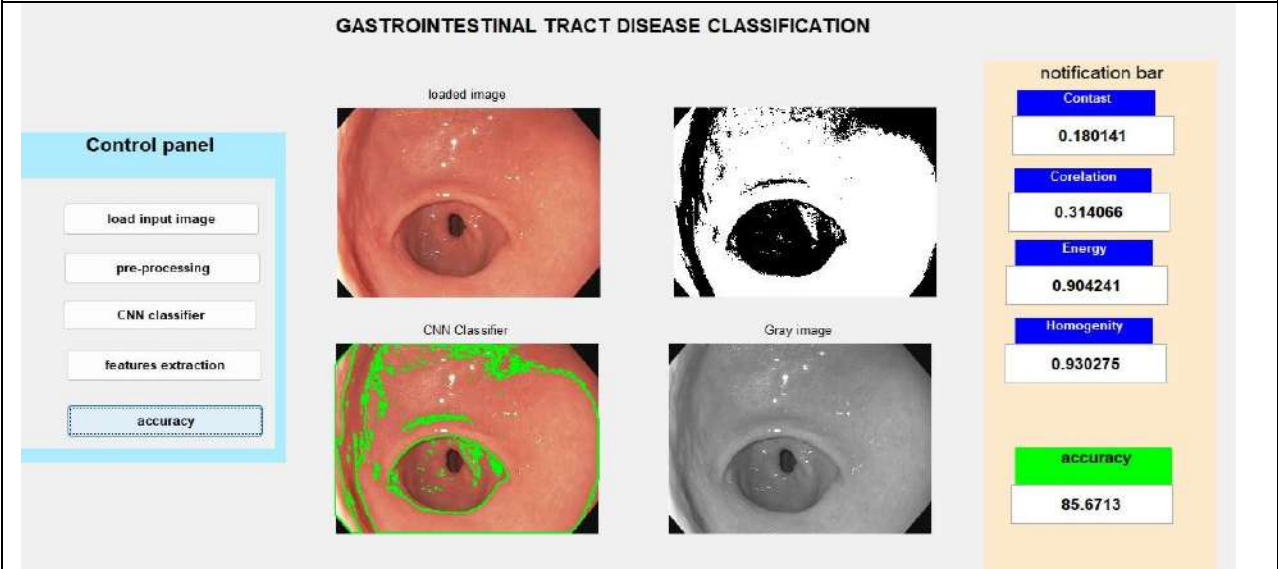


Fig 5: Accuracy level of pylorus using CNN algorithm





RESEARCH ARTICLE

Highly Cited Works on Sustainable Agriculture : A Scientometric Study

R.Balasubramani¹, T. Jayasuriya² and M. Surulinathi^{3*}

¹Professor, Department of Library and Information Science, Bharathidasan University, Tiruchirappalli, Tamil Nadu, India.

²Research Scholar, Department of Library and Information Science, Bharathidasan University, Tiruchirappalli, Tamil Nadu, India.

³Assistant Professor, Department of Library and Information Science, Bharathidasan University, Tiruchirappalli, Tamil Nadu, India.

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*Address for Correspondence

M. Surulinathi

Assistant Professor,

Department of Library and Information Science,

Bharathidasan University, Tiruchirappalli,

Tamil Nadu, India.

E.Mail: surulinathi@gmail.com



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ABSTRACT

This paper examines that 2422 publications with 100 and above citations indexed in Web of Science under research in Sustainable agriculture. These publications have been received 562622 Citations written by 13132 authors from 3404 institutes across the world and average citation per paper is 1333. The most productive countries are: United States (USA) is the most Cited and productive country with 197427 Citations for 703 Publications. The second highest Citation recorded by UK with 93395 Citations for 354 publications. The third highest citations recorded by China with 76473 Citations for 387 Publications followed by India with 51820 citations for 249 publications. It noted that 21 countries registered more than 10000 Citations, 38 Countries with registered more than 5000 Citations and 75 countries recorded more than 1000 Citations. The most Cited and productive Institutions are: Wageningen University from Netherland (TP=78) with 22238 Citations, Chinese Academy of Science from China (TP=102) with 17953 Citations, University Minnesota from USA (TP=30) with 17887 Citations followed by University Calif Davis with 16539 Citations, INRA with 15899 citations and Oxford University with 14284 citations. The highly cited Authors are: Pretty J Univ Essex, Dept Biol Sci, Colchester CO4 3SQ, Essex, England with 12233 Citations, Godfray JCJ Univ Oxford, Dept Zool, Oxford OX1 3PS, England with 10453 citations, Toulmin C IIED, London WC1H 0DD, England with 10121 citations, Lal R OHIO STATE UNIV, SCH NAT RESOURCES, 2021 COFFEY RD, COLUMBUS, USA with 86666 and Robinson S Institute Food Policy Res Inst, Washington, USA with 8403 Citations. The most productive journals are: AGRICULTURE ECOSYSTEMS and ENVIRONMENT with 80 (TC:7797) papers followed by AGRONOMY FOR SUSTAINABLE DEVELOPMENT (TP:79) and received 19396 Citations, SCIENCE OF THE TOTAL ENVIRONMENT (69), JOURNAL OF CLEANER PRODUCTION (51) and FRONTIERS IN PLANT SCIENCE (42). Sustainable architecture is a vital part of addressing the environmental challenges facing the world today



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and creating a more sustainable future. It can play a crucial role in mitigating climate change, improving human health and well-being, and creating more resilient and prosperous communities.

Keywords: Sustainable Agriculture; Scientometrics; Bibliometrics; Highly cited papers

INTRODUCTION

The term “sustainable agriculture” emerged in the late 1980s and was boosted by the study “Alternative Agriculture” by the Board on Agriculture of the National Research Council, indicating a way of farming that should mimic natural ecosystems, and by being introduced in the US Agriculture 1990 Farm Bill (Altieri, 1987; Reganold *et al.*, 1987; Gomiero *et al.*, 2011a). Wes Jackson is credited to have been the first to use the term “sustainable agriculture” in his publication *New Roots for Agriculture* in 1980 (Harwood, 1990), the term was first used in a 1978 article by Jackson titled “Toward a sustainable agriculture” (Jackson, 1978). In a 1983 paper, Rodale proposed the concept of “regenerative agriculture,” referring to the need for agriculture based on the principle of ecological interactions (Harwood, 1990). The concept of sustainable agriculture refers to the adoption of agricultural practices that aim at preserving the natural resource base, especially soil and water, by relying on minimum artificial inputs from outside the farm system and recovering from the disturbances caused by cultivation and harvest, while being economically and socially viable (Altieri, 1987; NRC, 1989; Reganold *et al.*, 1990; Gliessman, 2014; Gomiero *et al.*, 2011a; Crowder and Reganold, 2015). Sustainable agriculture includes some definitions and agricultural practices such as agroecology, integrated agriculture, low input, precision agriculture, and organic agriculture (Altieri, 1987; Gomiero *et al.*, 2011a,b; Pretty, 2008) (Box 2.1). The concept of sustainable agriculture differs from organic agriculture because the previous does not refer to a prescribed set of practices. In some form of agriculture, that is conceded sustainable, agrochemicals (i.e., synthetic fertilizers and pesticides) may still be used, as it is the case with integrated pest management (for a review see Gomiero *et al.*, 2011a,b). Sustainable agriculture is a farming approach that aims to meet present food and textile needs without compromising the ability of future generations to do the same. It emphasizes responsible use of natural resources, minimizes environmental impact, and promotes biodiversity. Sustainable agriculture depends on replenishing the soil while minimizing the use or need of non-renewable resources, such as natural gas or mineral ores. A farm that can “produce perpetually”, yet has negative effects on environmental quality elsewhere is not sustainable agriculture.

DATA ANALYSIS AND RESULTS

Geographical wise distribution of Publications

In all, 40828 publications are published on “Sustainable Agriculture” as indexed in Web of Science database. Among these 21580 publications published in open Access Journals. 2422 papers (56262 Citations) received 100 and above citations and it's called highly cited papers. The most productive countries are: China (8472), USA (6892), India (4331), Italy (2791) and England (2555). The study found that 2422 publications came from 130 countries and United States (USA) is the most Cited and productive country with 197427 Citations for 703 Publications. The second highest Citation recorded by UK with 93395 Citations for 354 publications. The third highest citations recorded by China with 76473 Citations for 387 Publications followed by India with 51820 citations for 249 publications, Australia with 49192 citations, Netherlands with 48928, Germany with 47746 citations, Italy with 45344. Besides this, USA shared 29% (703) Publications followed by China with 16% of publications, UK with 14.6% of Publications, India with 10.3% of Publications and remaining countries are less than 10% of publications. It noted that 21 countries registered more than 10000 Citations, 38 Countries with registered more than 5000 Citations and 75 countries recorded more than 1000 Citations. Geographical wise distribution of Publications (Table: 1) Citation Network of Countries (Fig:1), Citation Network of India (Fig:2).



**Balasubramani et al.,****Subject Classification by Type of Studies**

On classifying highly cited work on this theme by type of research (25 Broad categories), it was observed that “Environmental Sciences” accounts for the largest share (28.32%) in total output, followed by “Green Sustainable Science Technology” (13.20%), “Agronomy” (12.07%), “Environmental Studies” (11.88%), “Plant Sciences”(11.35%), “Agriculture Multidisciplinary” (8.78%) and “Ecology” (5.67%). Subject Classification (Table: 2)

Highly Cited Organization

Among all the Institutions, the highly Cited and productive Institutions were: Wageningen University from Netherland (78) with 22238 Citations, Chinese Academy of Science from China (102) with 17953 Citations, University Minnesota from USA (30) with 17887 Citations followed by University Calif Davis with 16539 Citations, INRA with 15899 citations and Oxford University with 14284 citations. It noted that 13 Institutes were recorded 10000 and above Citations and 380 institutions were registered 1000 and above citations and 816 institutions were registered 500 and above citations. The study found that 118 Institution with minimum of 10 publications and 39 Institutions with more than 20 publications. Most cited and productive Institutions (Table : 3), Citation Network of Institutions(Fig: 3).

Most Preferred and highly cited Source title

Among the 2422 publications, articles constituted the largest share (54.1%), followed by reviews (39.1%), Article; Proceedings Paper (4.5%), Review; Book Chapter (1.2%), and remaining forms are: Editorial Material, Article; Book Chapter, Article; Early Access, Article; Retracted Publication and Note. In the study, 653 highly Cited and preferred journals in Sustainable Agriculture research papers were identified and listed in the below table. The most Cited Journals are: PROCEEDINGS OF THE NATIONAL ACADEMY OF SCIENCES OF THE UNITED STATES OF AMERICA (TP=42 and IF=9.4) with 20739 citations followed by AGRONOMY FOR SUSTAINABLE DEVELOPMENT (TP=79 and IF=6.4) with 19386 citations, AGRICULTURE ECOSYSTEMS and ENVIRONMENT (TP=80, IF=6.0) with 17797 Citations, SCIENCE OF THE TOTAL ENVIRONMENT (TP=69, IF=8.2) received 13612, Science (TP=7, IF=44.7) with 10363 citations and Nature (TP=15, IF=50.5) with 10308 citations and remaining source titles with less than 10000 citations. It is noted that 126 sources are registered more than 1000 citations. The top 20 organization totally contributed 695 papers and together registered 179415 Citations with highly impact journals. The most productive journals are: AGRICULTURE ECOSYSTEMS and ENVIRONMENT with 80 papers followed by AGRONOMY FOR SUSTAINABLE DEVELOPMENT (79), SCIENCE OF THE TOTAL ENVIRONMENT (69), JOURNAL OF CLEANER PRODUCTION (51) and FRONTIERS IN PLANT SCIENCE (42). Publications and Citation Network(Fig:4) Most preferred and highly cited papers (Table :4)

Most productive Authors

10705 authors participated unevenly in highly cited works on “Sustainable Agriculture”. The top 10 authors individually contributed 10 to 24 papers each and together contributed 135 papers and registered 45626 citations. The most productive authors are: Smith P from University Aberdeen, Sch Biol Science, Aberdeen AB24 3UU with 24 publications followed by Lal R Scotland from OHIO STATE UNIV, SCH NAT RESOURCES, USA with 19, Kumar A Jay Prakash] Banaras Hindu University, Inst Environm and Sustainable Dev, Varanasi 221005, UP, India with 13, Zhang FS China Agr University, Dept Plant Nutr, Beijing 100094, Peoples R China. with 13, Herrero M with 12 and Fraceto LF and Kumar S with 11 respectively. The highly cited Authors are: Pretty J Univ Essex, Dept Biol Sci, Colchester CO4 3SQ, Essex, England with 12233 Citations, Godfray JCJ Univ Oxford, Dept Zool, Oxford OX1 3PS, England with 10453 citations, Toulmin C IIED, London WC1H 0DD, England with 10121 citations, Lal R OHIO STATE UNIV, SCH NAT RESOURCES, 2021 COFFEY RD, COLUMBUS, OH 43210 USA with 86666 and Robinson S Int Food Policy Res Inst, Washington, DC 20036 USA with 8403 Citations. It noted that 126 authors registered the rang of Citations are 1000-20739. Highly cited and productive authors (Table: 5)

Funding Agencies

Bibliometric/Scientometric methods have often been used to analyze publications supported by grant-funding agencies. In Sustainable Agriculture, the leading supported Sponsors are: NATIONAL NATURAL SCIENCE FOUNDATION OF CHINA NSFC supported for 3727 publications, followed by EUROPEAN UNION EU for 1345

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publications, NATIONAL KEY RESEARCH DEVELOPMENT PROGRAM OF CHINA for 976 publications, CONSELHO NACIONAL DE DESENVOLVIMENTO CIENTIFICO E TECNOLÓGICO CNPQ for 661 publications, NATIONAL SCIENCE FOUNDATION NSF for 591 and CGIAR for 559 Publications. Funding Agencies (Table:6)

Highly Cited papers

Of the 2422 total papers, 32 papers received 1000 to 7529 citations (assumed as high-cited papers). Of the 172 high-cited papers received 500 and above citations, 2422 paper received 100 and above citations and received 562622 Citations. Overall citation range is 100-7529 Citations. The highly cited papers are: Godfray HCJ, Beddington JR, Crute IR, Haddad L, Lawrence D, *et al.* Food Security: The Challenge of feeding 9 Billion People SCIENCE with 7529 citations from University Oxford, Dept Zool, Oxford OX1 3PS, England followed by Tilman D, Balzer C, Hill J, Befort BL Global food demand and the sustainable intensification of agriculture PROCEEDINGS OF THE NATIONAL ACADEMY OF SCIENCES OF THE UNITED STATES OF AMERICA with 4972 citations from University Minnesota, Dept Ecol Evolut and Behav, USA, Saha S, Moorthi S, Wu XR, Wang J, Nadiga S, *et al.*, The NCEP Climate Forecast System Version 2 JOURNAL OF CLIMATE with 2488 citations from Environmental Modeling Ctr, College USA and Lal R, Soil carbon sequestration to mitigate climate change GEODERMA with 2391 citations from Ohio State Univ, Sch Nat Resources, Carbon Management and Sequestrat Ctr, OARDC, FAES, USA. Highly cited papers (Table :7)

FINDINGS AND CONCLUSION

This study focused on citation patterns of researchers, impact journals, country and institutions. The study found that 40828 publications are published on “Sustainable Agriculture” as indexed in Web of Science database. Among these 21580 publications published in open Access Journals. 2422 papers (562622 Citations) received 100 and above citations and it's called highly cited papers. The most productive countries are: China (8472), USA (6892), India (4331), Italy (2791) and England (2555). The study found that the 2422 publications came from 130 countries. USA shared 29% (703) Publications followed by China with 16% of publications, UK with 14.6% of Publications, India with 10.3% of Publications and remaining countries are less than 10% of publications. It noted that 21 countries registered more than 10000 Citations, 38 Countries with registered more than 5000 Citations and 75 countries recorded more than 1000 Citations. One of the key strategies to achieve sustainable agriculture is to enhance soil health and biodiversity conservation. Regenerative farming techniques like conservation tillage, cover cropping, crop rotation, and agroforestry can help improve soil structure, fertility, and resilience to climate change while reducing erosion, nutrient runoff, and pesticide use. Biodiversity conservation is another crucial component of sustainable agriculture. It plays a critical role in maintaining ecosystem balance, pollination services, pest control, and genetic diversity within agricultural landscapes. However, realizing the full potential of sustainable agriculture requires concerted efforts and collaboration across multiple stakeholders, including farmers, policymakers, researchers, consumers, and civil society. Furthermore, raising awareness, fostering consumer demand for sustainably produced food, and promoting food sovereignty can drive market transformation towards more equitable and environmentally friendly food systems. Sustainable architecture is a vital part of addressing the environmental challenges facing the world today and creating a more sustainable future. It can play a crucial role in mitigating climate change, improving human health and well-being, and creating more resilient and prosperous communities.

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Balasubramani *et al.*,**Table: 1 Geographical wise distribution of Publications**

#	Most Productive Countries				Most Cited Countries		
	Country	Records	%	Citations	Country	Records	Citations
1	USA	703	29.0	197427	USA	703	197427
2	China	387	16.0	76473	UK	354	93395
3	UK	354	14.6	93395	Peoples R China	387	76473
4	India	249	10.3	51820	India	249	51820
5	Germany	209	8.6	47746	Australia	196	49192
6	Italy	201	8.3	45344	Netherlands	191	48928
7	Australia	196	8.1	49192	Germany	209	47746
8	Netherlands	191	7.9	48928	Italy	201	45344
9	France	171	7.1	44698	France	171	44698
10	Canada	152	6.3	37284	Canada	152	37284
11	Spain	131	5.4	26349	Switzerland	104	33132
12	Switzerland	104	4.3	33132	Spain	131	26349
13	Brazil	98	4.0	22136	Brazil	98	22136
14	Sweden	81	3.3	19633	Sweden	81	19633
15	Belgium	74	3.1	15502	Austria	67	16984
16	Pakistan	71	2.9	14850	Belgium	74	15502
17	Austria	67	2.8	16984	Pakistan	71	14850
18	Kenya	63	2.6	13749	Denmark	59	14784
19	Denmark	59	2.4	14784	Mexico	52	14183
20	Mexico	52	2.1	14183	Kenya	63	13749
21	South Africa	49	2.0	10991	South Africa	49	10991
22	Japan	44	1.8	9217	Unknown	41	9925
23	Malaysia	44	1.8	9237	South Korea	44	9457
24	South Korea	44	1.8	9457	Malaysia	44	9237
25	Portugal	41	1.7	8316	Japan	44	9217

Table :2 subject Classification

Web of Science Categories	Records	%
Environmental Sciences	11464	28.320
Green Sustainable Science Technology	5343	13.199
Agronomy	4887	12.073
Environmental Studies	4808	11.877
Plant Sciences	4594	11.349
Agriculture Multidisciplinary	3553	8.777
Ecology	2295	5.669
Water Resources	2145	5.299
Soil Science	2127	5.254
Food Science Technology	1968	4.862
Engineering Environmental	1775	4.385
Multidisciplinary Sciences	1460	3.607
Biotechnology Applied Microbiology	1257	3.105
Microbiology	1141	2.819
Energy Fuels	1083	2.675
Geosciences Multidisciplinary	1002	2.475
Chemistry Multidisciplinary	1000	2.470



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Economics	899	2.221
Biodiversity Conservation	781	1.929
Biochemistry Molecular Biology	766	1.892
Geography	712	1.759
Meteorology Atmospheric Sciences	689	1.702
Engineering Chemical	651	1.608
Materials Science Multidisciplinary	618	1.527
Horticulture	610	1.507

Table : 3 Most cited and productive Institutions

#	Highly Cited Institutions			Most Productive Institutions		
	Institution	Records	Citations	Institution	Records	Citations
1	Wageningen University	78	22238	Chinese Academy of Science	102	17953
2	Chinese Academy of Science	102	17953	Wageningen University	78	22238
3	University Minnesota	30	17887	University Calif Davis	51	16539
4	University Calif Davis	51	16539	INRA	49	15899
5	INRA	49	15899	China Agr University	48	9512
6	University Oxford	27	14284	Cornell University	48	11535
7	University Calif Berkeley	46	13815	University Calif Berkeley	46	13815
8	University Essex	13	12051	Michigan State University	45	11382
9	Cornell University	48	11535	University Aberdeen	34	9939
10	USDA ARS	33	11450	University Chinese Acad Sci	34	6019
11	Michigan State University	45	11382	USDA ARS	33	11450
12	University Sussex	13	11142	Swedish University Agr Sci	31	6329
13	Ohio State University	26	10262	University Minnesota	30	17887
14	University Aberdeen	34	9939	University Ghent	28	5383
15	China Agr University	48	9512	University Reading	28	6212
16	McGill University	23	9402	Chinese Acad Agr Sci	27	4891
17	University Stirling	4	8347	CSIC	27	4743
18	Agr and Hort Dev Board	3	8298	University Oxford	27	14284
19	Syngenta AG	2	7941	Ohio State University	26	10262
20	UK Govt Off Science	2	7941	University Florida	26	6832

Table :4 Most preferred and highly cited papers

#	Journal	Records	Citations
1	AGRICULTURE ECOSYSTEMS and ENVIRONMENT	80	17797
2	AGRONOMY FOR SUSTAINABLE DEVELOPMENT	79	19386
3	SCIENCE OF THE TOTAL ENVIRONMENT	69	13612
4	JOURNAL OF CLEANER PRODUCTION	51	8631
5	FRONTIERS IN PLANT SCIENCE	42	9997
6	PROCEEDINGS OF THE NATIONAL ACADEMY OF SCIENCES OF THE UNITED STATES OF AMERICA	42	20739
7	SUSTAINABILITY	39	8038
8	AGRICULTURAL WATER MANAGEMENT	32	5121
9	SOIL and TILLAGE RESEARCH	31	6177
10	AGRICULTURAL SYSTEMS	29	5170
11	JOURNAL OF ENVIRONMENTAL MANAGEMENT	29	4967
12	FRONTIERS IN MICROBIOLOGY	26	6215





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13	RENEWABLE and SUSTAINABLE ENERGY REVIEWS	25	4824
14	PLANT AND SOIL	24	6676
15	APPLIED SOIL ECOLOGY	22	4648
16	JOURNAL OF RURAL STUDIES	21	5466
17	LAND USE POLICY	21	3653
18	SOIL BIOLOGY and BIOCHEMISTRY	20	4989
19	AGRONOMY-BASEL	19	2817
20	ECOLOGICAL ECONOMICS	18	3310
21	FIELD CROPS RESEARCH	17	4866
22	PHILOSOPHICAL TRANSACTIONS OF THE ROYAL SOCIETY B-BIOLOGICAL SCIENCES	17	6073
23	PLOS ONE	16	4411
24	ENVIRONMENTAL SCIENCE AND POLLUTION RESEARCH	15	3275
25	NATURE	15	10308
26	NEW PHYTOLOGIST	15	3730
27	RESOURCES CONSERVATION AND RECYCLING	15	2575
28	SCIENTIFIC REPORTS	15	2645
29	AGRICULTURE AND HUMAN VALUES	14	2691
30	BIORESOURCE TECHNOLOGY	14	3051
31	TRENDS IN PLANT SCIENCE	14	3045
32	FRONTIERS IN SUSTAINABLE FOOD SYSTEMS	13	2169
33	JOURNAL OF APPLIED ECOLOGY	13	2271
34	NATURE SUSTAINABILITY	13	2813
35	CRITICAL REVIEWS IN PLANT SCIENCES	12	2562
36	ECOLOGICAL INDICATORS	12	1603
37	GLOBAL ENVIRONMENTAL CHANGE-HUMAN AND POLICY DIMENSIONS	12	3240
38	GLOBAL FOOD SECURITY-AGRICULTURE POLICY ECONOMICS AND ENVIRONMENT	12	1936
39	INTERNATIONAL JOURNAL OF MOLECULAR SCIENCES	12	1994
40	JOURNAL OF AGRICULTURAL AND FOOD CHEMISTRY	12	2602
41	JOURNAL OF HYDROLOGY	12	1890
42	ANNALS OF BOTANY	11	3903
43	ENVIRONMENTAL RESEARCH LETTERS	11	1720
44	FOOD POLICY	11	2491
45	FOOD SECURITY	11	2496
46	GLOBAL CHANGE BIOLOGY	11	2487
47	BIOSCIENCE	10	2711
48	CHEMOSPHERE	10	2030
49	COMPUTERS AND ELECTRONICS IN AGRICULTURE	10	2757
50	CURRENT OPINION IN ENVIRONMENTAL SUSTAINABILITY	10	2292
51	ECOLOGY AND SOCIETY	10	2398
52	ENVIRONMENTAL SCIENCE and TECHNOLOGY	10	2159
53	GEODERMA	10	4278
54	JOURNAL OF EXPERIMENTAL BOTANY	10	2086
55	JOURNAL OF HAZARDOUS MATERIALS	10	2144
56	NATURE COMMUNICATIONS	10	2622
57	RENEWABLE AGRICULTURE AND FOOD SYSTEMS	10	1675





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58	APPLIED ENERGY	9	1598
59	BIOTECHNOLOGY ADVANCES	9	2370
60	CATENA	9	1447

Table :5 Highly cited and productive authors

#	Author	Records	Citations	Author	Records	Citations
1	Smith P	24	7755	Pretty J	<u>11</u>	12233
2	Lal R	19	8666	Godfray HCJ	<u>8</u>	10453
3	Kumar A	13	2819	Toulmin C	<u>5</u>	10121
4	Zhang FS	13	3831	Lal R	<u>19</u>	8666
5	Herrero M	12	3184	Robinson S	<u>4</u>	8403
6	Fraceto LF	11	1731	Haddad L	<u>3</u>	8298
7	Kumar S	11	2043	Lawrence D	<u>3</u>	8292
8	Pretty J	11	12233	Crute IR	<u>2</u>	7941
9	Singh A	11	1842	Muir JF	<u>2</u>	7941
10	Thierfelder C	10	1522	Smith P	<u>24</u>	7755
11	Wang Y	10	1377	Foley JA	<u>6</u>	7585
12	Babalola OO	9	2721	Beddington JR	<u>1</u>	7529
13	Giller KE	9	2398	Thomas SM	<u>1</u>	7529
14	Glaser B	9	2880	Tilman D	<u>2</u>	5893
15	Jat ML	9	1465	Ramankutty N	<u>6</u>	5660
16	Ladha JK	9	1882	Hill J	<u>2</u>	5182
17	Singh R	9	1526	Balzer C	<u>1</u>	4972
18	Thornton PK	9	2761	Befort BL	<u>1</u>	4972
19	White JC	9	2290	Ray DK	<u>3</u>	4360
20	Godfray HCJ	8	10453	Mueller ND	<u>3</u>	4306

Table: 6 Funding Agencies

Funding Agencies	Record Count	%
NATIONAL NATURAL SCIENCE FOUNDATION OF CHINA NSFC	3727	9.207
EUROPEAN UNION EU	1345	3.323
NATIONAL KEY RESEARCH DEVELOPMENT PROGRAM OF CHINA	976	2.411
NATIONAL KEY RESEARCH DEVELOPMENT PROGRAM OF CHINA	783	1.934
CONSELHO NACIONAL DE DESENVOLVIMENTO CIENTIFICO E TECNOLÓGICO CNPQ	661	1.633
NATIONAL SCIENCE FOUNDATION NSF	591	1.460
CGIAR	559	1.381
COORDENACAO DE APERFEICOAMENTO DE PESSOAL DE NIVEL SUPERIOR CAPES	519	1.282
SPANISH GOVERNMENT	474	1.171
UNITED STATES DEPARTMENT OF AGRICULTURE USDA	451	1.114
FUNDAMENTAL RESEARCH FUNDS FOR THE CENTRAL UNIVERSITIES	375	0.926
KING SAUD UNIVERSITY	348	0.860
BIOTECHNOLOGY AND BIOLOGICAL SCIENCES RESEARCH COUNCIL BBSRC	344	0.850
NATIONAL KEY R D PROGRAM OF CHINA	338	0.835
FEDERAL MINISTRY OF EDUCATION RESEARCH BMBF	332	0.820
CHINESE ACADEMY OF SCIENCES	326	0.805
FUNDACAO DE AMPARO A PESQUISA DO ESTADO DE SAO PAULO FAPESP	284	0.702
FUNDACAO PARA A CIENCIA E A TECNOLOGIA FCT	284	0.702



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NATURAL ENVIRONMENT RESEARCH COUNCIL NERC	284	0.702
GERMAN RESEARCH FOUNDATION DFG	258	0.637

Table :7 Highly cited papers

#	Date / Author / Journal	Citations
1	602 Godfray HCJ, Beddington JR, Crute IR, Haddad L, Lawrence D, <i>et al.</i> Food Security: The Challenge of Feeding 9 Billion People SCIENCE. 2010 FEB 12; 327 (5967): 812-818	7529
2	754 Tilman D, Balzer C, Hill J, Befort BL, Global food demand and the sustainable intensification of agriculture, PROCEEDINGS OF THE NATIONAL ACADEMY OF SCIENCES OF THE UNITED STATES OF AMERICA. 2011 DEC 13; 108 (50): 20260-20264	4972
3	961 Saha S, Moorthi S, Wu XR, Wang J, Nadiga S, <i>et al.</i> , The NCEP Climate Forecast System Version 2, JOURNAL OF CLIMATE. 2014 MAR; 27 (6): 2185-2208	2488
4	274 Lal R, Soil carbon sequestration to mitigate climate change GEODERMA. 2004 NOV; 123 (1-2): 1-22	2391
5	921 Philippot L, Raaijmakers JM, Lemanceau P, van der Putten WH Going back to the roots: the microbial ecology of the rhizosphere NATURE REVIEWS MICROBIOLOGY. 2013 NOV; 11 (11): 789-799	2303
6	889 Ray DK, Mueller ND, West PC, Foley JA, Yield Trends Are Insufficient to Double Global Crop Production by 2050, PLOS ONE. 2013 JUN 19; 8 (6): Art. No. e66428	2196
7	1764 Sánchez-Bayo F, Wyckhuys KAG, Worldwide decline of the entomofauna: A review of its drivers, BIOLOGICAL CONSERVATION. 2019 APR; 232: 8-27	2027
8	828 Mueller ND, Gerber JS, Johnston M, Ray DK, Ramankutty N, <i>et al.</i> Closing yield gaps through nutrient and water management NATURE. 2012 OCT 11; 490 (7419): 254-257	1989
9	1227 Zhang X, Davidson EA, Mauzerall DL, Searchinger TD, Dumas P, <i>et al.</i> Managing nitrogen for sustainable development, NATURE. 2015 DEC 3; 528 (7580): 51-59	1744
10	72 Kemp R, Schot J, Hoogma R, Regime shifts to sustainability through processes of niche formation: The approach of strategic niche management TECHNOLOGY ANALYSIS and STRATEGIC MANAGEMENT. 1998 JUN; 10 (2): 175-195	1652
11	98 Altieri MA, The ecological role of biodiversity in agroecosystems AGRICULTURE ECOSYSTEMS and ENVIRONMENT. 1999 JUN; 74 (1-3): 19-31	1572
12	107 Ramankutty N, Foley JA, Estimating historical changes in global land cover: Croplands from 1700 to 1992 GLOBAL BIOGEOCHEMICAL CYCLES. 1999 DEC; 13 (4): 997-1027	1460
13	756 Xu GH, Fan XR, Miller AJ, Plant Nitrogen Assimilation and Use Efficiency ANNUAL REVIEW OF PLANT BIOLOGY, VOL 63. 2012; 63: 153-182	1439
14	789 Bhattacharyya PN, Jha DK, Plant growth-promoting rhizobacteria (PGPR): emergence in agriculture, WORLD JOURNAL OF MICROBIOLOGY and BIOTECHNOLOGY. 2012 APR; 28 (4): 1327-1350	1401
15	793 Seufert V, Ramankutty N, Foley JA, Comparing the yields of organic and conventional agriculture, NATURE. 2012 MAY 10; 485 (7397): 229-U113	1361
16	430 Howden SM, Soussana JF, Tubiello FN, Chhetri N, Dunlop M, <i>et al.</i> Adapting agriculture to climate change, PROCEEDINGS OF THE NATIONAL ACADEMY OF SCIENCES OF THE UNITED STATES OF AMERICA. 2007 DEC 11; 104 (50): 19691-19696	1338
17	419 Montgomery DR, Soil erosion and agricultural sustainability PROCEEDINGS OF THE NATIONAL ACADEMY OF SCIENCES OF THE UNITED STATES OF AMERICA. 2007 AUG 14; 104 (33): 13268-13272	1336
18	576 Powles SB, Yu Q, Evolution in Action: Plants Resistant to Herbicides ANNUAL REVIEW OF PLANT BIOLOGY, VOL 61. 2010; 61: 317-347	1266



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19	651 Kearney J, Food consumption trends and drivers PHILOSOPHICAL TRANSACTIONS OF THE ROYAL SOCIETY B-BIOLOGICAL SCIENCES. 2010 SEP 27; 365 (1554): 2793-2807	1203
20	624 Masclaux-Daubresse C, Daniel-Vedele F, Dechorgnat J, Chardon F, Gaufichon L, <i>et al.</i> , Nitrogen uptake, assimilation and remobilization in plants: challenges for sustainable and productive agriculture ANNALS OF BOTANY. 2010 JUN; 105 (7): 1141-1157	1180
21	894 Garnett T, Appleby MC, Balmford A, Bateman IJ, Benton TG, <i>et al.</i> Sustainable Intensification in Agriculture: Premises and Policies SCIENCE. 2013 JUL 5; 341 (6141): 33-34	1140
22	173 Morland K, Wing S, Roux AD, Poole C, Neighborhood characteristics associated with the location of food stores and food service places AMERICAN JOURNAL OF PREVENTIVE MEDICINE. 2002 JAN; 22 (1): Art. No. PII S0749- 377(01)00403-2	1119
23	1166 Montoya JH, Tsai C, Vojvodic A, Norskov JK, The Challenge of Electrochemical Ammonia Synthesis: A New Perspective on the Role of Nitrogen Scaling Relations, CHEMSUSCHEM. 2015 JUL 8; 8 (13): 2180-2186	1118
24	874 van Ittersum MK, Cassman KG, Grassini P, Wolf J, Tittmonell P, <i>et al.</i> Yield gap analysis with local to global relevance-A review FIELD CROPS RESEARCH. 2013 MAR 1; 143: 4-17	1117
25	1322 Nicolopoulou-Stamati P, Maipas S, Kotampasi C, Stamatis P, Hens L Chemical Pesticides and Human Health: The Urgent Need for a New Concept in Agriculture, FRONTIERS IN PUBLIC HEALTH. 2016 JUL 18; 4: Art. No. 148	1094
26	615 Diacono M, Montemurro F, Long-term effects of organic amendments on soil fertility. A review, AGRONOMY FOR SUSTAINABLE DEVELOPMENT. 2010 APR-JUN; 30 (2): 401-422	1093
27	1190 Keenan RJ, Reams GA, Achard F, de Freitas JV, Grainger A, <i>et al.</i> Dynamics of global forest area: Results from the FAO Global Forest Resources Assessment 2015, FOREST ECOLOGY AND MANAGEMENT. 2015 SEP 7; 352: 9-20	1087
28	724 Zimmerman AR, Gao B, Ahn MY, Positive and negative carbon mineralization priming effects among a variety of biochar-amended soils SOIL BIOLOGY and BIOCHEMISTRY. 2011 JUN; 43 (6): 1169-1179	1084
29	271 Lal R, Carbon emission from farm operations ENVIRONMENT INTERNATIONAL. 2004 SEP; 30 (7): 981-990	1049
30	1090 Pittelkow CM, Liang XQ, Linquist BA, van Groenigen KJ, Lee J, <i>et al.</i> Productivity limits and potentials of the principles of conservation agriculture NATURE. 2015 JAN 15; 517 (7534): 365-U482	1041
31	186 Olesen JE, Bindi M, Consequences of climate change for European agricultural productivity, land use and policy, EUROPEAN JOURNAL OF AGRONOMY. 2002 JUN; 16 (4): Art. No. PII S1161- 0301(02)00004-7	1024
32	1689 Backer R, Rokem JS, Ilangumaran G, Lamont J, Praslickova D, <i>et al.</i> Plant Growth-Promoting Rhizobacteria: Context, Mechanisms of Action, and Roadmap to Commercialization of Biostimulants for Sustainable Agriculture FRONTIERS IN PLANT SCIENCE. 2018 OCT 23; 9: Art. No. 1473	1019



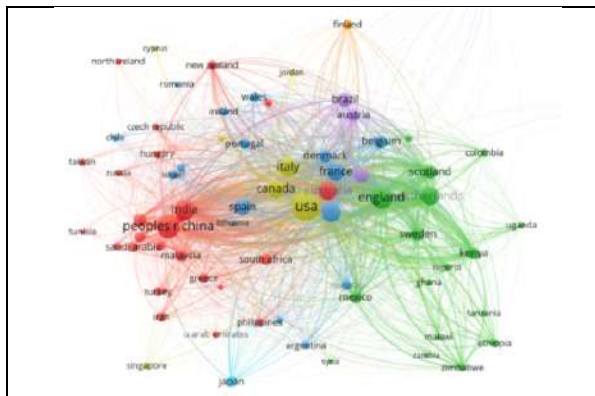


Fig.1: Citation Network of Countries

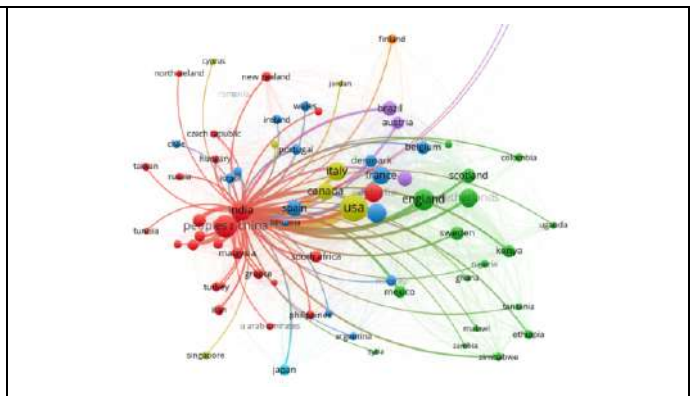


Fig.2: Citation Network of India

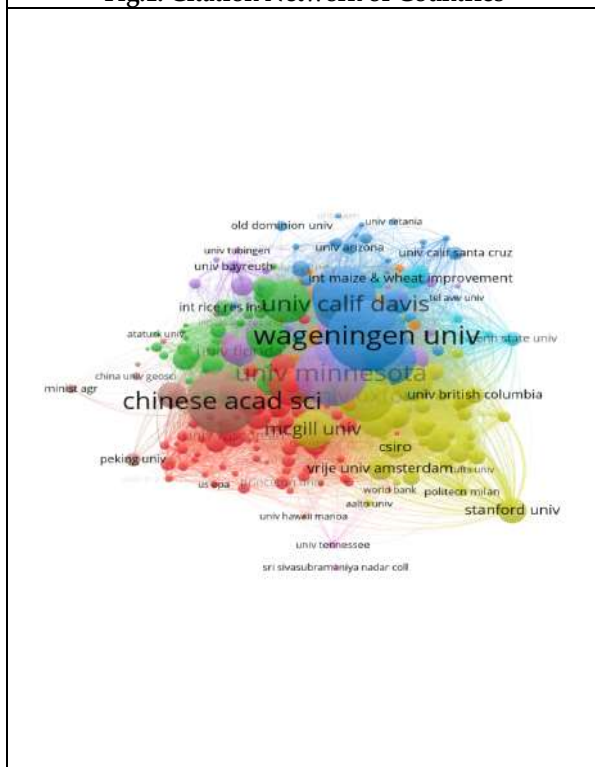


Fig.3: Citation Network of Institutions

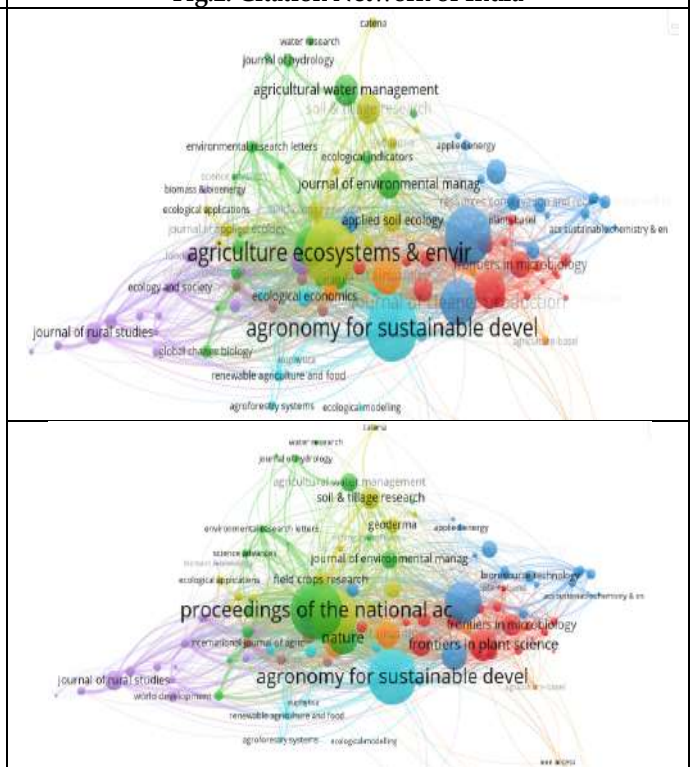


Fig.4: Publications and Citation Network

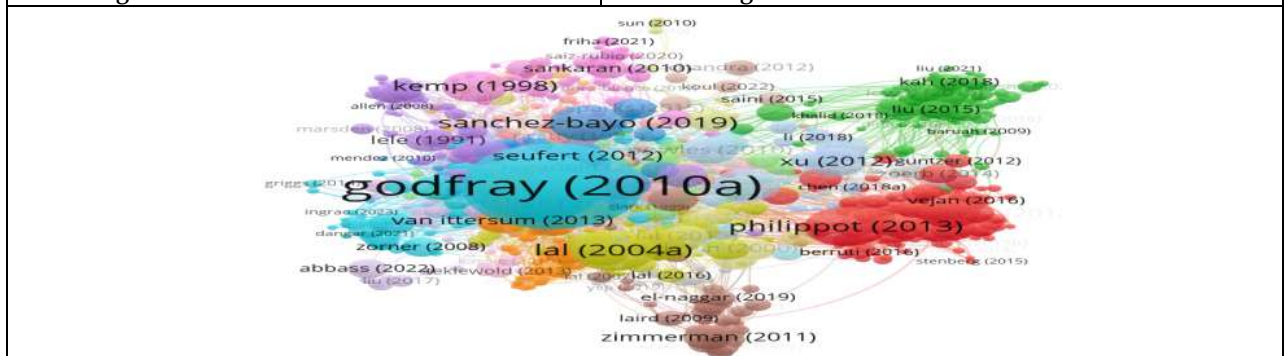


Fig.5: Highly Cited papers





RESEARCH ARTICLE

Phytochemical Composition, Antioxidant Potential and Anti-Bacterial Activity of Plant *Pennisetum hohenackeri* Hochst. Ex Steud.

Vasundhara Chauhan¹, Aanal Maitreya², Nainesh Modi^{3*}, Milan Dabhi⁴ and Dweipayan Goswami⁵

¹M.Sc Botany Student, Department of Botany, Gujarat University, Ahmedabad, Gujarat, India.

²Ph.D. Scholar, Department of Botany, Gujarat University, Ahmedabad, Gujarat, India.

³Professor, Department of Botany, Gujarat University, Ahmedabad, Gujarat, India.

⁴Ph.D. Scholar, Department of Microbiology Gujarat University, Ahmedabad, Gujarat, India.

⁵Professor, Department of Microbiology Gujarat University, Ahmedabad, Gujarat, India.

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*Address for Correspondence

Nainesh Modi

Professor,

Department of Botany,

Gujarat University, Ahmedabad, Gujarat, India.

E.Mail: nrmodi@gujaratuniversity.ac.in



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ABSTRACT

Pennisetum hohenackeri Hochst. ex Steud. is a tropical and subtropical plant that belongs to the poaceae family. This perennial grass has linear leaves and 1.5-meter-tall panicle inflorescences that resemble spikes. It grows in woodlands, meadows, and at the sides of roads. It can be used to paint animals, make traditional medicines, and make an appealing plant. Plant extract was prepared in three solvent like D.W., methanol, and hexane by cold extraction method. There were several activities performed such as, qualitative and quantitative analysis of phytochemicals, antioxidant, and antibacterial analysis. Using the spectrophotometric approach, quantitative assays have been employed to determine the total amount of phenols, flavonoids, and tannins. Using the 2,2-diphenyl-1-picrylhydrazyl (DPPH) and phosphomolybdate assay (PMA), the antioxidant activity was assessed. Gram-positive bacteria (*Staphylococcus aureus*) and Gram-negative bacteria (*Escherichia coli*) were the two bacterial strains against antibacterial activity was assessed using the well diffusion method. The result provided statistical information on the plant's ability to scavenge free radical and lessen oxidative stress. *P. hohenackeri* Hochst. ex Steud. methanolic extract of stem possesses the highest flavonoid content with value of (3.570±0.003). Whereas, the highest phenolic content was found in hexane extract of leaves (6.041±0.046). The highest tannin content was seen in the methanolic extract of leaves with the value of (4.036±0.056). The D.W. extract of leaves shows the highest antioxidant activity in DPPH assay with the lowest IC50 value of 6.80. While, in PMA assay hexane extract of leaves shows highest total antioxidant capacity with the value of 0.79 ± 0.018. In antibacterial activity, highest bacterial inhibition was seen in methanolic



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extract of stem against *S. aureus* with the zone of inhibition of 15 mm. The plant contains primary and secondary metabolites and also shows significant properties of antioxidants and antibacterial activities.

Keywords: *Pennisetum hohenackeri* Hochst. ex Steud., Phytochemicals, Antioxidant activity, Antibacterial activity

INTRODUCTION

Pennisetum hohenackeri Hochst. ex Steud. is a plant belonging to family Poaceae and is also known as the 'Fountain Grass', which has been the focus of various taxonomic study because of its distinctive traits and broad range. It is essential to comprehend this plant's taxonomy and evolutionary links in order to properly identify, conserve, and maybe use it in a variety of ecological and agricultural uses. The evolutionary ties between the closely related genus *Cenchrus* and the genus *Pennisetum* have been clarified by recent molecular investigations (Donadio *et al.*, 2009). These investigations have shown that the species of *Pennisetum* and *Cenchrus* in the United States may have had many origins from Old World species, indicating a complicated evolutionary history (Donadio and colleagues, 2009).

A grass species of significant ecological value, *Pennisetum hohenackeri* Hochst. ex Steud., has drawn more attention recently because of its potential as a storehouse of many phytochemicals, which calls for careful scientific investigation (Yong *et al.*, 2021). Plants produce bioactive substances called phytochemicals, which are essential for mediating interactions between plants and their surroundings, providing tolerance to biotic and abiotic stressors, and promoting the general survival and growth of plants. As of their varied pharmacological properties, these compounds are also useful in a variety of applications, such as medicines, nutraceuticals, and cosmetics (Yong *et al.*, 2021). Examining *Pennisetum hohenackeri* Hochst. ex Steud. phytochemical makeup has great potential to reveal its potential advantages in a number of industries. According to preliminary studies, *Pennisetum* species, including *Pennisetum hohenackeri* Hochst. ex Steud., may contain a wide range of phytochemicals, such as phenolic compounds, alkaloids, terpenoids, and flavonoids, each of which contributes distinct qualities and bioactivities (Mitsi and Echeverría, 2024). To maximize extraction and utilization strategies, it is essential to comprehend the phytochemicals' temporal and spatial distribution within plant tissues as well as how they react to environmental stimuli (Yong *et al.*, 2021). The observed resilience and adaptability to a variety of environmental conditions, which point to the presence of strong defence mechanisms mediated by specialized metabolites, is what spurred research into *Pennisetum hohenackeri* Hochst. ex Steud. phytochemical profile (Feng *et al.*, 2023). These metabolites might provide important hints for creating new crop protection techniques or locating possible sources of bioactive substances with medicinal value.

MATERIALS AND METHODOLOGY

Plant collection

Pennisetum hohenackeri Hochst. ex Steud (Fig. 1).

Leaves and stem of *Pennisetum hohenackeri* Hochst. ex Steud. were collected from Botanical garden, Department of Botany, Gujarat University on 16th January, 2025.

Preparation of sample extract

The leaves and stems of the plant were dehydrated by being exposed to sunlight. Then the leaves and stems were properly smashed and stored them in sterile zip bags for the extraction process. 10 g of the sample powder was combined and dissolved in distilled water and methanol, accordingly. Given the mixture enough time to dissolve properly in the appropriate solvents. Dried the liquid extract in a Petri dish and let it dry after separating the mixture in test tubes using filter paper. After that, made an extract by combining 0.030 g of dry extract with 30 ml of the appropriate solvent.



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Chemicals: Plant extract, Folin-Ciocalteu phenol reagent, Folin-Ciocalteu reagent, sodium hydroxide, aluminium chloride, sodium phosphate, sodium nitrite, carbonate, ammonium molybdate, DPPH powder, Mueller-Hinton Broth (MHB), distilled water, bacterial strain of *Staphylococcus aureus* and *Escherichia coli*.

Phytochemical Screening

Qualitative Analysis

Alkaloids test

Wagner's test: In the test tubes, 1 mL of extract and 1 mL of Wagner's reagent were added. Alkaloids are indicated by their brown or reddish appearance (Raaman, N., 2006).

Iodine test: In a test tube, 3 mL of extract and then 3-4 drops of iodine solution were added. Alkaloids are indicated by blue precipitates. (Bhatt and Dhvani, 2012).

Flavonoid test

The lead acetate test: Involves adding a few drops of 10% lead acetate to a test tube containing 1 mL of plant extract. When a yellow precipitate appears, flavonoids are present in the extract (De Silva, G. et al., 2017).

Concentrated H₂SO₄ test: In a test tube, 1 mL of concentrated H₂SO₄ was added after 2 mL of plant extract. Flavonoids are indicated by an orange appearance (Tyagi, T., 2017).

Phenol Test

Iodine test: 1 mL of plant extract was added into a test tube, then a few drops of diluted iodine solution were added into the test tube. Phenol is indicated by a crimson appearance (Jagessar, R., 2017).

Folin-Ciocalteu test: In a test tube, 0.5 mL of extract and 1 mL of Folin-Ciocalteu reagent were added. There is phenol present in the extract when the precipitate appears in bluish green colour.

Saponin Test

The sodium bicarbonate test: Involved adding 1 mL of a 5% sodium bicarbonate solution to a test tube containing 2 mL of extract. Saponins are present when a honeycomb-like foam appears in the test tube.

Olive oil test: Filled the test tubes with 2 mL of extract and added 2 drops of olive oil. The test tubes were then shaken. Saponins are indicated by the appearance of foam or emulsification.

Lignin test

Labat test: Added 2 mL of extract into a test tube, then added a few drops of gallic acid. The presence of lignin is indicated by an olive-green appearance (Bhatt, S. and Dhvani, S., 2012).

Tannin Test

Lead acetate test: In a test tube, added 2 mL of extract and 1 mL of 10% lead acetate solution. Tannin is present when precipitates appear to be in white or brownish colour. (Sheel, R. et al., 2014).

Quantitative Analysis

Total Phenolic Content (TPC) determination: TPC is determined using the Folin-Ciocalteu technique. TPC is measured using gallic acid as a standard. 3 mL of distilled water was added to 1 mL of extracted water, followed by 0.5 mL of Folin-Ciocalteu reagent. The mixture is then left to incubate for three minutes at room temperature. 2 mL of Na₂CO₃ was added after incubation, and test tubes were then heated in a water bath for one minute.

Total Flavonoid Content (TFC) determination: The AlCl₃ technique is employed to determine TFC. The standard for TFC is quercetin. After adding 1 mL of extract and 0.3 mL of 5% NaNO₂, the test tube was allowed to rest at room temperature for five minutes. The test tube was then allowed to incubate for another six minutes at room temperature after adding 0.3 mL of 10% AlCl₃. 2 mL of 1M NaOH was then added after 3.3 mL of distilled water. Using a spectrophotometer, the absorbance of the sample was determined at 510 nm (Zhishen, J. et al., 1999).





Total Tannin Content (TTC) determination: TTC is calculated using the Folin-phenol technique. The standard for TTC is tannic acid. 0.4 mL of the Folin-phenol reagent and 7.5 mL of distilled water were added after 1 mL of plant extract. After that, made the volume up to 10 mL in the test tubes, followed by the addition of 1 mL of 35% Na₂CO₃. The test tubes were then left to incubate at room temperature for half an hour. The absorbance of the sample was determined using a spectrophotometer set to 725 nm (Lahare, R. *et al.*, 2021).

Antioxidant Activity

DPPH scavenging activity

1 mg of leaf extract was mixed with 1 mL of methanol. In triplicate, the standard and plant extract series were prepared using 1 mL of extract per test tube with concentrations ranging from 20 to 100 mg/mL. A new solution was made by dissolving 4 mg of powdered DPPH in 100 mL of methanol (DPPH is insoluble in water) and stored it in a dark location, as DPPH is a light-sensitive chemical. A series of extracts with varying concentrations were prepared, followed by the addition of 3 mL of DPPH solution and an incubation period of 20 to 30 minutes. The absorbance of these incubated colour-altered extracts was measured at 517 nm using a spectrophotometer, and the results were then computed using the ascorbic acid standard curve (Pattni *et al.*, 2023).

PMA (Phosphomolybdate Assay)

The total antioxidant capacity was determined using the phosphomolybdenum assay method. The standard for PMA is ascorbic acid. For the test, 0.2 mL of extract was used, and then 2 mL of phosphomolybdenum reagent was added. The test tubes were then allowed to cool to room temperature after being incubated in a water bath at 90 degrees for 90 minutes. The absorbance of the sample was then determined using a spectrophotometer set to 765 nm (Prieto, P. *et al.*, 1999).

Anti-bacterial activity

The antibacterial activity of the plant extracts was evaluated using the agar well diffusion assay against *Escherichia coli* and *Staphylococcus aureus*. The bacterial strains were freshly sub-cultured in Mueller-Hinton Broth (MHB) and incubated at 37°C for 18–24 hours to obtain actively growing cultures. Prior to inoculation, the bacterial suspensions were standardized to 0.5 McFarland turbidity standard, corresponding to approximately 1.5×10^8 CFU/mL. This standardization was achieved using a spectrophotometer at 600 nm. Mueller-Hinton Agar (MHA) plates were prepared and surface-inoculated by uniformly spreading the standardized bacterial suspension using sterile cotton swabs in three directions to ensure even lawn growth, following the Clinical and Laboratory Standards Institute (CLSI) guidelines (CLSI, 2023). After allowing the inoculated plates to dry for 10–15 minutes at room temperature, wells of 6 mm diameter were aseptically punched into the agar using a sterile cork-borer. Each well was carefully filled with 50 µL of the plant extract under aseptic conditions. The plates were then incubated at $37 \pm 1^\circ\text{C}$ for 18 to 24 hours under aerobic conditions. Following incubation, the antibacterial efficacy of the plant extract was assessed by measuring the diameter of the clear zones of inhibition surrounding each well.

RESULT AND DISCUSSION

Qualitative Analysis

Phytochemical screening result (Table 1)

Primary and secondary metabolites such as alkaloids, flavonoids, phenol, tannin, and lignin were detected by phytochemical screening of plant extracts.

Quantitative Analysis

Total Phenolic Content (TPC)

Standard graph of total phenolic content (Graph 1).





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Table 2 displays the overall phenolic content of the plant *Pennisetum hohenackeri* Hochst. ex Steud., including plant parts such as leaves and stem. Hexane from the stem exhibits the highest total phenolic content value of any extract, at 6.041 ± 0.046 GAE/g. The stem lowest phenolic value is 0.025 ± 0.052 GAE/g.

Total Flavonoid Content (TFC)

Standard graph for the total flavonoid content (Graph 2).

Table 3 displays the overall flavonoid content of the plant *Pennisetum hohenackeri* Hochst. ex Steud., including plant parts such as leaves and stem. The stem methanol has the highest total flavonoid content value of 3.570 ± 0.003 QE/g. The lowest flavonoid value is 0.297 ± 0.007 QE/g in leaf methanol extracts.

Total Tannin Content test (TTC)

Standard graph for total tannin content (Graph 3).

Table 4 displays the overall tannin content of the plant *Pennisetum hohenackeri* Hochst. ex Steud., including the stem and leaves. The leaves methanol exhibits the highest total tannin content value of 4.036 ± 0.056 QE/g. The lowest tannin content is 0.174 ± 0.005 QE/g in leaf hexane extracts.

RESULT OF ANTIOXIDANT ACTIVITY

DPPH Antioxidant activity

IC₅₀ value of plant *Pennisetum hohenackeri* Hochst. ex Steud (Table 5). Standard graph of DPPH Antioxidant (Graph 4). % inhibition by D.W. extract of *Pennisetum hohenackeri* Hochst. ex Steud. leaves (Graph 5). % inhibition by D.W. extract of *Pennisetum hohenackeri* Hochst. ex Steud. stem (Graph 6). % inhibition by methanolic extract of *Pennisetum hohenackeri* Hochst. ex Steud. Leaves (Graph 7). % inhibition by methanolic extract of *Pennisetum hohenackeri* Hochst. ex Steud. Stem (Graph 8). % inhibition by hexane extract of *Pennisetum hohenackeri* Hochst. ex Steud. Stem (Graph 9). % inhibition by hexane extract of *Pennisetum hohenackeri* Hochst. ex Steud. Leaves (Graph 10). The IC₅₀ values for the several extract the plant *Pennisetum hohenackeri* Hochst. ex Steud. are shown in the table 5. Among all of the plant extracts, the D.W. extract of leaves has the strongest antioxidant activity, as its IC₅₀ value is the lowest, at 6 methanolic extract of leaves and stem have the lowest antioxidant activity to combat free radical because their IC₅₀ value is 2, the highest of all the extracts. Off all the extract of stem has the highest percentage radical scavenging activity (45.9).

Phosphomolybdate Assay (PMA)

Graph 11: Standard graph of Phosphomolybdate Assay (PMA)

PMA Assay of plant sample (Table 6)

Table 6 displays the overall antioxidant capacity of the plant *Pennisetum hohenackeri* Hochst. ex Steud. leaves and stem. The hexane extract of leaves has the maximum total antioxidant capacity (TAC) at 0.79 ± 0.018 AAE/g, whereas the D.W. extract of leaves has the lowest total antioxidant capacity 0.639 ± 0.006 AAE/g.

Anti- bacterial activity

Antibacterial activity for the plant extracts were performed against two bacterial strains: *Staphylococcus aureus* and *Escherichia coli*. Results are described in the table below:

Result of anti- bacterial activity of *Pennisetum hohenackeri* Hochst. ex Steud (Table 7).

The plant *Pennisetum hohenackeri* Hochst. ex Steud. was tested for its antibacterial properties against two distinct of *Escherichia coli* and *Staphylococcus aureus*. The zone of inhibition is visible in some extract. The acetone extract of the stem has the smallest zone of inhibition against *S. aureus*, measuring just 2 mm, whereas the methanolic extract of stem shows 15 mm zone of inhibition. Only methanolic extract of fresh leaves demonstrates 11 mm zone of inhibition against *E. Coli*, indicating that the leaves have the least capacity to respond to bacterial growth.





CONCLUSION

This study discovered that *Pennisetum hohenackeri* Hochst. ex Steud. possess noteworthy number of phytochemical constituents; which shows presence of tannin, alkaloids, phenols, protein, lignin. The presence of phenols, tannins, and flavonoids indicates the antibacterial and antioxidant properties of plant. *P. hohenackeri* Hochst. ex Steud. shows the highest amount of phenols; while moderate amount of tannin and flavonoids. The DPPH antioxidant assay and PMA antioxidant assay shows the plant's ability to scavenge free radicals. It shows activity against the bacterial strain *S. aureus*. The plant may be used as a source for natural activity components, which have potential to use as important part in pharmaceutical industries.

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Table 1: Phytochemical screening result

Sr. No.	Phytochemical	Tests	Methanol	Hexane	D.W.			
			Leaf	Stem	Leaf	Stem	Leaf	Stem
1	Alkaloids	Wagner's test	+	+	-	+	-	-
		Iodine test	+	+	+	+	-	-
2	Flavonoids	Lead acetate test	-	-	-	-	+	+
		Conc. H ₂ SO ₄ test	-	-	-	+	+	+
3	Phenol	Iodine test	+	+	-	+	-	-
		Folin-Ciocalteu	+	+	+	+	-	-
4	Saponin	Sodium bicarbonate test	+	+	+	+	+	+
		Olive oil test	+	+	+	-	+	+
5	Lignin	Gallic acid test	+	+	-	+	+	+
6	Tannin	Lead acetate test	-	-	-	-	+	+

Table 2: Result of Total Phenolic Content (TPC) test of plant *Pennisetum hohenackeri* Hochst. ex Steud.

Plant Name	Plant Part	Extract Solvent	Volume (mL)	Total phenolics in mg of GAE/g
<i>Pennisetum hohenackeri</i> Hochst. ex Steud.	Leaves	Methanol	1 mL	0.283±0.006
	Stem	Methanol	1 mL	0.025±0.052
	Leaves	D.W.	1 mL	0.394±0.031
	Stem	D.W.	1 mL	0.040±0.022
	Leaves	Hexane	1 mL	6.041±0.046
	Stem	Hexane	1 mL	5.953±0.036

Table 3: Result of Total Flavonoid Content (TFC) test of plant *Pennisetum hohenackeri* Hochst. ex Steud.

Plant Name	Plant Part	Extract Solvent	Concentration (mL)	Total flavonoid in mg of (QE/g)
<i>Pennisetum hohenackeri</i> Hochst. ex Steud.	Leaves	Methanol	1 mL	0.297±0.007
	Stem	Methanol	1 mL	3.570±0.003
	Leaves	D.W.	1 mL	1.113±0.008
	Stem	D.W.	1 mL	0.821±0.001
	Leaves	Hexane	1 mL	1.359±0.004
	Stem	Hexane	1 mL	2.298±0.001

Table 4: Result of Total Tannin Content (TTC) test of plant *Pennisetum hohenackeri* Hochst. ex Steud.

Plant name	Plant Part	Extract Solvent	Concentration (mL)	Total tannin in mg of (QE/g)
<i>Pennisetum hohenackeri</i> Hochst. ex Steud.	Leaves	Methanol	1 mL	4.036±0.056
	Stem	Methanol	1 mL	3.833±0.005
	Leaves	D.W.	1 mL	0.289±0.409
	Stem	D.W.	1 mL	0.469±0.043
	Leaves	Hexane	1 mL	0.174±0.005
	Stem	Hexane	1 mL	1.198±0.018



Table 5: IC₅₀ value of plant *Pennisetum hohenackeri* Hochst. ex Steud.

Plant part	IC ₅₀ value of extracts		
	Methanol	Hexane	D.W.
Leaves	22.53	9.83	6.80
Stem	22.53	8.21	6.87

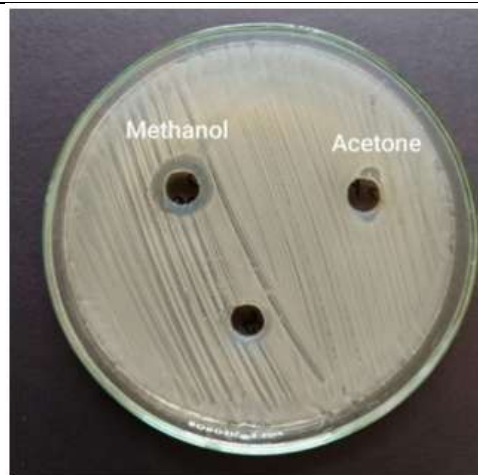
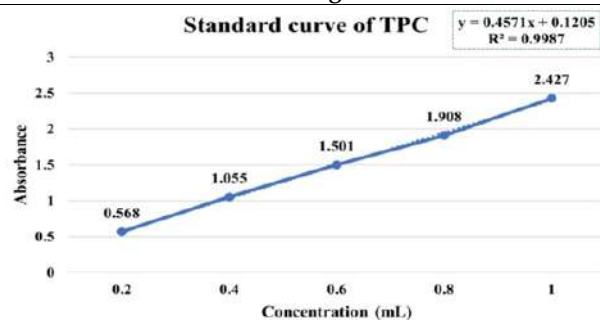
Table 6: PMA Assay of plant sample

Plant name	Plant Part	Extract Solvent	Concentration (mL)	Total Antioxidant capacity (TAC) in mg of AAE/g
<i>Pennisetum hohenackeri</i> Hochst. ex Steud.	Leaves	Methanol	1 mL	0.754±0.011
	Stem		1 mL	0.643±0.008
	Leaves	D.W.	1 mL	0.634±0.006
	Stem		1 mL	0.639±0.004
	Leaves	Hexane	1 mL	0.79±0.018
	Stem		1 mL	0.754±0.008

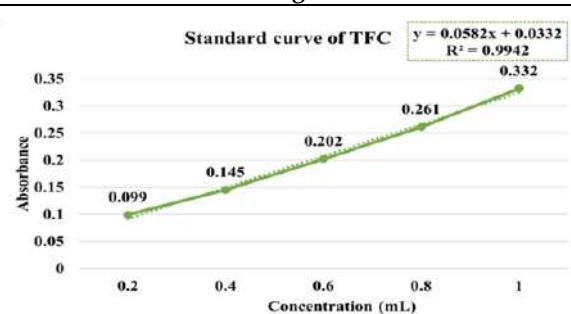
Table 7: Result of anti- bacterial activity of *Pennisetum hohenackeri* Hochst. ex Steud.

Plant Part	Extracts solution	Zone of inhibition with bacterial strain in millimetres (mm)	
		<i>Staphylococcus aureus</i>	<i>Escherichia coli</i>
Leaves	Methanol	-	-
	Acetone	-	-
	D.W.	-	-
Fresh Leaves	Methanol	-	11 mm
	Acetone	-	-
	D.W.	-	-
Stem	Methanol	15 mm	13 mm
	Acetone	2 mm	9 mm
	D.W.	-	-
Fresh Stem	Methanol	-	-
	Acetone	-	-
	D.W.	-	-

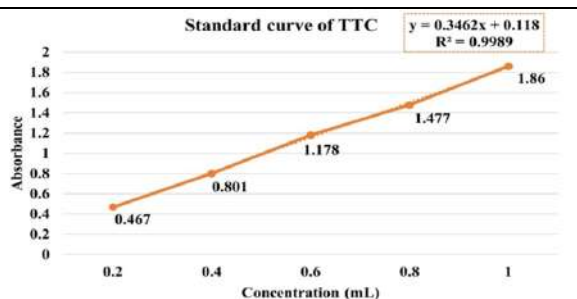
Fig. 1: *Pennisetum hohenackeri* Hochst. ex Steud.Fig 2: Antibacterial activity in Methanolic extract of fresh leaves against *E. coli*

Vasundhara Chauhan *et al.*,Fig. 3: Antibacterial activity in Methanol and Acetone extracts of stem against *E. coli*Fig 4: Antibacterial activity in Methanol and Acetone extracts of stem against *S. aureus*

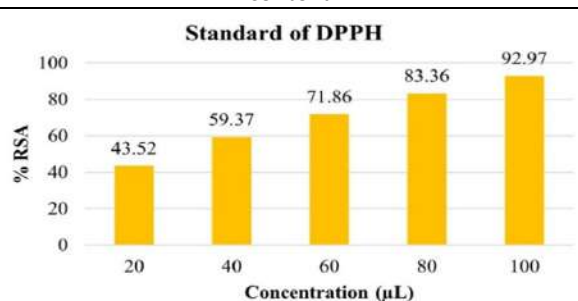
Graph 1: Standard graph of total phenolic content



Graph 2: Standard graph for the total flavonoid content



Graph 3: Standard graph for total tannin content



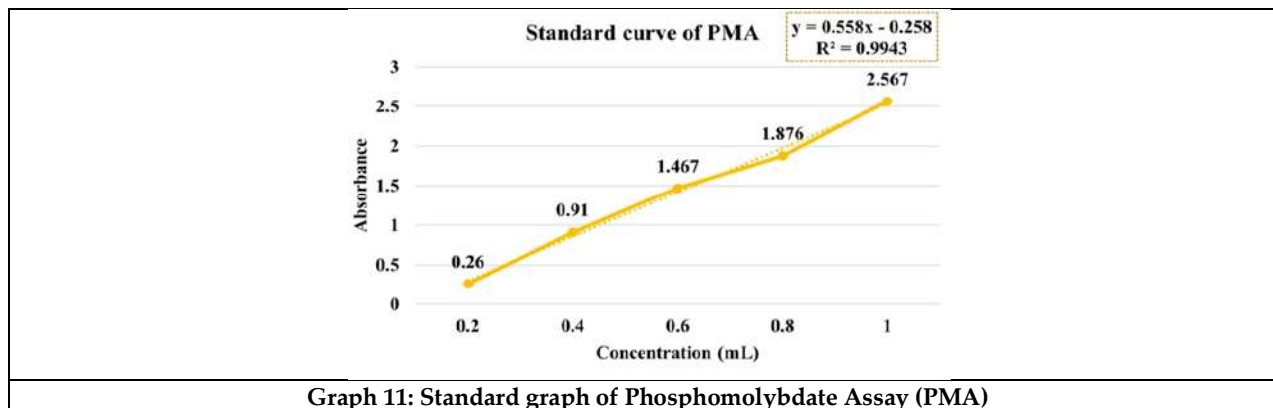
Graph 4: Standard graph of DPPH Antioxidant





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REVIEW ARTICLE

A Review on Advanced Nanocarrier - based Treatment Strategies for Peripheral Artery Disease

Vinamrata Vishwakarma^{1*}, Garvita Joshi^{2*} and Vikas Jain³

¹M.Pharm Student, Department of Pharmacy, Mahakal Institute of Pharmaceutical Studies, Ujjain, (Affiliated to Rajiv Gandhi Proudyogiki Vishvavidhyalaya, Bhopal), Madhya Pradesh, India.

²Professor, Department of Pharmacy, Mahakal Institute of Pharmaceutical Studies, Ujjain, (Affiliated to Rajiv Gandhi Proudyogiki Vishvavidhyalaya, Bhopal), Madhya Pradesh, India.

³Principal, Department of Pharmacy, Mahakal Institute of Pharmaceutical Studies, Ujjain, (Affiliated to Rajiv Gandhi Proudyogiki Vishvavidhyalaya, Bhopal), Madhya Pradesh, India.

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*Address for Correspondence

Vinamrata Vishwakarma

M.Pharm Student,

Department of Pharmacy,

Mahakal Institute of Pharmaceutical Studies, Ujjain,

(Affiliated to Rajiv Gandhi Proudyogiki Vishvavidhyalaya, Bhopal),

Madhya Pradesh, India.

E.Mail: vinamratavishwakarma@gmail.com



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ABSTRACT

Peripheral Artery Disease (PAD) is a progressive vascular disorder caused by the narrowing or occlusion of peripheral arteries, primarily due to atherosclerotic plaque formation. It leads to reduced blood flow to the limbs, causing claudication, ischemia, and in severe cases, limb loss. Despite its high global prevalence and association with cardiovascular morbidity, current treatment strategies—including pharmacological agents, angioplasty, and bypass surgery—often suffer from limitations such as poor drug bioavailability, systemic side effects, and lack of targeted efficacy. In this context, nanocarrier-based drug delivery systems offer a promising platform to enhance therapeutic outcomes in PAD management. Nanocarriers, including liposomes, polymeric nanoparticles, dendrimers, micelles, and inorganic nanoparticles, have demonstrated potential in delivering therapeutic agents with precision and control. These systems can be engineered to improve pharmacokinetics, selectively target ischemic or inflamed vascular tissues, and facilitate the sustained release of drugs or genes promoting angiogenesis and vascular repair. Functionalization with specific ligands enables active targeting to endothelial adhesion molecules or hypoxia-induced markers, while some systems are designed for theranostic applications, integrating imaging and therapy into a single platform. This review explores the latest advancements in nanocarrier technologies for PAD treatment, highlighting their mechanisms, delivery strategies, and preclinical efficacy. Furthermore, it addresses the current translational challenges, including issues



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related to safety, scalability, regulatory approval, and clinical heterogeneity. By synthesizing emerging research, we aim to provide insight into how nanomedicine can bridge current therapeutic gaps and pave the way for more effective, personalized treatment strategies for PAD.

Keywords: Peripheral Artery Disease, Nanocarriers, Drug Delivery, Angiogenesis, Theranostics, Targeted Therapy.

INTRODUCTION

Peripheral Artery Disease (PAD) is a chronic and progressive atherosclerotic disorder that primarily affects the lower extremities, resulting from the narrowing or complete obstruction of peripheral arteries[1]. It is estimated that over 200 million individuals worldwide suffer from PAD, making it a significant public health concern[2]. PAD is not only a leading cause of mobility limitations and diminished quality of life in aging populations, but it is also associated with a markedly increased risk of cardiovascular events, including myocardial infarction and stroke[3, 4]. Despite its prevalence, PAD remains underdiagnosed and undertreated, particularly in developing countries and among asymptomatic individuals[5]. The pathophysiology of PAD is complex and multifactorial, involving endothelial dysfunction, lipid accumulation, chronic inflammation, smooth muscle cell proliferation, and oxidative stress[6]. These factors lead to the development of atherosclerotic plaques that gradually occlude arterial blood flow. In severe cases, this ischemia results in critical limb ischemia (CLI), characterized by chronic pain, ulcers, and gangrene, often culminating in limb amputation[7]. A major clinical challenge in PAD management is the inability of current therapies to reverse or adequately halt disease progression in many patients[8]. Conventional treatment approaches for PAD include lifestyle interventions such as smoking cessation and exercise rehabilitation, pharmacologic therapies including antiplatelet agents, statins, and vasodilators, and invasive procedures such as endovascular angioplasty, stenting, and surgical bypass[9]. While these strategies provide symptomatic relief and improve circulation, they often do not adequately address the underlying pathobiological processes or prevent long-term complications. Moreover, systemic drug delivery is frequently associated with poor bioavailability, off-target effects, and dose-limiting toxicities[10]. To address these therapeutic limitations, the field of nanomedicine has emerged as a promising avenue for enhancing drug delivery to ischemic tissues and promoting vascular regeneration[11]. Nanocarrier-based systems are engineered at the nanoscale (1–1000 nm) and designed to encapsulate, protect, and transport therapeutic agents—including small molecules, proteins, peptides, nucleic acids, and imaging agents—directly to targeted tissues. These nanocarriers can improve the solubility and stability of drugs, prolong their circulation time, and enhance their accumulation at disease sites through passive or active targeting mechanisms[12–14]. Passive targeting exploits the enhanced permeability and retention (EPR) effect associated with inflamed and ischemic tissues, where the leaky vasculature allows preferential accumulation of nanoparticles[15]. In contrast, active targeting involves the functionalization of nanocarriers with ligands—such as antibodies, peptides, aptamers, or small molecules—that recognize specific biomarkers overexpressed in diseased endothelium, such as vascular cell adhesion molecule-1 (VCAM-1), intercellular adhesion molecule-1 (ICAM-1), or integrins (e.g., $\alpha_v\beta_3$). This specificity allows for more efficient delivery of therapeutic payloads with reduced systemic exposure[16, 17]. Various types of nanocarriers have been explored for PAD applications, including liposomes, polymeric nanoparticles, dendrimers, micelles, solid lipid nanoparticles, and inorganic systems such as gold or iron oxide nanoparticles[18]. Each of these platforms offers unique advantages in terms of drug loading capacity, release kinetics, biocompatibility, and potential for surface modification. For instance, liposomes are spherical vesicles composed of phospholipid bilayers that can encapsulate both hydrophilic and lipophilic drugs, while polymeric nanoparticles made from materials like PLGA (poly(lactic-co-glycolic acid)) can offer sustained and controlled drug release profiles[19]. Beyond drug delivery, nanocarriers can also be engineered for gene therapy applications in PAD. Delivering plasmid DNA, mRNA, or small interfering RNA (siRNA) that modulates angiogenic signaling or suppresses inflammatory mediators has shown significant promise in preclinical models[20]. For example, nanoparticles carrying vascular endothelial growth factor (VEGF) genes can stimulate neovascularization in ischemic limbs, while siRNA-loaded



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nanoparticles targeting monocyte chemoattractant protein-1 (MCP-1) can reduce vascular inflammation and monocyte recruitment[16]. One of the most exciting frontiers in nanomedicine is the development of theranostic nanocarriers—systems that combine therapeutic and diagnostic capabilities[21]. These multifunctional platforms allow for real-time monitoring of drug delivery, biodistribution, and therapeutic efficacy using imaging modalities such as magnetic resonance imaging (MRI), computed tomography (CT), photoacoustic imaging, or near-infrared fluorescence. Theranostic nanoparticles not only enhance the precision of PAD treatment but also facilitate personalized medicine approaches by enabling treatment decisions based on imaging feedback[22]. Despite the significant promise of nanocarrier-based systems in PAD, several challenges remain before they can be routinely implemented in clinical settings. One major hurdle is ensuring the biocompatibility and safety of nanocarriers, particularly with respect to immunogenicity, long-term accumulation in organs such as the liver and spleen, and potential interference with normal vascular functions[23]. Furthermore, scalable and reproducible manufacturing processes must be developed to meet Good Manufacturing Practice (GMP) standards for clinical translation. Regulatory frameworks for nanomedicines are still evolving, and rigorous clinical trials are required to establish their efficacy, safety, and cost-effectiveness compared to conventional therapies[24]. Another limitation lies in the heterogeneity of PAD itself. The disease manifests differently among individuals depending on age, gender, genetics, comorbidities such as diabetes and hypertension, and lifestyle factors. This variability necessitates the development of personalized treatment strategies, which nanomedicine is well poised to deliver. Advances in biomarker discovery and molecular imaging will be essential for patient stratification and for selecting the most appropriate nanotherapeutic intervention[25]. This review aims to provide a comprehensive overview of current advances in nanocarrier-based therapeutic strategies for PAD. We will discuss various classes of nanocarriers, their functionalization and targeting mechanisms, therapeutic applications—including pro-angiogenic, anti-inflammatory, and gene therapy approaches—and their integration into theranostic systems. Furthermore, we will highlight the current translational challenges and future prospects of bringing these innovative technologies from bench to bedside. By synthesizing emerging research in this rapidly evolving field, we seek to shed light on the transformative potential of nanocarrier-based solutions in addressing one of the most challenging vascular diseases of our time.

TYPES OF NANOCARRIERS FOR PERIPHERAL ARTERY DISEASE

Nanocarrier-based drug delivery systems have demonstrated immense potential in addressing the complex pathophysiology of PAD, which includes inflammation, endothelial dysfunction, and tissue ischemia[26]. Various nanocarrier platforms have been explored for their ability to deliver therapeutic agents with improved specificity, controlled release profiles, and enhanced cellular uptake. The following subsections describe the most widely investigated nanocarrier systems for PAD.

Liposomes

Liposomes are spherical vesicles composed of one or more phospholipid bilayers surrounding an aqueous core. Their amphiphilic nature allows them to encapsulate both hydrophilic drugs, which are housed within the aqueous core, and hydrophobic drugs, which are integrated into the lipid bilayer. This structural versatility makes liposomes highly suitable for a wide range of therapeutic applications[27]. In the context of PAD, liposomes offer several significant advantages. Firstly, their biocompatibility and biodegradability—stemming from their composition of naturally occurring lipids—minimize immunogenic responses and systemic toxicity. Secondly, liposomes can be engineered for targeted delivery by functionalizing their surface with ligands such as peptides, antibodies, or aptamers[19, 28]. This allows them to actively bind to molecular markers overexpressed in PAD, including vascular cell adhesion molecule-1 (VCAM-1), intercellular adhesion molecule-1 (ICAM-1), and various integrins present on inflamed endothelial tissues. Additionally, liposomal formulations can be tailored to provide controlled drug release, ensuring that therapeutic agents are delivered precisely and efficiently to ischemic sites. Research has demonstrated the efficacy of liposomes in PAD models, particularly those encapsulating anti-inflammatory agents like dexamethasone or pro-angiogenic factors such as vascular endothelial growth factor (VEGF) and fibroblast growth factor (FGF)[29]. Liposomes functionalized with RGD peptides, for instance, have shown increased accumulation in neovascularized tissues and effectively promoted angiogenesis in ischemic limbs. However, despite these promising attributes, liposomes are not without limitations. They may exhibit limited stability in systemic circulation, face



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challenges with premature drug leakage, and present difficulties in maintaining consistency across large-scale production batches, which can hinder clinical translation[30, 31].

Polymeric Nanoparticles

Polymeric nanoparticles are solid colloidal carriers engineered from biodegradable polymers such as poly(lactic-co-glycolic acid) (PLGA), polylactic acid (PLA), and polyethylene glycol (PEG). These nanocarriers are capable of encapsulating a diverse range of therapeutic agents, including small molecules, peptides, and proteins, and are particularly well-suited for delivering drugs in a sustained and targeted manner[32]. In the treatment of PAD, polymeric nanoparticles offer several important advantages. One of their key benefits is the ability to provide controlled and sustained release of therapeutic agents; the degradation rate of the polymer matrix can be precisely tuned to achieve drug release over days or even weeks, which is critical for maintaining therapeutic levels in ischemic tissues[33]. Additionally, polymeric nanoparticles can be designed to co-deliver multiple agents, such as a combination of anti-inflammatory drugs and pro-angiogenic factors, enabling a synergistic therapeutic effect. These systems are also highly biocompatible—especially when constructed from FDA-approved polymers like PLGA, which degrade into naturally occurring byproducts such as lactic and glycolic acid, minimizing systemic toxicity. Research has shown the efficacy of PLGA nanoparticles in delivering angiogenic growth factors like vascular endothelial growth factor (VEGF) and basic fibroblast growth factor (bFGF), resulting in improved capillary density and blood perfusion in animal models of PAD. Furthermore, polymeric nanoparticles have been used to deliver drugs such as statins and corticosteroids, helping to modulate endothelial function and reduce vascular inflammation[34]. However, certain limitations persist, including the risk of initial burst release, which can compromise drug stability and efficacy, low drug-loading capacity for some therapeutic agents, and the need for precise control over polymer synthesis and degradation kinetics to ensure reproducibility and safety in clinical applications (Figure 1).

Dendrimers

Dendrimers are synthetic, highly branched, and monodisperse macromolecules characterized by a tree-like architecture and precise molecular uniformity. Structurally, they consist of a central core, repetitive interior branching layers (known as generations), and numerous terminal functional groups on the surface. This unique configuration gives dendrimers a high degree of molecular definition, multivalency, and surface functionality, making them exceptionally attractive for biomedical applications, including the treatment of PAD[35]. One of the key advantages of dendrimers in PAD therapy is their multivalency—the large number of terminal groups allows for the simultaneous attachment of therapeutic agents, targeting ligands, and imaging molecules. This enhances the potential for combinatorial delivery and site-specific action. Furthermore, the positively charged surface of many dendrimers, particularly polyamidoamine (PAMAM) dendrimers, facilitates complexation with nucleic acids such as plasmid DNA, small interfering RNA (siRNA), or microRNA (miRNA), making them highly effective vectors for gene delivery. Their surfaces can also be chemically modified to improve solubility, reduce toxicity, and enhance cellular uptake and targeting capabilities[36]. In the context of PAD, dendrimers have shown promising results in preclinical studies. For example, PAMAM dendrimers have been used to deliver siRNAs targeting pro-inflammatory cytokines like tumor necrosis factor- α (TNF- α) and monocyte chemoattractant protein-1 (MCP-1), both of which play critical roles in PAD-associated vascular inflammation. These interventions have resulted in reduced inflammatory cell infiltration and attenuated vascular injury in animal models. Additionally, dendrimer-based gene delivery platforms encoding angiogenic factors such as hypoxia-inducible factor-1 α (HIF-1 α) have demonstrated potential in promoting neovascularization and improving blood perfusion in ischemic limbs[37]. Despite these promising attributes, dendrimers are not without limitations. Cationic dendrimers, while effective in nucleic acid delivery, can induce cytotoxicity and hemolytic effects due to their strong interactions with cellular membranes. These adverse effects underscore the need for careful design and surface modification, such as PEGylation, to reduce toxicity and enhance biocompatibility. Furthermore, challenges related to in vivo stability, biodistribution, and large-scale synthesis must be addressed before dendrimer-based systems can be translated into clinical therapies for PAD[38].



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Micelles are nanosized colloidal carriers formed through the spontaneous self-assembly of amphiphilic block copolymers in aqueous environments. Structurally, they are composed of a hydrophobic core surrounded by a hydrophilic shell, which allows them to effectively encapsulate and transport hydrophobic therapeutic agents that otherwise have poor water solubility[39]. This unique architecture makes micelles especially suitable for delivering lipophilic drugs in the treatment of PAD, where local drug concentration and sustained action are critical. One of the primary advantages of micelles is their ability to solubilize poorly water-soluble drugs such as curcumin, paclitaxel, and rapamycin, which possess potent anti-inflammatory and anti-proliferative properties relevant to PAD pathology[40]. Their small size—typically ranging from 10 to 100 nanometers—enhances their ability to penetrate tissue, remain in circulation for extended periods, and exploit the enhanced permeability and retention (EPR) effect in inflamed or ischemic vascular regions. Micelles can also be engineered for targeted delivery by modifying their surfaces with ligands such as peptides or antibodies that bind to overexpressed receptors in diseased vasculature, thereby increasing drug accumulation at the site of ischemia[41]. In research settings, polymeric micelles have been investigated for their potential to deliver anti-proliferative agents aimed at reducing smooth muscle cell proliferation, a major contributor to restenosis following angioplasty. Additionally, responsive micelle systems that release drugs in response to redox changes or acidic pH—conditions typical of ischemic tissues—are being developed to further refine drug delivery specificity. However, despite these promising attributes, micelles are subject to certain limitations. One of the key challenges is their potential instability upon dilution in the bloodstream, which can result in premature drug release and reduced therapeutic efficacy. To address this, researchers are exploring strategies such as cross-linking the micelle core or shell and employing core-shell stabilization techniques to improve their structural integrity and in vivo performance[31]. These innovations are critical for translating micellar drug delivery systems from experimental platforms into reliable clinical therapies for PAD.

Niosomes in the Treatment of Peripheral Artery Disease

Niosomes are non-ionic surfactant-based vesicles that structurally resemble liposomes but offer improved chemical stability and lower production costs. Composed of cholesterol and non-ionic surfactants such as Span or Tween, niosomes form bilayered vesicles capable of encapsulating both hydrophilic and lipophilic therapeutic agents. Their amphiphilic nature, biocompatibility, and customizable surface properties make them a promising nanocarrier platform for drug delivery in various vascular diseases, including PAD[27, 42]. In the context of PAD, niosomes offer several advantages for delivering therapeutic agents to ischemic and inflamed tissues. They can improve the solubility and bioavailability of poorly water-soluble drugs, provide sustained and controlled release, and reduce systemic toxicity by concentrating the therapeutic load at the site of disease. Moreover, the surface of niosomes can be functionalized with targeting ligands, such as peptides or antibodies, to achieve active targeting of endothelial adhesion molecules or hypoxia-inducible markers that are commonly upregulated in PAD-affected vasculature[43]. Studies have demonstrated the potential of niosomes in delivering anti-inflammatory agents, antioxidants, and pro-angiogenic compounds relevant to PAD management. For example, niosomal formulations of curcumin, a natural anti-inflammatory and antioxidant agent, have shown enhanced cellular uptake and vascular protection in oxidative stress models. Similarly, niosomes encapsulating growth factors such as VEGF (vascular endothelial growth factor) have been explored for their ability to promote angiogenesis in ischemic limbs, supporting the restoration of perfusion and tissue regeneration[44]. Despite these promising attributes, niosomal drug delivery for PAD remains largely in the preclinical phase, and challenges such as vesicle stability in circulation, scalability of production, and regulatory hurdles need to be addressed. Nevertheless, the unique characteristics of niosomes including their structural versatility, non-immunogenicity, and ability to accommodate various drug types make them an attractive and emerging tool for advancing PAD therapy.

Targeted Delivery Strategies

Targeted delivery strategies play a crucial role in improving the efficacy and safety of nanocarrier-based therapies for PAD. By directing therapeutic agents specifically to diseased tissues—such as inflamed endothelium or ischemic muscle—these strategies minimize systemic exposure, reduce off-target effects, and enhance local drug





concentration[16]. Two major approaches have been developed to achieve targeted delivery: passive targeting and active targeting.

Passive Targeting

Passive targeting is based on the enhanced permeability and retention (EPR) effect, a phenomenon commonly observed in pathological tissues, including inflamed and ischemic regions associated with PAD. In these areas, the vascular endothelium becomes more permeable due to inflammation and endothelial dysfunction, allowing nanoscale carriers (typically <200 nm) to extravasate and accumulate more easily than in healthy tissues. Moreover, the impaired lymphatic drainage in such regions further contributes to the retention of these nanocarriers[15]. Although passive targeting does not involve any specific recognition mechanisms, it enables the accumulation of therapeutic agents at the site of disease by simply leveraging the altered vascular architecture. Nanocarriers such as liposomes, polymeric nanoparticles, and micelles designed with optimal size and surface properties (e.g., PEGylation to prolong circulation) can exploit the EPR effect to achieve higher local drug concentrations in ischemic limbs. While effective to a certain extent, passive targeting alone may be insufficient for achieving the precision required in advanced PAD cases, where spatial and molecular heterogeneity is common[45].

Active Targeting

Active targeting enhances the specificity of drug delivery by functionalizing nanocarriers with targeting ligands that recognize and bind to molecular markers over expressed in diseased tissues. This approach enables receptor-mediated uptake by endothelial or tissue cells in the PAD-affected area, ensuring a more efficient and selective therapeutic effect[46]. Several classes of ligands have been explored for active targeting in PAD:

Antibodies against VCAM-1 and ICAM-1: Vascular cell adhesion molecule-1 (VCAM-1) and intercellular adhesion molecule-1 (ICAM-1) are cell-surface proteins that are highly expressed on inflamed endothelium. Nanocarriers decorated with monoclonal antibodies or antibody fragments against these molecules have shown improved localization to inflamed vascular segments, particularly in the context of early atherosclerotic lesions and ischemic injury in PAD[16].

RGD peptides: These short peptides contain the Arg-Gly-Asp (RGD) sequence, which selectively binds to $\alpha v\beta 3$ integrins, a family of receptors that are upregulated in angiogenic endothelial cells and neovasculature. Nanocarriers conjugated with RGD peptides have been successfully used to target newly forming blood vessels in ischemic tissues, thereby enhancing the delivery of pro-angiogenic agents or imaging probes in PAD models[47].

Aptamers and small molecules: Aptamers are short, single-stranded DNA or RNA oligonucleotides that can bind with high affinity to specific proteins, including growth factor receptors or hypoxia-inducible factors (HIFs). These molecules are particularly useful for targeting ischemic tissues, where hypoxia-induced signaling is dominant. Additionally, small molecule ligands targeting receptors such as VEGFR (vascular endothelial growth factor receptor) or PDGFR (platelet-derived growth factor receptor) can be employed for precision drug delivery to regenerating vasculature or smooth muscle cells[43, 48]. Together, active targeting strategies significantly enhance the selectivity and potency of nanocarrier-based therapies in PAD by guiding the payload directly to the pathological sites. When combined with passive targeting, these strategies can synergistically improve drug accumulation, therapeutic index, and clinical outcomes in PAD treatment (Figure 2). However, careful optimization of ligand density, binding affinity, and nanoparticle surface properties is essential to avoid unintended immune responses or clearance by the reticuloendothelial system (RES).

Clinical Translation and Challenges

Despite the promising preclinical success of nanocarrier-based therapies for PAD, their clinical translation faces significant challenges. One major concern is the biocompatibility and long-term safety of these nanomaterials. Although many nanocarriers are designed using biodegradable and biocompatible components, comprehensive data on their chronic toxicity, immunogenicity, and potential accumulation in off-target organs remain limited[49]. This



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uncertainty complicates risk assessment and patient safety evaluations. Additionally, scaling up nanocarrier production while ensuring batch-to-batch reproducibility poses considerable manufacturing challenges. The complexity of synthesis processes, stringent quality control requirements, and the need for stable formulations under clinical conditions add layers of difficulty in moving from laboratory prototypes to clinically viable products[50, 51]. Regulatory pathways for nanomedicine are still evolving, which further complicates the approval process. The unique properties of nanocarriers often place them in regulatory gray areas, requiring tailored evaluation criteria that address both the drug and the delivery system[52]. Moreover, the heterogeneity of human vascular disease including variability in lesion size, location, and molecular markers limits uniform targeting efficiency observed in preclinical models. This biological variability necessitates personalized approaches and adaptive designs in nanocarrier development. To overcome these obstacles, ongoing clinical trials, coupled with an improved understanding of nano–bio interactions, are essential. Such efforts will provide critical insights into optimizing safety, efficacy, and patient selection, ultimately paving the way for successful clinical integration of advanced nanocarrier therapies in PAD management[53].

CONCLUSION AND FUTURE PERSPECTIVES

Nanocarrier-based strategies represent a transformative advancement in the treatment of Peripheral Artery Disease by offering precise, site-specific, and controlled delivery of therapeutic agents. These nanoscale delivery systems ranging from liposomes and polymeric nanoparticles to dendrimers and micelles address many limitations of conventional therapies, such as poor drug bioavailability, systemic toxicity, and lack of targeted action. By enabling multifunctional platforms that can simultaneously deliver drugs, genes, and imaging agents, nanocarriers provide a comprehensive approach to tackling the complex pathophysiology of PAD, which includes endothelial dysfunction, inflammation, and tissue ischemia. The ability to engineer nanocarriers for active targeting to inflamed or ischemic tissues further enhances therapeutic efficacy while minimizing off-target effects. Moreover, advances in surface modification, controlled release kinetics, and co-delivery of synergistic agents have paved the way for more effective and safer treatment regimens. Looking ahead, future efforts in nanomedicine for PAD should prioritize the development of stimuli-responsive nanocarriers that can release their payloads in response to local physiological cues such as pH changes, redox gradients, or specific enzyme activity present in ischemic and inflamed tissues. Such smart delivery systems will improve temporal and spatial control over drug release, maximizing therapeutic impact while reducing side effects. Additionally, the emergence of personalized Nanomedicine tailoring treatment based on individual patient biomarkers and disease heterogeneity—holds great promise for optimizing efficacy and minimizing adverse reactions. This could involve designing nanocarriers that respond to patient-specific molecular signatures or adapting dosing regimens through real-time feedback. Furthermore, integration of nanocarriers with wearable diagnostics and smart delivery systems could revolutionize PAD management by enabling continuous monitoring and on-demand drug release, creating a closed-loop therapeutic platform. This interdisciplinary approach, combining advances in nanotechnology, molecular biology, and digital health, is expected to accelerate the clinical translation of nanocarrier-based therapies. With sustained research, regulatory support, and collaborative efforts across academia, industry, and healthcare, nanomedicine has the potential to fundamentally change how PAD is diagnosed, treated, and managed—offering hope for improved patient outcomes and quality of life.

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Conflict of Interest Statement

The authors declare no conflicts of interest related to this research.





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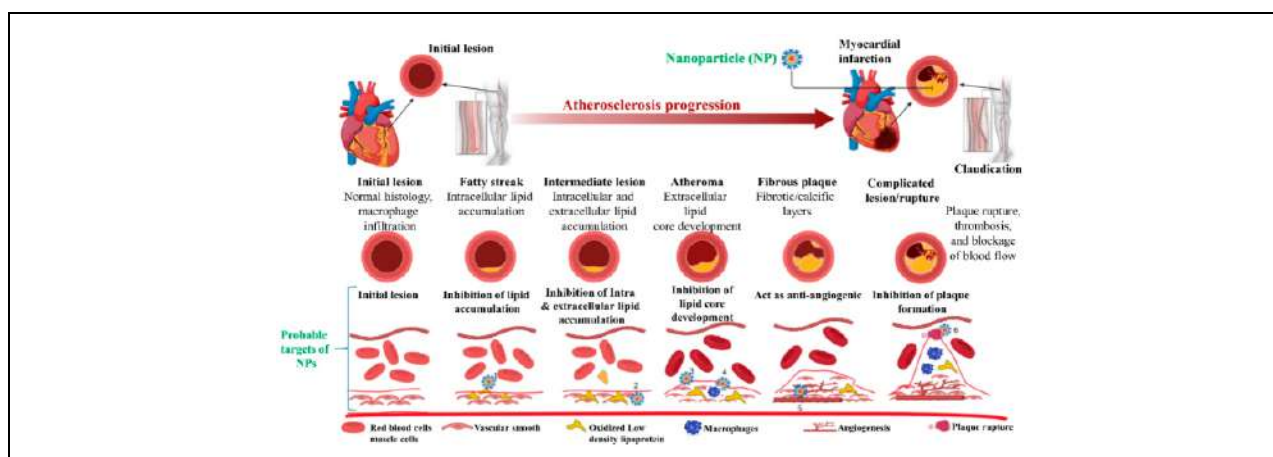


Figure 1: Targeting of atherosclerosis using nanoparticles [<https://doi.org/10.3390/jnt2010001>].

Characteristic	Passive Targeting	Active Targeting
 Mechanism	Exploits EPR effect	Ligand-receptor binding
 Specificity	Lower	Higher
 Target Area	Inflamed/Ischemic Regions	Specific Cells/Markers
 Examples	Liposomes, polymeric nanoparticles	Antibodies, RGD peptides, aptamers
 Advantages	Simpler, size-dependent accumulation	Enhanced selectivity, receptor-mediated uptake
 Limitations	Insufficient for advanced cases	Requires ligand optimization

Figure 2: Targeting Strategies for Nanocarriers to treat PAD





REVIEW ARTICLE

The Role of Herbs and Herbal Formulations in Alcohol Hangover Relief or Recovery: A Review

Yogesh H. Nikam^{1*}, Mayuri Patil² and Laxmikant Borse³

¹Research Scholar, Department of Pharmaceutics, Sandip Foundation, Nashik, (Affiliated to Savitribai Phule Pune University, Pune), Maharashtra, India.

²Assistant Professor, Department of Pharmaceutics, Sandip Foundation, Nashik, (Affiliated to Savitribai Phule Pune University, Pune), Maharashtra, India.

³Principal, Department of Pharmacology, Sandip Foundation, Nashik, (Affiliated to Savitribai Phule Pune University, Pune), Maharashtra, India.

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*Address for Correspondence

Yogesh H. Nikam

Research Scholar,

Department of Pharmaceutics,

Sandip Foundation, Nashik,

(Affiliated to Savitribai Phule Pune University, Pune),

Maharashtra, India.

E.Mail: yogeshnikam2k@gmail.com



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ABSTRACT

Around the world, alcoholic beverages like wine, beer, and spirits are widely consumed. But acetaldehyde, a byproduct of alcohol, is toxic and dangerous to humans. Drinking too much alcohol on a regular basis or infrequently can lead to a wide range of health issues, including cancer, liver damage, and hangovers. There are social, physiological, and financial ramifications to the development of alcoholism therapies. With the negative effects of synthetic drugs, such as psychological dependence and undesired behavioral impacts, there is great market potential for the creation of low-toxicity, high-efficiency medications made from natural sources. Based on these concerns, we investigated the effects of natural medicines on alcohol consumption, metabolism, and absorption as well as the protective effects on acute and chronic tissue injury caused by alcohol. The objective of this¹ to explore the Chemical properties physiological effects and societal impacts of alcohol and Natural Remedies for Hangover and Alcohol Use Disorder Prevention and Treatment.²

Keywords: Herbal product, Liquid preparation



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INTRODUCTION

Alcohol, especially in the form of ethanol, has been used for centuries for medicinal, recreational, and ritualistic purposes. The wide accessibility and consumption of alcohol have made it an integral part of human culture, but its potential for abuse has led to significant health issues globally. Alcohol, specifically ethanol (C_2H_5OH), is a psychoactive substance consumed in various forms across the world. It is widely recognized for its use in social, cultural, and religious contexts, but also for its potential health risks when consumed excessively. The symptoms of an alcohol overload are collectively referred to as a hangover. Facial pain, nausea, exhaustion, light and sound sensitivity, and headaches are typical side effects. Individual tolerance, the type and quantity of alcohol ingested, and hydration levels are some of the variables that can affect the severity. A hangover is a set of unpleasant symptoms that can arise from consuming excessive amounts of alcohol. In addition to make you feel terrible, frequent hangovers are linked to subpar work and friction at the office. In general, the more alcohol you consume, the more likely it is that you will experience a hangover the following day. Still, there's no magic number that can tell you how much alcohol you can have before becoming inebriated or experiencing a hangover. Although they can last up to 24 hours, most hangovers gone on their own, despite how terrible they are. If you choose to drink, practicing responsible alcohol use can help you avoid future hangovers. A hangover is a collection of symptoms brought on by excessive drinking. A hangover can vary from person to person.¹

The physiological processes that lead to a hangover are intricate and involve a number of factors that upset normal bodily processes. When you drink alcohol, it influences many systems in the body, resulting in a myriad of symptoms, including dehydration, electrolyte imbalances, acetaldehyde toxicity, inflammation, and gastrointestinal disorders.

The following is an explanation of the most important physiological processes involved in a hangover:

Dehydration

Mechanism: Alcohol is a diuretic, which means it increases urine production. This occurs because alcohol inhibits the release of antidiuretic hormone (ADH), which normally helps the kidneys retain water. As a result, when alcohol is consumed, the kidneys excrete more water than usual, leading to dehydration.

Consequences: Dehydration is one of the primary contributors to many hangover symptoms, including:

Dry mouth and excessive thirst: The body's water stores are depleted.

Headache: Shrinkage of brain cells due to dehydration causes discomfort and pain.

Fatigue and dizziness: Dehydration affects balance and energy.

Electrolyte Imbalances

Mechanism: Not only does urination increase due to alcohol, but the loss of water is also accompanied by the excretion of vital electrolytes like sodium, potassium, and magnesium.

Consequences:

Muscle cramps: Potassium and magnesium deficiencies at low levels are known to result in muscle spasms or cramps.

Fatigue and weakness: Electrolytes are needed for optimal muscle and nerve conduction function, and so imbalances may result in tiredness and generalized weakness.

Headaches: Electrolyte imbalance also causes headaches because it affects the balance of fluids within the brain.

Acetaldehyde Toxicity

Mechanism: Alcohol, when you consume it, is metabolized by your liver into acetaldehyde, which is a very toxic substance. Acetaldehyde is further metabolized to acetic acid by the enzyme ALDH. In the case of excessive consumption of



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alcohol, your liver cannot break down acetaldehyde quickly enough, and therefore this toxic product builds up within your body

Consequences

Nausea and vomiting: Acetaldehyde is a strong irritant to the gastrointestinal tract, resulting in nausea, vomiting, and general discomfort.

Facial flushing: In certain individuals, particularly those with an inherited deficiency of ALDH, acetaldehyde accumulation may result in flushing and other symptoms such as tachycardia.

Liver stress: Acetaldehyde accumulation may stress the liver, making it less capable of detoxifying the body and metabolizing other compounds.

Inflammatory Response

Mechanism: Alcohol drinking leads to an inflammatory process in the body. Ethanol, as well as acetaldehyde and other alcohol metabolites, stimulates the immune system and leads to the release of pro-inflammatory cytokines. These cytokines can be responsible for inflammation in the brain and other tissues.

Consequences:

Headaches: Inflammation in the brain and vessels can lead to or worsen headaches

Fatigue and malaise: Inflammation may cause the overall sense of illness and fatigue felt in a hangover.

Sensitivity to light and sound: Inflammatory mechanisms in the brain may sensitize individuals to exogenous stimuli, which is why a person with a hangover might suffer from photophobia (sensitivity to light) or phonophobia (sensitivity to sound).

Gastrointestinal Disturbances

Mechanism: Alcohol hurts the gastrointestinal (GI) system, including stomach and intestines. It heightens gastric acid secretion and causes inflammation of stomach and intestinal linings.

Effects:

Nausea and vomiting: Alcohol immediately can irritate stomach lining to create nausea with possibility of vomiting.

Indigestion: Production of excess gastric acid can produce indigestion, heartburn, and unease.

Changed gut motility: Alcohol can influence the intestines' movement, resulting in diarrhea or constipation, depending on the person.

Hypoglycemia (Low Blood Sugar)

Mechanism: Alcohol may hinder the liver from releasing glucose into the blood. Under normal **circumstances**, when blood sugar is low, the liver releases glucose stored as glycogen. Alcohol, however, interferes with this process, which can result in hypoglycemia (low blood sugar).

Consequences:

Fatigue: Severe fatigue, weakness, and dizziness caused by low blood sugar are common features of hypoglycemia.

Mood disturbances: Irritability and mood swings caused by hypoglycemia may contribute to the general misery of a hangover.

Disruption of Sleep Patterns

Mechanism: Although alcohol will initially make you sleepy, it disturbs REM sleep and sleep quality.

Alcohol affects the body's ability to progress into the deeper stages of sleep and can lead to numerous awakenings during the course of the night.

Consequences:

Fatigue: Poor sleep quality adds to general tiredness and mental confusion during a hangover.

Cognitive impairment: The disturbance of sleep and recovery processes is able to impair memory, concentration, and mood.

Acid-Base Imbalance

Mechanism: Drinking alcohol may enhance the body's acidity through the production of lactic acid as a byproduct of



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alcohol metabolism. This may result in a low-grade metabolic acidosis, which upsets the body's pH balance. Consequences: The upset in pH balance may be responsible for causing nausea, dizziness, and fatigue. 3

Alcoholism

Alcoholism, also known as alcohol use disorder (AUD), is a long-term condition marked by an inability to manage or decrease alcohol intake, even when it leads to harmful effects. It is characterized by intense cravings for alcohol, a lack of control over drinking, and withdrawal symptoms when not drinking. The unpleasant symptoms that appear in the body and mental 8. to 16 hours after consuming alcohol are known as hangover symptom 4 Chronic alcoholism is the frequent use of ethyl alcohol (ethanol) in amounts that are high enough to damage a person's social, psychological, or physical functioning. It is difficult to determine the bare minimum number of "drinks" required to diagnose alcoholism because each person is sensitive differently. On the other hand, there are detrimental effects that are linked to both acute and long-term alcohol consumption based on the quantity and duration of alcohol intake. Generally, ten grams of ethanol are added to:

- one can (or half a bottle) of beer,
- 120 ml of straight wine, or
- Liquor with a 43% alcohol content in 30 millilitres (small peg) 5

Types of Alcoholic Beverages and Their Typical ABV

Fermented Alcoholic Beverages

Made by fermenting sugars from fruits, grains, or vegetables (Table 1).

Distilled Alcoholic Beverages (Spirits/Liquor) Table 2

Fortified Wines (Table 3.)

Wine with added distilled spirits (usually brandy) to boost alcohol content.

- **Methanol (wood alcohol) and isopropanol (rubbing alcohol) are not suitable for human consumption and are toxic.**
- **Alcohol should always be consumed responsibly to avoid health risks like liver disease, addiction, or alcohol poisoning**
- Since ethanol is the primary element, all forms of alcohol have similar basic effects on the body, although their effects might vary depending on their concentration, additions, and congeners.⁶⁷⁸

Metabolism of ethanol

Alcohol contains 7 calories per gram, but it cannot be stored in the body and must be metabolized, mainly in the liver. Therefore, aside from providing energy, these calories lack any nutritional value. After being consumed and absorbed in the small intestine, ethanol makes its way to the liver, where 90% is converted into acetate by two enzymes: alcohol dehydrogenase (ADH), located in the cytosol, and acetaldehyde dehydrogenase (ALDH), found in the mitochondria of liver cells. The remaining 10% of ethanol is oxidized by other organs and tissues in the body.⁵

- **First step:** The liver employs one primary pathway and two secondary methods to convert ethanol into acetaldehyde.
- In the cytosol, the primary rate-limiting pathway for converting ethanol involves alcohol dehydrogenase (ADH).
- In the smooth endoplasmic reticulum, a portion of ethanol is metabolized using microsomal P-450 oxidases, commonly referred to as the microsomal ethanol oxidizing system (MEOS).
- In the peroxisomes, there is a minor pathway involving catalase and substances such as H₂O₂. Acetaldehyde, which is toxic, can damage membranes and lead to cell necrosis. Meanwhile, nicotinamide adenine dinucleotide (NAD), which acts as a cofactor and hydrogen acceptor, is reduced to NADH
- **Second step:** In the second stage, acetaldehyde is converted to acetate in the mitochondria, with ALDH acting as a coenzyme in this process. Most of the acetate is eventually oxidized to produce carbon dioxide





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and water, or it is converted through the citric acid cycle into other substances, such as fatty acids. At the same time, NAD is reduced to NADH, which increases the NADH

- redox ratio—this is the primary metabolic change occurring during ethanol metabolism. The ratio of its oxidized and reduced metabolites, lactate to pyruvate and beta-hydroxybutyrate to acetoacetate, serves as a reliable indicator of the NADH ratio.

Pathophysiology

This article provides an overview of the biomedical and cellular pathophysiology that results from long-term alcohol use and causes the morphologic lesions associated with alcoholic hepatitis, alcoholic cirrhosis, and alcoholic steatosis (fatty liver). Alcoholic liver injury's specific cause is still unknown. It is also unknown why some chronic drinkers experience all of the liver changes while others do not.

1. Ethanol can cause direct damage to the liver. Research indicates that regular consumption of ethanol for eight to ten days may lead to a direct hepatotoxic effect, resulting in fatty changes in the liver.
2. Ethanol metabolites can lead to liver damage, with acetaldehyde being the primary metabolite responsible for most of its hepatotoxic effects. Acetaldehyde contributes to hepatotoxicity through the formation of two types of adducts: First, it creates protein-aldehyde adducts that are highly toxic and can damage cell membranes and the cytoskeleton, ultimately causing hepatic necrosis. Second, it forms malondialdehyde-acetaldehyde (MAA) adducts, which can trigger the production of autoantibodies and initiate an autoimmune response.
3. Oxidative stress occurs when ethanol is oxidized by cytochrome P450 oxidases (MEOS), leading to the production of free radicals that can damage proteins and membranes.
4. An immune system response is involved in alcohol-related liver disease, which weakens cell-mediated immunity. Ethanol directly attacks hepatocytes, and in some cases, liver cell damage continues even after drinking has ceased, due to immune mechanisms.
5. Inflammation occurs as a result of prolonged ethanol consumption, which also damages intestinal cells. Damaged intestinal cells release key pro-inflammatory cytokines such as tumor necrosis factor, IL-1, IL-6, and TGF-. These cytokines, along with endotoxemia, lead to the apoptosis and necrosis of hepatocytes, triggering an inflammatory response in the liver that has already been compromised by alcohol.
6. Fibrogenesis is primarily driven by the activation of stellate cells, which can be stimulated by various factors, including damaged hepatocytes, malondialdehyde-acetaldehyde adducts, activated Kupffer cells, and acetaldehyde.
7. An elevated redox ratio leads to lactic acidosis due to a significant rise in the lactate-pyruvate redox ratio resulting from the NADH ratio in hepatocytes. This altered redox potential has been associated with increased gout incidence, collagen synthesis, impaired gluconeogenesis, and changes in steroid metabolism.
8. liver cells' retention of water and proteins. Alcohol causes the liver to be less able to produce newly synthesized proteins, which keeps the proteins inside the hepatocytes. Hepatomegaly in alcoholics is caused by water being simultaneously kept in the cell in proportion to the protein, which causes the hepatocytes to expand.
9. Hypoxia occurs when chronic alcohol consumption raises the liver's oxygen demand, creating a hypoxic condition that causes hepatocellular necrosis in the centrilobular zone (zone 3)..
10. An increase in liver fat occurs with chronic alcoholism, leading to a higher availability of fat in the liver. This fat can originate from external (dietary) sources, increased mobilization of adipose tissue, or enhanced lipid synthesis by the liver itself. This accumulation of lipids in hepatocytes may be attributed to these factors.

Alcohol-Related Disease and : Alcohol-related disorders include various conditions associated with excessive drinking, primarily categorized as Alcohol Use Disorder (AUD). Key types include:

Alcohol Use Disorder (AUD): A chronic condition defined by an inability to control alcohol intake, leading to significant distress or impairment.

Alcohol Dependence: Frequently used interchangeably with AUD, it specifically denotes physical reliance on alcohol, characterized by tolerance and withdrawal symptoms.



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Alcohol Abuse: A drinking pattern that causes ongoing problems, such as legal issues, relationship conflicts, or dangerous situations.

Binge Drinking: Involves consuming a large amount of alcohol in a short period, typically defined as five or more drinks for men and four or more for women during a single occasion.

Alcohol-Induced Mental Disorders: Includes conditions like alcohol-induced anxiety or depression that arise directly from alcohol use.

Alcohol Withdrawal Syndrome: A potentially dangerous condition that can occur when a dependent person abruptly reduces or stops drinking, leading to symptoms such as tremors, sweating, and seizures.

Alcohol-Related Liver Disease: Encompasses conditions like fatty liver, alcoholic hepatitis, and cirrhosis that result from long-term alcohol abuse.

Each of these disorders requires specific treatment strategies, underscoring the necessity of early intervention and support.

Alcohol-Related Liver Disease and Cirrhosis:

The spectrum of liver damage resulting from acute and chronic drunkenness is referred to as "alcoholic liver disease". The three stages of alcoholic liver disease are alcoholic cirrhosis, alcoholic hepatitis, and alcoholic steatosis.⁴

HOME REMEDIES AND HERBS

Suggested Home Remedies for Hangover:

Give your body adequate time to recuperate from the harmful effects of alcohol; there is no secret formula for removing hangovers. To help you manage your symptoms and speed up your recuperation, try these natural cures in the interim.

- **Drink plenty of fluids:** People who drink alcohol tend to urinate more frequently, which results in fluid loss. In the event that you additionally sweat, throw up, or experience diarrhea, your body can get dehydrated. Try to drink a lot of water when you wake up to replace the fluids you've lost.
- **Eat more carbohydrates:** Drinking alcohol reduces blood sugar, which can lead to headaches and fatigue. A common mistake made by people who binge drink is not eating. This lowers the blood sugar levels even more. Consuming more carbohydrates can⁸
- **Drinking tea or coffee:** Caffeine, a stimulant, is an ingredient in both tea and coffee. It can lessen the grogginess that follows a hangover. Make your favorite cup of tea or coffee as soon as you get up. In this way, you could eliminate the feeling that you have just returned from battle by sipping some tea or coffee.
- **Take a nap:** You'll need a lot of sleep to recover from your hangover. The aftereffects of alcohol can make it difficult for you to complete chores, even if you feel well the following morning. To combat fatigue, attempt getting as much rest as you can.¹⁰
- **Ginseng:** Ginseng can help the body eliminate alcohol more quickly by accelerating the metabolism of alcohol. In this way, it helps reduce hangover symptoms.

Be patient: You need at least 24 hours to fully recover from the symptoms of a hangover. It takes time for your body to flush out all of the toxic alcohol byproducts that are already in your system, heal your liver, drink lots of water, and resume normal functions.¹¹

Useful various herbs like,

- Draksha
- Giloy
- Ashwangandha
- Aloe vera
- Bhuiamlaki
- Saunf
- Greentea
- Mulethi



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- Amla,
- Ginger

Mulethi/ Liquorice:**Liquorice :**

- **Family:** Fabaceae
- **Kingdom:** Plantae
- **Order:** Fabales
- **Genus:** Glycyrrhiza
- **Species:** Glycyrrhiza glabra
- **Common Name:** Licorice
- **Category:** Herbaceous plant
- **Functions / Role :**
 - It's Anti-inflammatory.
 - It's Boost the immune system.
 - It's Maintained the Digestive system.

Licorice (*Glycyrrhiza glabra*) primarily grows in temperate regions and prefers specific environmental conditions. licorice prefers dry, sunny areas with well-drained soil and is commonly found in regions with mild winters and warm summers.

liquorice's characteristics:

- It may have antimicrobial properties.
- It could have anti-inflammatory effects.
- It might act as an expectorant, helping with sputum production.
- It may possess demulcent properties, relieving itchiness.
- Liquorice could be utilized for treating respiratory infections.^{12,13}

Mulethi for liver:

Mulethi extract has shown the ability to prevent and alleviate symptoms of liver diseases such as hepatitis C, non-alcoholic fatty liver disease, and jaundice. It possesses anti-inflammatory properties that help soothe the liver during hepatitis. When consumed with a warm cup of tea twice daily for several weeks, mulethi can detoxify the liver and enhance its disease resistance. Health benefits of mulethi include: boosting immunity, regulating cholesterol levels, treating coughs and colds, increasing fertility in women, supporting digestive health, and addressing skin issues. The roots and rhizomes of licorice can be used in various forms, including powder, tea, tonic, extract, and tincture 14

Ashwagandha

Synonym: Withania root, Asgandh, Winter cherry.

- **Botanical Classification:**
- **Family:** Solanaceae
- **Kingdom:** Plantae
- **Plantae Order:** Solanales
- **Genus:** Withania
- **Species:** Withania somnifera
- **Common Name:** Indian ginseng
- **Category :** Antidepressant , Adaptogenic
- **Functions / Role :**
 - Heartburn
 - Improve Brain Functions





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- Reduced Anxiety

Biological Source: It consists of dried roots and stem bases of *Withania somnifera* (Linn.) Dunal, belonging to family Solanaceae and should contain not less than 0.02 per of total withanolide A and withaferin A on dried basis. This plant grows wild in all dry parts and subtropical India. It occurs in Madhya Pradesh, U. Pradesh, Punjab plains and North Western parts of India like Gujarat and Rajasthan. It is also found in Congo, South Africa, Egypt, Morocco, Jordan, Pakistan and Afghanistan. Various illnesses, including anxiety and fertility issues, can be treated with extracts or powder from the plant's roots or leaves.

May reduce stress and anxiety: Ashwagandha is best known for its ability to alleviate stress. It is classified as an adaptogen, which helps the body manage stress. Research suggests that ashwagandha may help regulate stress mediators like heat shock proteins (Hsp70), cortisol, and stress-activated c-Jun N-terminal protein kinase (JNK-1). It also appears to reduce the activity of the HPA axis, which governs the body's stress response.

May enhance cognitive function, including memory: Consuming ashwagandha may positively impact brain function[16].

Amla :

- **Family:** Phyllanthaceae
- **Kingdom:** Plantae
- **Order:** Malpighiales
- **Genus:** Phyllanthus
- **Species:** Phyllanthus emblica
- **Common Name:** Amla, Indian Gooseberry
- **Category:** Fruit-bearing deciduous tree
- **Function / Role :**
- It's Anti- heart burn.
- Antioxidants.
 - High in Vit-C.
 - Antacids.

Amalaki contains not less than 1.0 percent w/w Gallic acid calculated on the dried basis.

Amla grows in variety of soil types , preferring well- drained, sandy or loamy soil. It grows best in regions with a tropical or subtropical climate and is often found in both wild and cultivated forms. 17 18

Giloy

- **Family:** Menispermaceae
- **Kingdom:** Plantae
- **Order:** Ranunculales
- **Genus:** *Tinospora*
- **Species:** *Tinospora cordifolia*
- **Common Name:** Giloy, Guduchi
- **Category:** Medicinal herb
- **Function:**
- Immunomodulatory
- Antipyretic (fever-reducing)
- Anti-inflammatory
- Antioxidant
- Hepatoprotective (liver-protecting)
- Anti-diabetic





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- Adaptogenic (helps the body adapt to stress)

Biological Source:

These are the dried leaves and stem pieces of woody climber *Tinospora cordifolia*, Miers belonging to family Menispermaceae.

It contains not less than 0.02 per cent of cordifolioside

Traditional Uses: The ability of this substance to promote freshness, vitality, and longevity has been utilized in traditional medicine for centuries. Today, it is referred to as "Amrita" because of these attributes. Its potent immunostimulant effects are contributing to its rising popularity. In Ayurveda, it is also recognized as "Rasayan dravya" for these benefits. 19

Ginger

- **Family:** Zingiberaceae
- **Kingdom:** Plantae
- **Order:** Zingiberales
- **Genus:** *Zingiber*
- **Species:** *Zingiber officinale*
- **Common Name:** Ginger
- **Category:** Medicinal and culinary herb
- **Function:**
 - Anti-inflammatory
 - Antiemetic (prevents nausea and vomiting)
 - Antioxidant
 - Digestive aid
 - Carminative (relieves flatulence)
 - Analgesic (pain relief)
 - Antimicrobial

Synonyms: Zingiber, Zingiberis, Sunthi.

Biological Source:

Ginger consists of whole or cut, dried scrapped or unscrapped rhizomes of *Zingiber officinale* Roscoe, family Zingiberaceae. It contains not less than 0.8 per cent of total gingerols on dried basis. **Uses:** Ginger serves multiple purposes, including as a stimulant, flavoring agent, fragrance, carminative, and stomach tonic. Ginger oil is commonly used in mouthwash, ginger-flavored drinks, and alcoholic beverages. It is reported that ginger powder is effective for motion sickness. Some theories suggest that ginger's adsorbent, aromatic, and carminative properties in the gastrointestinal tract help absorb toxins and improve stomach motility, which may alleviate symptoms of nausea and gastrointestinal discomfort [20].

Bhumyamlaki

Synonyms : Tamalaki, Jata, *Phyllanthus vira*, uccata.

Botanical Name : Niruri

Family : Phyllanthaceae

Bhumyamalaki promotes kidney function by supporting a healthy liver and gallbladder. It helps the kidneys by detoxifying the body and reducing mineral accumulation. In Ayurveda,

- **Botanical Classification:**
- **Family:** Phyllanthaceae
- **Kingdom:** Plantae





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- **Plantae Order:** Malpighiales
- **Genus:** Phyllanthus
- **Species:** *Phyllanthus niruri*
- **Common Name:** Bhuiamla, Indian Gooseberry, Stonebreaker
- **Category :** Antiviral , Hepatoprotective ,Antidiabetic
- **Functions / Role :**
- It's Support immune system.
- It's support Kidney functions.
- It's Improve the Function of Liver & Gall bladder

Bhuiamla contains of the dried aerial parts of the *Phyllanthus amarus schum.* And Thom [Fam Euphorbiaceae. Bhuiamla contains not less than 0.25 percent w/w of total Phyllanthin and Hypophyllanthin, Calculated on the dried basis. This plants grows in Wide range of soil types but prefers in well-drained and sandy soils. It occurs in Kerala, Tamil Nadu, Karnataka, and Andhra Pradesh, Rajasthan and Gujarat.

Bhumyamalaki is believed to balance the kapha and pitta doshas, which represent the elements of water and fire, respectively [21]

Clear Skin: This plant's ability to detoxify the liver contributes to achieving bright, radiant skin, as liver health is closely linked to skin condition.

Immune System: It supports a healthy inflammatory response and combats stress, benefiting the immune system. The diuretic root is also utilized to treat jaundice and remove bladder stones. An infusion of the tender young roots is effective for chronic dysentery, while an infusion of the leaves can help treat dysentery.

Honey

Synonyms : Madhu, Honey Purified, Mel

Sanskrit name: Madhu, Madvika, Kshaudra, Saradha, Makshika.

Biological Source:

Honey is a sugar secretion deposited in honey comb by the bees, *Apis mellifera*, *Apis dorsata*, and other species of *Apis*.

Family: Apidae. Order : Hymenoptera.

Honey serves as a demulcent and sweetener. It is easily absorbed, making it a nutritious option for infants and patients. With antiseptic properties, it is often applied to burns and wounds. Additionally, honey is a common component in various cough syrups, lozenges, and Ayurvedic formulations. Recently, it has also been included in creams, lotions, soft drinks, and candies

Aloe vera

- **Family:** Asphodelaceae
- **Kingdom:** Plantae
- **Order:** Asparagales
- **Genus:** *Aloe*
- **Species:** *Aloe vera* (also known as *Aloe barbadensis miller*)
- **Common Name:** Aloe vera
- **Category:** Medicinal succulent herb
- **Function:**
- Skin healing (burns, wounds, cuts)
- Anti-inflammatory
- Moisturizing agent
- Antioxidant





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- Antimicrobial
- Digestive aid (laxative effect in some forms)
- Immune booster

Synonym: Aloe, Musabbar, Kumari.

Biological source: Aloes is the dried juice of the leaves of Aloe barbadensis Miller, known as Curacao aloes; or of Aloe perryi Baker, known as Socotrine aloes; or of Aloe ferox Miller and hybrids of this species with Aloe africana Miller and Aloe, belonging to family Liliaceae.

Uses: Aloe vera juice can reduce inflammation and regulate acidity by coating the stomach lining. While it's best consumed on its own, it can also be mixed with coconut water or non-acidic juices. Studies have demonstrated that aloe vera extract possesses antioxidant properties in both humans and animals [22]

The compounds of Aloe vera gel include –

antioxidant, water-soluble and fat-soluble vitamins, enzymes, minerals, polysaccharides, phenolic compounds, and organic acids gastro-protective (peptic ulcer)²³

Draksha

- **Family:** Vitaceae
- **Kingdom:** Plantae
- **Order:** Vitales
- **Genus:** Vitis
- **Species:** Vitis vinifera
- **Common Name:** Draksha, Grape
- **Category:** Medicinal fruit / Herb (used in Ayurveda)
- **Function:**
- Antioxidant
- Cardioprotective (supports heart health)
- Cooling and energizing tonic
- Mild laxative
- Supports digestion
- Helps relieve fatigue and thirst
- Supports respiratory health

Synonym: Mrudwika, gostani, rasala, guda, swaduphala, madhuyoni, madhuras, brumhani, charuphala.

Botanical Name: Vitis vinifera Linn. 24

Family : Vitaceae.

Grapes can be eaten raw, fermented into wine, dried, or processed into raisins. In Ayurveda, grapes are known as "Draksha Phalottama," signifying that they are the finest of all fruits. Various remedies utilize grapes at different stages of ripeness—dry, mature, semi-ripe, or fully ripe—characterized by their sweet and sour taste.²⁵

Fennel:

- **Family:** Apiaceae
- **Kingdom:** Plantae
- **Order:** Apiales
- **Genus:** Foeniculum
- **Species:** Foeniculum vulgare
- **Common Name:** Fennel, saunf
- **Category :** Carminative, spasmolytic





- **Functions / Role :**

- It's Anti-inflammatory.
- It's Reduce Headache.
- Taste masking.
- Digestion.
- Natural anti inflammotor.

Fennel grows in Prefers well- drained , sandy, or loamy soil and requires a temperate climates with Moderate rainfall or irrigation. It's occurs in Rajasthan, Gujarat , Haryana , Madhya Pradesh 26

Uses: Fennel is an excellent herb for alleviating hangovers due to its digestive benefits. Alcohol can irritate the stomach lining, leading to nausea and other digestive problems, but fennel's natural anti-inflammatory properties can help reduce this inflammation. Many people also find that fennel is effective for relieving headaches. To combat a hangover, you can use fennel seeds or brew fennel tea. 27 28

How Herbs Help With Hangovers

Antioxidant & Anti-Inflammatory Action

alcohol metabolism produces reactive oxygen species (ros) and acetaldehyde, both of which contribute to oxidative stress and inflammation.

Hepatoprotective Effects

the liver is the primary organ for alcohol metabolism. herbal compounds can protect liver cells from damage.

Support Alcohol Metabolism

some herbs help by enhancing **aldh (aldehyde dehydrogenase)** activity, which speeds up the conversion of toxic acetaldehyde to acetate.

Anti-Nausea And Gastroprotective Effects

alcohol irritates the stomach lining, leading to nausea and indigestion

Essential Oils Help With Hangover Recovery

An essential oil is a concentrated hydrophilic liquid that contains fragrant active components derived from plants. Essential oils play a crucial role in that they preserve the essence of the plant's aroma, which is often extracted through distillation and often involves the use of steam. They provide a number of wellness and health advantages and can help cure hangovers. It's believed that using some essential oils can help prevent hangovers naturally.

Some claim to feel more energised and refreshed after using pure essential oils to relieve hangover symptoms, despite the fact that there is little study or scientific proof to support this claim. Given that essential oils can lessen anxiety and make you feel less worn out and lethargic, it might be the best explanation. Furthermore, the majority exhibit anti-inflammatory qualities, hence mitigating headache discomfort. One study indicates that inhaling lavender essential oil lowers alcohol-related impairment by relaxing the central nervous system and treating anxiety and sleep difficulties. This makes lavender essential oil one of the finest essential oils for hangovers. ²³

The night before's inevitable hangover can be prevented organically with pure essential oils. a list of the top essential oils for hangovers that might help reduce your symptoms, including exhaustion, nausea, flushing, and inflammation.

Ginger Essential Oil:

Warm, aromatic, and stimulating, ginger essential oil helps to center the mind while energizing and revitalizing the senses. It works wonders as an aromatherapy remedy to help you recover from a hangover. If you're feeling lethargic or unfocused, partly from overindulging the previous evening, try inhaling some ginger essential oil. Inhale this product to soothe nausea and upset stomachs as well. Ginger is also well known for its ability to relieve stomach





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discomfort. This works well as a natural hangover cure and provides nausea relief without causing any negative side effects.

Essential Oil of Peppermint: Peppermint is a cross between spearmint and water mint. It's regarded as one of the best essential oils for aches and pains, including hangover headaches, and for helping get over fatigue or drowsiness. Although it might cause burning sensations if used directly, this minty and fresh essential oil can be massaged into the temples to reduce headaches. It is best to dilute essential oils before using them topically. Because of its cooling qualities and high menthol content, peppermint is the finest herb for treating overindulgence because it increases mental alertness and lessens sensations of lethargy.

Essential Oil of Grapefruit: The peel is steam-distilled to extract the essential oil. Its main functions are digestive assistance, antimicrobial, and antispasmodic. Its upbeat and soothing scent can be diffused or used in a bath to relieve vertigo and nausea. Its zesty aroma will fight hangover grogginess and make you feel more awake in the morning after a night out. Its superiority as a hangover cure and mood enhancer stems from this.

Lavender Essential Oil: Lavender oil has a pleasant aroma and is a well-liked headache remedy substitute. This oil has numerous applications and its characteristics help to lessen the effects of alcohol intake. In aromatherapy, lavender oil and flowers are used to treat hangovers, reduce tension and anxiety, and treat insomnia. It is also used in massage therapy to treat tense or inflammatory muscles and their spasms. Therefore, diffuse it in your room and enjoy a restful night's sleep without worrying about the effects of a hangover the next day.

Rosemary Essential Oil: The steam distillation process is used to extract the essential oil from the leaves and twigs of *Rosmarinus Officinalis* L. It is used in aromatherapy to relieve hangover symptoms like fatigue, anxiety, and stress. It has a very minty, herbal scent. Try this great natural hangover cure for mental clarity and energy if you're feeling sleepy after a bad hangover.

Available Marketed Formulations

The following are some of the formulations that are available in the market:

CONCLUSION

Alcohol misuse is a well-known contributor to a variety of health problems and can impair the function of vital organs such as the liver, brain, heart, lungs, and prostate. Many herbal medicines have shown remarkable protection against alcohol-related damage and a significant reduction in human hangover symptoms. Natural plant medicines improved the biochemical indicators of liver damage, lowered blood alcohol levels, and reduced the severity of hangover symptoms. The primary modes of action involve antioxidant and anti-inflammatory properties. A variety of herbal treatments may also help people with alcohol use disorders reduce their voluntary alcohol use, improve their drinking patterns, and lessen their symptoms of alcohol withdrawal. It also includes a few historically used plants that have no scientific backing.

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Table 1. Types of Alcoholic Beverages and Their Typical ABV

Beverages	ABV Range	Description
Beer	4-6 Light beer & 3 to 12 strong beer	Made from barley or other grains
Wine	9-15%	Fermented grape juice or other fruits.
Cider	4-8%	Fermented apple or pear juice

Table 2. Distilled Alcoholic Beverages (Spirits/Liquor)

Beverages	Abv Range	Description
Vodka	30-50%	Neutral spirit ,often flavorless
Whiskey	40-50%	Distilled from grains and aged in barrels
Rum	37-50%	Made from sugarcane / molasses
Gin	35-50%	Flavored with juniper berries
Tequila	35-55%	Made from blue agave
Brandy	35-60%	Distilled wine or fruit juice



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Absinthe	45-74%	Herbal spirit with anise flavour
Everclear	60-95%	Extremely high-proof grain alcohol (used cautiously, not for casual drinking)

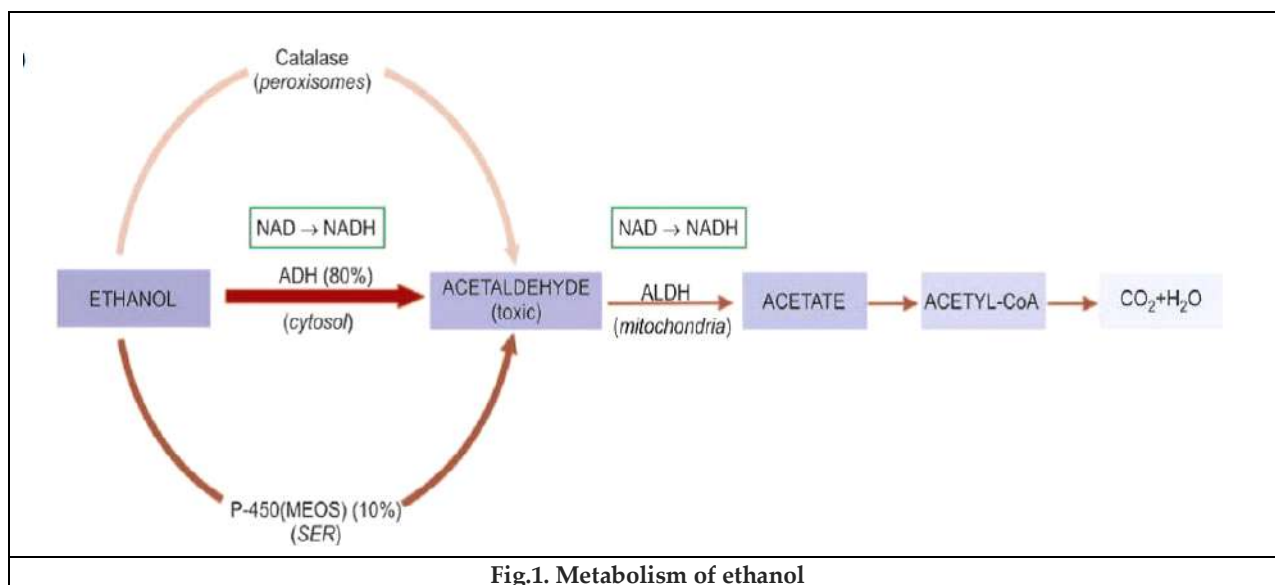
Table 3. Fortified Wines

Fortified Wine	ABV Range	Description
Port	16–20%	Sweet red wine from Portugal
Sherry	15–20%	Fortified white wine from Spain
Vermouth	15–18%	Wine flavored with herbs and botanicals

Safety Note

Table 4. Available Marketed Formulations

Sr. No.	Marketed Preparation	Brand Name	Ingredients
1.	Liquid	ARMR Lemonick	Giloy, Ashwangandha, Aloe vera, Punarnava, Kutki and Bhuiamlaki, Saunf, Greentea, Mulethi, Amla, Bhiringraj Pittapapada, Kamalphul Ginger, Kasani
2.	Capsules	Himalaya Party smart capsules	Chicory, Grape, Dates, Green chiretta
3.	Capsules	Dr.Vaidya's new age ayurveda LIVit up[36]	Kalmegh Ghan, Airogyavardhin Rasa, Lactose
4	Liquid	Tree hang and over	Kasani, Ashwagandha, Aloe vera, Ginger, Giloy, Saunf, Punarnava, Pitpara, Kutki, Bhiringraj, BhumiAmla, Mulethi, Amla, Greentea, Kamalful
5	Liquid	Vringa Antihangover shots	Amla, Mulethi, Bhuiamla, Giloy, kutki Green tea, Aloe vera, soya, Ginger
6	Strips	Work nutritions Slips Slip	Khajura, Curcumin, Yavatikta, Kasni, Draksha Bhumyamalaki, Amalaki

**Fig.1. Metabolism of ethanol**

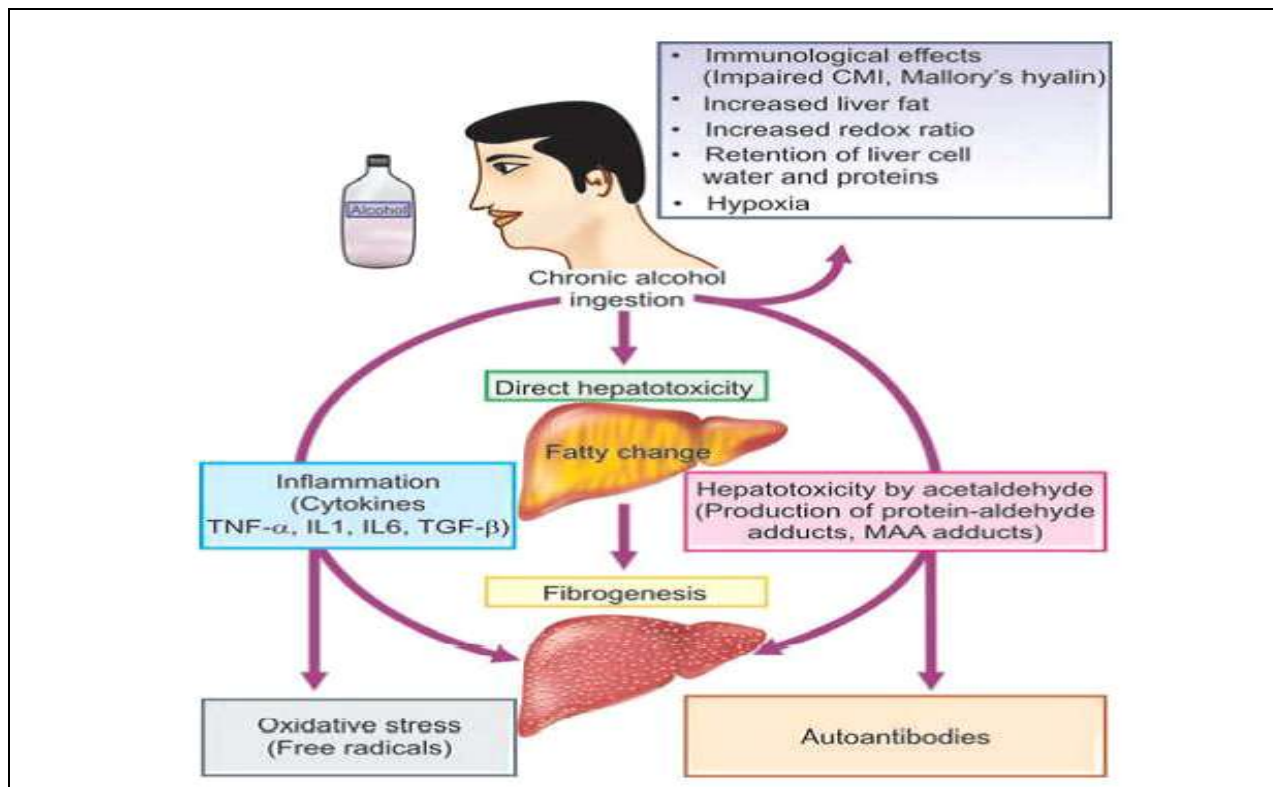


Fig.2. Pathophysiology



Fig. 3. Licorice Root & powder



Fig.4. Ashwagandha





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Fig. 5. <i>Amala</i>	Fig.6. <i>Tinospora cordifolia</i>
	
Fig. 7. <i>Zingiber officinale</i>	Fig. 8. <i>Phyllanthus niruri</i>
	
Fig. 9. Honey	Fig. 10. <i>Aloe vera</i>
	
Fig. 11. <i>Vitis vinifera</i>	Fig. 12. <i>Foeniculum vulgare</i>





RESEARCH ARTICLE

A Study to Assess Effectiveness of Video Assisted Teaching Program Regarding Oral Hygiene in Terms of Knowledge and Attitude among School Going Children

Dhara Vyas^{1*}, Janvi Patel², Jignesh Parmar², Kamini Amin², Khushbu Yadav² and Khushi Rathod²

¹Associate Professor and HOD, Department of Child Health Nursing, Dinsha Patel College of Nursing, Nadiad, (Affiliated to Sardar Patel University, Vallabh Vidyanagar, Anand), Gujarat, India.

²Final Year B.Sc Nursing, Department of Child Health Nursing, Dinsha Patel College of Nursing, Nadiad, (Affiliated to Sardar Patel University, Vallabh Vidyanagar, Anand), Gujarat, India.

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Accepted: 18 Aug 2025

*Address for Correspondence

Dhara Vyas

Associate Professor and HOD,
Department of Child Health Nursing,
Dinsha Patel College of Nursing, Nadiad,
(Affiliated to Sardar Patel University,
Vallabh Vidyanagar, Anand), Gujarat, India.



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ABSTRACT

Maintaining good oral health enhances the quality of life by enabling essential functions such as speech, enjoyment of food through taste and chewing, and emotional expression through smiling. Preventive measures like reducing carbohydrate intake can help manage plaque formation and decrease the risk of periodontal diseases and dental decay. This study aimed to assess the effectiveness of a Video-Assisted Teaching Program (VATP) on oral hygiene knowledge and attitude among school-going children. A quasi-experimental one group pre-test post-test design was adopted in this study with 60 school children selected using a simple random sampling technique. Data were collected using a structured questionnaire to assess knowledge and a Likert attitude scale to evaluate attitudes toward oral hygiene. The post-test results demonstrated a significant improvement in knowledge and attitude compared to the pre-test. In the pre-test, 90% of children had inadequate knowledge, 10% had moderate knowledge, and none had adequate knowledge. Regarding attitude, 91.7% showed a moderately favourable attitude, 8.3% had unfavourable attitudes, and none had a favourable attitude. Post-test results revealed 55% of children had moderately adequate knowledge, 45% had adequate knowledge, and none had inadequate knowledge. Attitudes improved with 60% showing moderately favourable attitudes and 40% having favourable attitudes. Paired t-tests showed significant differences in pre- and post-test knowledge ($t=39.93$) and attitudes ($t=12.42$) score. The VATP effectively enhanced both knowledge and attitudes regarding oral hygiene among school-going children, demonstrating its potential as a positive educational intervention.

Keywords: Knowledge, Attitude, Children, Oral Hygiene



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INTRODUCTION

Oral hygiene involves maintaining the cleanliness of the mouth and preventing diseases and other issues through regular brushing of teeth. Regular oral hygiene is crucial to prevent dental diseases. Maintaining good oral health enhances quality of life by enabling speech, enjoyment of food through taste and chewing, and expressing emotions such as smiling. Oral hygiene involves maintaining cleanliness in the mouth, particularly keeping the teeth free from dental plaque, a substance that is a major cause of dental diseases. Children are particularly susceptible to dental plaque, tooth decay, toothaches, gum diseases, and periodontal diseases. Diet also plays a significant role in influencing dental disorders. Foods high in sugar and carbohydrates contribute to plaque formation on teeth. Sweet cookies, certain soft drinks, and cakes contain significant amounts of sugar, so avoiding these foods can help prevent dental diseases to some extent. Reducing carbohydrate intake helps manage plaque formation and lowers the risk of periodontal diseases and dental decay. Children with dental issues often experience persistent dental pain, which can hinder their ability to concentrate on daily activities and chew food properly, affecting physical growth. This can also impact their school performance and academic achievement, leading to decreased self-esteem and challenges in interpersonal relationships. Chronic infections from tooth decay can affect learning, speech, and eating abilities.

Cavities, also known as tooth decay, are significantly affected by our lifestyle choices, including diet, oral hygiene practices, and exposure to fluoride in toothpaste and water. They are most prone to form in the grooves on the chewing surfaces of molars, between teeth, and close to the gum line. In Indian culture, hygiene holds significant importance and is integrated into daily life. It is crucial to disseminate evidence-based oral health information to every household. Schools can play a vital role in promoting oral health across all age groups within families and communities. This approach aims to foster a new India where everyone can enjoy healthy smiles. Most oral health conditions are largely preventable and can be treated in their early stages. Most cases are dental caries (tooth decay), periodontal diseases, tooth loss and oral cancers.

OBJECTIVES

1. To assess the knowledge regarding oral hygiene before and after the administration of Video assisted teaching program Among school going children in selected school of Nadiad city.
2. To assess the attitude regarding oral hygiene before and after administration of the video Assisted teaching program among school going children in selected school of nadiad City .
3. To evaluate the effectiveness of video assisted teaching program among school going Children in selected school of nadiadcity.

METHODS

This quasi experimental one group pre-test post-test study was conducted after the institutional ethical committee approval. The structured knowledge questionnaire was used to assess the level of knowledge in school going children and likert attitude scale was used to assess the level of attitude in school going children by simple random technique. A brief description of study objectives was explained by convenience, those who agreed respond to the questionnaire confirmed their agreement through signing the consent form. Participants who were not willing to participate were excluded. The data collection tool was comprised of three sections, namely the participants demographic details. For structured knowledge questionnaire minimum score is 0 and maximum score is 30. The score and category were calculated as below <50 % indicates inadequate knowledge, between 50-75 % indicates moderately adequate and above >75 % indicates Adequate knowledge. For likert attitude scale minimum score is 0 and maximum score was 50. The score and category were calculated as below <50% indicates unfavourable attitude, between 50-75 indicates moderately favourable attitude and above > 75 % indicates favourable attitude. The school children were included 6-12 year from primary nagar School of Nadiad City. Data of oral hygiene were distributed in percentage based on age, gender, Father occupation, mother occupation and having dental caries in previous history.



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The concurrent validity and reliability were obtained by Karl person 0.8 for Knowledge and Attitude domain respectively.

Ethical Considerations

The study was approved by the institutional ethical committee (IEC) of Dinsha Patel College Of Nursing, Nadiad. There is a total 15 members in the committee from various departments. The Ethical Approval Reference number is MAM Uni/IECHR/2024/50 And a formal written Consent was gathered from the samples prior to data collection.

RESULTS

The table presents demographic information and its corresponding data for a group of participants. Regarding age, 31.7% of the participants are between 6 to 8 years old, 33.3% fall within the 8 to 10 years range, and 35% are between 10 to 12 years old. When considering sex, 38.3% are male and 61.7% are female. For fathers' occupations, 13.3% hold jobs, 60% work as labourer's, 20% are workers, and 6.7% have other types of employment. As for mothers, 68.3% are housewives, 11.7% are workers, 10% are labourer's, and another 10% engage in other occupations. In terms of the sources of information, 55% of the participants rely on parents for information, 43.3% learn from teachers, 0% use the internet, and 1.7% receive information from dentists. Finally, when asked about dental caries, 18.3% of the participants reported having them, while 81.7% do not.

This figure 1 compares the results of a pre-test and post-test conducted to assess the knowledge levels of 60 participants. In the pre-test, a significant 90% of participants (54 out of 60) demonstrated inadequate knowledge, scoring below 50%. Only 10% (6 participants) showed moderately adequate knowledge, with scores ranging from 50% to 75%, while no participants (0%) reached an adequate level, scoring above 75%. After the post-test, the results indicated a marked improvement in the participants' knowledge. The percentage of participants with inadequate knowledge dropped to 0%, with none scoring below 50%. A majority of 55% (33 participants) fell into the moderately adequate category, showing scores between 50% and 75%. Furthermore, 45% (27 participants) achieved an adequate level of knowledge, scoring above 75%. This shift highlights a substantial improvement in the participants' knowledge after the intervention.

This figure 2 presents a comparison of levels in a pre-test and post-test scenario, with a total of 60 participants in each phase. Initially, in the pre-test, 8.3% of participants (5 individuals) exhibited an unfavourable attitude, scoring below 50%. A significant majority, 91.7% (55 individuals), demonstrated a moderately favourable attitude, scoring between 50% and 75%, while none of the participants fell into the favourable category (above 75%). In the post-test, there was a notable shift in attitudes. No participants remained in the unfavourable category, representing a 100% reduction. The percentage of participants with a moderately favourable attitude decreased to 60% (36 individuals), showing a change in their attitudes towards a more positive outlook. On the other hand, the number of individuals with a favourable attitude increased significantly to 40% (24 individuals), indicating an overall improvement in attitude.

The table 2 presents the results of a knowledge test conducted before and after an intervention. The pre-test mean score was 7.80, with a standard deviation of 2.02, indicating the average score and the variability of scores from the mean in the pre-test. The mean difference between the pre-test and post-test scores was 5.37, suggesting an improvement in knowledge. In the post-test, the mean score increased to 13.17, with a reduced standard deviation of 1.49, indicating a more consistent performance among participants. The calculated 't' value for the pre-test was 39.93, which is significantly high, implying that the difference between the pre-test and post-test scores is statistically significant. This suggests that the intervention or training had a meaningful effect on the participants' knowledge.

The table 3 presents the results of an attitude test administered before and after an intervention. The pre-test mean score was 33.10, with a standard deviation of 5.00, reflecting the average attitude score and the spread of individual scores in the pre-test. The mean difference between the pre-test and post-test was 10.1, indicating a substantial



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improvement in participants' attitudes. The post-test mean score increased to 43.20, with a reduced standard deviation of 2.77, signifying a more consistent attitude across participants. The calculated 't' value for the pre-test was 12.42, a high value that suggests the observed difference between pre-test and post-test scores is statistically significant. This indicates that the intervention or treatment likely had a positive effect on the participants' attitudes.

Oral health is crucial for overall well-being, yet many school-going children lack adequate knowledge and attitudes about it. This study assessed the impact of a Video-Assisted Teaching Program on oral hygiene knowledge and attitudes. A pre-test revealed significant gaps, with 90% having inadequate knowledge. Post-intervention, 45% achieved adequate knowledge, and 40% developed favorable attitudes, highlighting Video-Assisted Teaching Program's effectiveness. However, 55% still showed only moderate knowledge, indicating the need for follow-up programs. Despite its success, the study's limited sample size and lack of a control group suggest further research is needed to generalize findings and ensure lasting behavioral change.

CONCLUSION

Our study found that the Post-test Knowledge and Attitude of school going children regarding the oral hygiene was higher than the Pre-test Knowledge and Attitude. It means that video Assisted Teaching program has Positive impact on the Knowledge and Attitude of school going children regarding the oral hygiene. The study findings suggest that Video-Assisted Teaching Programs can be an effective tool for enhancing oral health awareness among children. However, the study had certain limitations, including a small sample size and the absence of a control group, which restrict the generalizability of the results. Future research with larger sample sizes and comparative studies would help validate the effectiveness of such interventions further. Additionally, incorporating periodic follow-up sessions could reinforce knowledge retention and encourage lasting behavioral changes.

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Dhara Vyas *et al.*,**Table 1: Frequency and percentage distribution of Selected demographic variables of the School children such as Age, Gender, Father's occupation, Mother's occupation, Source of information.**

SR.NO	DEMOGRAPHIC VARIABLES	FREQUENCY	PERCENTAGE
1.	Age (in years) A. 6 to 8 years B. 8 to 10 years C. 10 to 12years	A. 19 B. 20 C. 21	A. 31.7 % B. 33.3 % C. 35 %
2.	Sex A. Male B. Female	A. 23 B. 37	A. 38.3% B. 61.7%
3.	Father's Occupation A. Job B. Worker C. Labour D. Any other	A. 8 B. 36 C. 12 D. 4	A. 13.3% B. 60 % C. 20 % D. 6.7 %
4.	Mother's Occupation A. Housewife B. Worker C. Labour D. Any other	A. 41 B. 7 C. 6 D. 6	A. 68.3% B. 11.7% C. 10% D. 10%
5.	Source of Information A. Parents B. Teacher C. Internet D. Dentist	A. 33 B. 26 C. 00 D. 1	A. 55% B. 43.3% C. 00% D. 1.7%
6.	Do you have any dental caries ? A. Yes B. No	A. 11 B. 49	A. 18.3% B. 81.7%

Table.2 Mean , Mean Difference , Standard deviations and Paired t-test analysis for the significance of pre-test and post-test Knowledge regarding oral hygiene.

Knowledge Test	Mean	Mean Difference	SD	Calculated 't' value
Pre-test	7.80	5.37	2.02	39.93
Post-test	13.17		1.49	

Table.3 Mean , Mean Difference , Standard deviations and Paired t-test analysis for the significance of pre-test and post-test Attitude regarding oral hygiene.

Attitude Test	Mean	Mean Difference	S.D	Calculated 't' value
Pre-test	33.10	10.1	5.00	12.42
Post-test	43.20		2.77	





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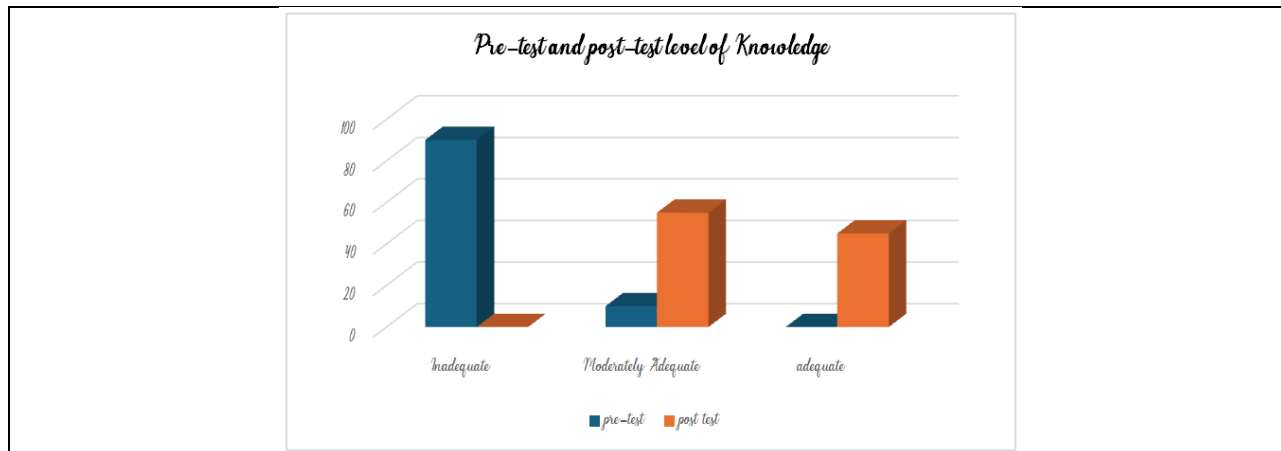


Figure.1 Comparison of pre-test and post-test level of Knowledge regarding oral hygiene.

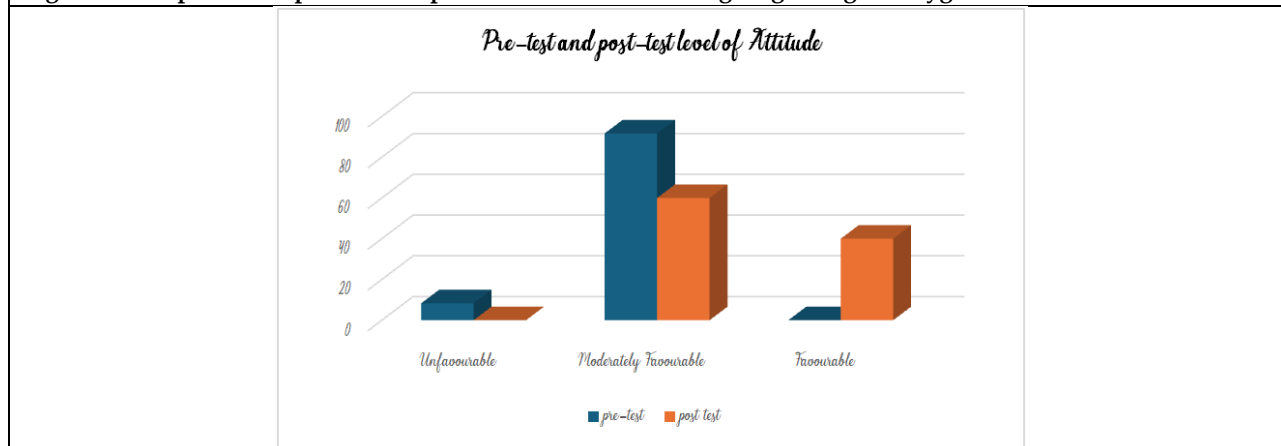


Figure. 2 Compression of pre-test and post-test level of Attitude Frequency regarding oral hygiene





RESEARCH ARTICLE

Questionnaire Study on Quality of Life of General Dental Practitioners during COVID-19 and Post COVID-19

Sivachandran A¹, Aravindhnan R¹, Magesh K T² and M. Sathyakumar^{3*}

¹Associate Professor, Department of Oral Pathology and Microbiology, SRM Kattankulathur Dental College and Hospital, SRM Institute of Science and Technology (Deemed to be University), Chengalpattu, Tamil Nadu, India.

²Professor and Head, Department of Oral Pathology and Microbiology, SRM Institute of Science and Technology (Deemed to be University), Chengalpattu, Tamil Nadu, India.

³Professor, Department of Oral Pathology and Microbiology, SRM Institute of Science and Technology (Deemed to be University), Chengalpattu, Tamil Nadu, India.

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Revised: 21 Jul 2025

Accepted: 18 Aug 2025

*Address for Correspondence

M. Sathyakumar

Professor,

Department of Oral Pathology and Microbiology,

SRM Institute of Science and Technology (Deemed to be University),

Chengalpattu, Tamil Nadu, India.

E.Mail: sathyakm@srmist.edu.in



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ABSTRACT

To assess the quality of life regarding health, family and finance of dentists during the covid-19 and post covid-19. A verified questionnaire in the form of a Google form was circulated among general dental practitioners from March 2023 to October 2023. Simple sampling method was used and the estimated sample size was 315 which was determined using of formula $4pq/d^2$. The responses received were statistically analyzed. Regarding the Health-Related Quality of Life (HRQOL) among the 315, 173 had one incidence of COVID-19 (54.9%), 48 had two incidences (15.2%) and 88 did not have any incidences (27.9%). According to general dental practitioners' the Family Related Quality of Life survey results showed that 172 general dental practitioners (54.6%) and 131 general dental practitioners (41.6%) had daily and weekly interactions with their families during the pandemic respectively. Related to general dental practitioners' the Financial Related Quality of Life survey results showed, that 215 general dental practitioners (68.3%) experienced financial difficulties, while 100 of them (31.7%) did not. Practitioners should exercise caution in Health quality by avoiding oversteering themselves as well as adhere to all preventive measures both during and after the virus outbreak. Practitioners must spend adequate time with family and friends and stay in isolation when infected. To overcome the financial crisis, practitioners must develop alternative strategies.

Keywords: General Dental Practitioner, Health related quality of life, Pandemic, Finance related quality of life, Family related quality of life, COVID-19.





INTRODUCTION

The COVID-19 pandemic, suddenly emerged from a place in Wuhan, China, due to a virus named severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2). Then named as coronavirus (COVID-19), which infects the respiratory system and making the alveoli of lung to fibrosis of squamous metaplasia (Haraldstad *et al.* 2019 [1]; Hertz-Palmor *et al.* 2022) [2]. The virus spreads rapidly the most vulnerable healthcare professionals includes ophthalmologists, ENT surgeons and most importantly dentists who are closely associated with oral and nasal cavities, according to Occupational Safety and Health Administration (OSHA), dental health care personnel (DHCP) (Dentists) are considered as very high exposure risk category (Goriuc *et al.* 2022) [3]. Also, dental procedures involve the use of rotary instruments producing more aerosols such as hand pieces and ultrasonic scalers. The most important mode of transmission of coronavirus is through inhalation of droplets and aerosols from an infected individual or by direct contact of mucous membranes, saliva and contaminated instruments (Yuki *et al.* 2020) [4]. Dentist face lot of challenges due to restrictions placed on their practice and the need to comply with biosafety measures like PPE kits and so on. After this pandemic outbreak dentists are mostly having compromised quality of life in health, family associations, economy, mental, and social wellbeing aspects (Kandula *et al.* 2021) [5].

MATERIALS AND METHODS

A verified questionnaire (questionnaire is attached at end of the article-Table 1) was used to study on quality of life of general dental practitioner during COVID and post COVID. Sample size was determined using of formula $4pq/d^2$ and the minimum sample size required for the study was estimated to be 315.

Inclusion Criteria

Private dental practitioner who worked during COVID and after COVID

Exclusion Criteria

- Clinics closed during COVID period
- Dental Professors who are not practicing

RESULTS

Throughout the study period, Dentists were asked about their concern to participate in this study, and all of them agreed. A total of 315 doctors—187 men and 128 women—who were employed during COVID and post-COVID period. According to the physician's health quality of life survey, out of 315, 173 had one incidence of COVID-19 (54.9%), 48 had two incidences (15.2%), and 88 did not have any incidences (27.9%). A total of 182 Dentists (57.8%) reported no post-COVID problems; 94 Dentists (27.8%) experienced breathing difficulties; and 13 Dentists (7.3%) reported sleeping disturbances. 230 doctors, or 73%, worked less than five hours during COVID-19, while 76 doctors, or 24.1%, worked five to ten hours and following the implementation of COVID, 17 Dentists (5.4%) worked for less than 5 hours, 64 Dentists (20.3%) for 5 to 10 hours, and 234 Dentists (74.3) for more than 10 hours. During the COVID-19 pandemic, 270 doctors, or 85.7%, treated 1–10 patients. Thirty doctors, or 9.5%, treated 10–20 patients. After COVID was implemented, 34 doctors, or 10.8%, treated 1–10 patients, 195 doctors, or 61.9%, treated 10–20 patients. 82.5% of 282 doctors showed no symptoms, and 10.5% of 33 doctors showed signs of anxiety and depression (Owen *et al.* 2022 [6]; Ahmadvand *et al.* 2018) [7]. About half of the doctors during COVID-19—160, or 50.8%—had back and neck pain, whereas the remaining half—154, or 49.2%—did not. 211 doctors, or 67%, reported that their illness did not worsen after COVID, whereas 103 doctors, or 33%, reported that it did. In the COVID-19 pandemic, 193 Dentists, or 61.3% of the total, took an hourly break while working, 99 Dentists, or 31.4%, took a break every five hours, and 23 Dentists, or 7.3%, took no breaks at all while practicing. Following COVID, 39 Dentists, or 12.4% of the total, took an hourly break while working, 194 Dentists, or 61.6%, took a break every five hours, and 82 Dentists, or 26%, did not take a break while practicing. During COVID-19, 195 Dentists, or 62.2%, did not exhibit any outward signs of fear,



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while 103 Dentists, or 33%, did exhibit symptoms like sweating. Following COVID, 171 doctors, or 54% of the total, still have these symptoms, while 87 doctors, or 27.6%, do not, and 57 doctors, or 18.1%, have never experienced these symptoms. Of the doctors who followed preventive measures during COVID-19, 282 doctors, or 89.5%, used gloves and masks, hand washing, fumigation, and PPE kits; 22 doctors, or 7%, just used gloves and masks. Following Covid-19, 275 Dentists, or 87.6%, are still adhering to all of these guidelines, while 39 Dentists, or 12.4%, are not (Jawad *et al.* 2021 [8]; Wolf *et al.* 2022) [9]. According to Dentist's family quality of life survey (Table 2) results show that 172 Dentists (54.6%) and 131 Dentists (41.6%) had daily and weekly interactions with their families during COVID-19. Following the implementation of COVID, 144 doctors (46%) interacted daily, 139 doctors (41%) interacted weekly, and 41 doctors (13%) interacted monthly. During the COVID pandemic, 193 doctors (61.3%) spent less than five hours interacting with family, 80 doctors (25.7%) spent five to ten hours interacting with family, and 41 doctors (13%) spent more than ten hours interacting with family per day. Following Covid-19, 129 Dentists (41%) had fewer than five hours of interaction, 141 Dentists (44.8%) had five to ten hours of interaction, and 45 Dentists (14.3%) had more than ten hours of interaction in a single day. 29 doctors (9.2%) went out with friends once a week during COVID, 46 doctors (14.6%) once a month, and 240 doctors (76.2%) once a year. Following COVID, 52 doctors (16.5%) went out with friends once a week, 152 doctors (48.3%) once a month, and 111 doctors (35.2%) once a year. While 40 Dentists (12.7%) were not placed under quarantine during COVID, 280 Dentists (87.3%) had done so. Out of these doctors, approximately 178 (56.5%) have mental health issues, whereas approximately 137 (43.5%) do not have symptoms. 305 doctors, 96.8% raised awareness among family members and adhered to COVID-19 protocol; the remaining clinicians did not. Following COVID-19, 186 Dentists (or 59% of them) continue to use them, while 129 Dentists (or 59% of them) do not raise family awareness. While the majority of doctors have attended most family gatherings during COVID, 293 doctors (93.3%) have only occasionally attended. Following COVID, 191 doctors (60.6%) attended monthly, 30 doctors (9.5%) attended every family function, and 93 doctors (29.8%) visited them infrequently.

Parents of 238 doctors (75.6%) have been impacted by COVID, while parents of 76 doctors (24.2%) have not. While 185 doctors' parents (58.7%) report no adverse effects, 130 doctors' parents (41.3%) still experience them. According to Dentist's financial quality of life survey (Table 3) results show, During the COVID-19 pandemic, 215 Dentists (68.3%) experienced financial difficulties, while 100 Dentists (31.7%) did not. 189 Dentists (or 60%) were able to cover their costs, while 126 Dentists (or 40%) were unable to do so following COVID-19. 51 doctors (16.2%) have not offered any COVID protection to patients or staff, whereas 267 doctors (83.8%) have given both. Following the Covid-19 pandemic, 132 Dentists (41.9%) continue to supply them to patients and staff, whereas 183 Dentists (58.1%) do not. 53 doctors (16.8%) have not charged additional expenditures from patients during COVID, while 198 doctors (62.9%) have partially paid the costs from patients. Of the doctors, 64 doctors (20.3%) have entirely covered the costs from the patients. Following COVID, 17 Dentists (5.4%) have paid for the patient's additional costs in full, 159 Dentists (50.5%) have paid for the patient's increased costs in part, and 139 Dentists (44.1%) have not collected further costs from the patient. During COVID-19, 222 Dentists (70.5%) have modified the treatment plan, whereas 93 Dentists (29.5%) have not. Following COVID, 122 doctors (38.7%) believe the treatment plan modifications are helpful, while 193 doctors (61.3%) disagree. 138 doctors (43.8%) practiced tele dentistry during COVID whereas 177 doctors (56.2%) did not. 74 doctors (23.5%) still practice tele dentistry after COVID whereas 241 doctors (76.5%) do not (Doan *et al.* 2023) [10]. In the aspect of the Health quality of life during and after COVID-19, the following factors demonstrated significant values: the number of patients seen; the length of time the practitioner practiced during and after COVID-19; symptoms of anxiety and depression; back and neck pain; any sign of fear during dental work; and preventative measures implemented during and after COVID-19, for which the value was 0.000. When it comes to Family quality of life during and after COVID-19, the following variables showed significant values: how often and how much time they spent with friends and family; whether they quarantined themselves; whether their mental health was affected; raising awareness within the family; and whether they had family members who got infected with the virus, for which the value was 0.000. The following variables showed significant values in the aspects of the Finance quality of life during and after COVID-19: whether they had experienced a financial crisis; whether they had to cover any additional costs in order to protect patients and staff; whether they had covered additional costs by charging patients; and whether they had changed treatment plans, for which the p value was 0.000.





DISCUSSION

This pandemic had a significant impact on the quality of life of general dental practitioners. Not only did dental practitioners face the physical health risks associated with treating patients during a pandemic, but they also experienced psychological stress and mental health issues. Multiple studies have highlighted the mental health sequelae, such as anxiety and distress, among various healthcare providers during this period. Furthermore, dental practitioners who worked on the frontline and had close contact with patients expressed higher levels anxiety, fear and depression compared to other healthcare professionals. These changes added additional stress and challenges for dental practitioners, including concerns about the risk of infection, uncertainty about the future of their practice, job insecurity, and worries about the well-being of their loved ones. The effects of the COVID-19 pandemic on the mental health and overall quality of life of dental practitioners cannot be overlooked. The COVID-19 pandemic has significantly impacted the quality of life of general dental practitioners. The study result highlights that 215 Dentists (68.3%) experienced financial difficulties, while 100 Dentists (31.7%) did not. (Chakraborty *et al.*2020) [11] identified that among 335 participants depressed most of them are males below 30 years old. And these findings were in consist with results of the present study where about 165 doctors, or 52.4%, experienced anxiety and depression symptoms during COVID, while 149 doctors, or 47.6%, showed no symptoms at all. Following the COVID pandemic, 82.5% of 282 doctors showed no symptoms, and 10.5% of 33 doctors showed signs of anxiety and depression even after pandemic. The pandemic brought about changes in the way dental practices operated, including implementing infection control measures which is why 51 doctors (16.2%) could not offer any COVID protection to patients or staff, whereas 267 doctors (83.8%) have given both. These reasons led to the major adaptation changes like telemedicine for consultations. As far as treatment plan is concerned the dentist considered alternative treatment options. 222 Dentists (70.5%) have modified the treatment plan due to the onset of the pandemic. These additional challenges have had negative consequences on the ability of dental practitioners (52.4%) to cope and have also caused them mental health issues and psychological stress. (De Haro *et al.* 2022)[12], concludes that more than 92% of the dental professionals underwent prolonged stress due to the negative attitude of the patients and fear of infection in the dental setting. To motivate patients to attend their clinic around 198 doctors (62.9%) have partially paid the treatment costs. (Hassan *et al.* 2022) [13], inferred that 82.3% did not charge their patients more even though there was a significant increase in the material cost and to provide safety measures to the patients attending the clinic (Ahn *et al.*2022[14]; Bhanushali *et al.*2020) [15].

CONCLUSION

This questionnaire study provides valuable insights into the quality of life (QoL) of dentists during pandemic and post-COVID-19. The findings underscore the multifaceted impact of the pandemic among the general dental practitioners, revealing significant challenges across various domains of their lives. One of the primary findings is the heightened level of stress experienced by dental practitioners, attributable to concerns about personal health and safety, financial strain due to practice disruptions, and uncertainty regarding the future of their profession. These stressors not only affect the mental well-being of dental professionals but also have implications for the quality of patient care and overall practice sustainability. Despite the adversities, dental practitioners have demonstrated resilience and adaptability in navigating through the challenges posed by the pandemic. Many have implemented innovative strategies to ensure continuity of patient care while prioritizing safety protocols. However, it evident that among the long-term consequences of this outbreak on the dental profession extend beyond clinical practice. Financial implications, such as reduced income and increased overhead costs, have exacerbated existing stressors and underscored the need for comprehensive support mechanisms. Moving forward, addressing the identified stressors and challenges is paramount to safeguarding the QoL of general dental practitioners. Interventions aimed at promoting mental health and well-being, enhancing practice sustainability, and ensuring workplace safety are imperative. Additionally, fostering a supportive professional community and providing access to resources for coping with stress and uncertainty can aid in mitigating the negative impact of this adverse situations on dental professionals. As the dental community navigates the post-COVID landscape, it is essential to prioritize the holistic





well-being of dental practitioners. This includes advocating for policy changes to support practice recovery, implementing targeted interventions to address financial hardships, and fostering a culture of resilience and mutual support within the profession.

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Table 1: Questionnaire used in this study –Health Quality of Life

	During COVID	Post COVID
1	1. How many times did you get Corona virus infection? a. 1 b) 2 c) 3 d) Nil	If affected by COVID, were there any Post COVID complications? a) Breathlessness b) Sleeping disorders c) Lightheadedness d) Depression and Anxiety
2	How many hours in a day did you practice during COVID? a) Less than 5 hours b) 5-10 hours	How many hours in a day do you practice now? a. Less than 5 hours b. 5-10 hours





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	c) More than 10 hours	c. More than 10 hours
3	How many patients did you see during COVID? a)1-10 b)10-20 c)20-30 d)30 and above	How many patients do you see now? a)1-10 b)10-20 c)20-30 d)30 and above
4	Had any symptoms of anxiety, fear and depression during dental practice during this pandemic? a) yes b) no If yes, were you under any medications?	Do you still have anxiety and depression during dental practice post- COVID? a) Yes b) No
5	5. Did you have neck pain/cervical spondylitis and back pain during practice? a) Yes b) No	Have the condition worsened post COVID? a. Yes b) No
6	How often did you take break in a day's practice? a. Every 1 hour b. every 5 hours c. No break	How often do you take break in a day's practice now? a. Every 1 hour b. every 5 hours c. No break
7	Any physical manifestations of fear during dental practice during COVID? a) Tremors b) Sweating c) Palpitations d) All of the above	Do you still have them post COVID? a) yes b) no
8	What were the measures for prevention taken during COVID? a. PPE kit, gloves, mask b. Fumigation c. Handwashing d. All of the above	Do you follow the measures for prevention post COVID? a. PPE kit, gloves, mask b. Fumigation c. Handwashing d. All of the above

Table 2: Questionnaire used in this study- Family quality of life

	During COVID	Post COVID
1	How often did you communicate with your family? a) Every day b) Every week c) Every month	How often do you communicate with your family now? a) Every day b) Every week c) Every month
2	How many hours in a day did you practice during COVID? a) Less than 5 hours b)5-10 hours c) more than 10 hours	How long in a day do you spend time with your family now? a. Less than 5 hours b. 5- 10 hours c. More than 10 hours
3	How often you go out with friends? a) Weekly b) Monthly c) Yearly	How often you go out with friends now? a. Weekly b. Monthly c. Yearly





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4	Have you quarantined yourself during COVID? a) Yes b) No	If so, has it affected your mental health? a. Yes b) No
5	Did you spread awareness amongst your family members and follow the COVID protocols? a) Yes b) No	If so, do you still implement them in your daily life? a. Yes b. No
6	How often did you attend a family function with your family? a. Every function b. Most of them c. Rare	How often do you attend a family function with your family now? a. Every function b. Most of them c. Rare
7	Did your family members suffer from COVID 19 symptoms? a. Yes b. No	If so, do they still have the side effects? a. Yes b. No

Table 3: Questionnaire used in this study- Financial Quality of Life

	During COVID	Post COVID
1	Have you undergone any Financial crisis during COVID? a) Yes b) No	If undergone any Financial crisis, were you able to meet them Post COVID? a) Yes b) No
2	Did you have to bear any additional expenses in providing required covid-19 protection to the staff and the patients? a. Yes b. No	Do you still provide them to the staff and the patients? a. Yes b. No
3	Did you cover additional expenses by charging from the patient during COVID? a) Yes, Fully b) Yes, Partially c) No	Do you still cover the additional expenses by charging from the patient? a) Yes, Fully b) Yes, Partially c) No
4	Did you change the treatment plans during COVID? a. Yes b. No	Are the changes in the treatment plan useful now? a. Yes b. No
5	Did you practice Tele dentistry? a. Yes b. No	Do you still practice Tele dentistry? a. Yes b. No





RESEARCH ARTICLE

A Constant an Average of a Real - Valued Stochastic Process in Discrete Time

A. Juliet Dayana^{1*} and V. Krishnan²

¹Assistant Professor, Department of Mathematics, Marudupandiyar College, Thanjavur, (Affiliated to Bharathidasan University, Tiruchirappalli), Tamil Nadu, India.

²Assistant Professor, Department of Mathematics, Jamal Mohamed College (Autonomous), (Affiliated to Bharathidasan University), Tiruchirappalli, Tamil Nadu, India.

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*Address for Correspondence

A. Juliet Dayana

Assistant Professor,
Department of Mathematics,
Marudupandiyar College, Thanjavur,
(Affiliated to Bharathidasan University, Tiruchirappalli),
Tamil Nadu, India.

E.Mail: julietdayana24932@gmail.com



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ABSTRACT

The essay begins with a traditional examination of real number sequences that focuses on their convergence. Likewise, fundamental assertions concerning sequence of real-valued random attributes are the backbone of stochastic analysis. The unique decomposition of every such sequence into a real-valued martingale is possible. Each stochastic process has a predictable and "constant on average" portion. As a result, stochastic analysis relies heavily on martingale estimates and convergence theorems.

Keywords: Martingale, Supermartingale, Submartingale.

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INTRODUCTION

A martingale and a predictable process may be broken down into any adjusted sequence of real-valued random attributes. Specifically, a martingale's variance process (M_n) in the related DOOB breakdown of the process is the predictable component (M_n^2). The DOOB decomposition for Markov stochastic model functions involves characterisation of Markov stochastic models with respect to the martingale issue. At first glance, a martingale seems to be a "fair" game; in other words, M_{n-1} is the most accurate forecast for the subsequent value, measured against the mean square error M_n has access to data up to time $n-1$. "Constant on average" characterizes a martingale, "growing on average" a submartingale, and "decreasing on average" a supermartingale. In particular, a martingale will satisfy the condition if induction is applied to n .





$E[M_n] = E[M_0]$ only if $n \geq 0$.

Likewise, the expectation values $E[M_n]$ for a supermartingale are going down.

Definitions : 1.1

The probability space is fixed $(\Omega, \mathcal{A}, P)$. Additionally, we will presume that we are provided with a rising sequence F_n ($n = 0, 1, 2, \dots$) of sub- σ -polynomials of $\mathcal{A}$. Our natural inclination is to assume F_n like detailing what we know as of time n .

Definitions:1.2

(1) Filtering on $(\Omega, \mathcal{A})$ is a sequential increase $F_0 \subseteq F_1 \subseteq F_2 \subseteq \dots$ of σ -algebras $F_n \subseteq \mathcal{A}$.

(2) The process of stochastic $(X_n)_{n \geq 0}$ is changed into the filtering $(F_n)_{n \geq 0}$ iff every X_n possible F_n -computable.

(3) A stochastic process (X_n) is used to construct the canonical filter F_n^X , which is defined as

$$F_n^X = \sigma(X_0, X_1, \dots, X_n).$$

Typically, we will take the canonical filtering into account when the Filtering is not specifically stated.

(4) Filterings that provide extra information, such as the filter, are also of interest.

$$F_n = \sigma(Z, X_0, X_1, \dots, X_n)$$

The above values are generated by the process (X_n) and also the random attributes are Z , processed by the filtering

$$F_n = \sigma(X_0, Y_0, X_1, Y_1, \dots, X_n, Y_n)$$

The result of the procedure (X_n) and subsequent process (Y_n) .

The procedure (X_n) may obviously be adjusted to fit any of these filters. The filtering of (X_n) is the norm, generally speaking (F_n) if any only if $F_n^X \subseteq F_n$ only if $n \geq 0$.

Martingales and Super Martingales

We can now explicitly say that the process of real number analysis as stochastic is one that, on regular, either stays the same or goes up or down:

Definition:2.1

(1) Regarding the filter on the likelihood space $(\Omega, \mathcal{A}, P)$ (F_n) , a martingale is defined as a order of simulated real numbers $M_n : \Omega \rightarrow \mathbb{R}$ ($n = 0, 1, \dots$) Only If

(a) (M_n) is modified w.r.t (F_n) ,

(b) M_n is compatible with some $n \geq 0$, and

(c) $E[M_n | F_{n-1}] = M_{n-1}$ if only $n \in \mathbb{N}$.

(2) Likewise, (M_n) is known as a super martingale (as opposed to a sub martingale) in relation to (F_n) the affirmative component, provided that (a) is true M_n^+ (resp. the negative part M_n^-) is integral for all values of n greater than or equal to zero, and (c) is true when the line "=" is substituted with " $\leq$ ", " $\geq$ " respectively.

The martingale definition's condition (c) may also be expressed as (c') $E[M_{n+1} - M_n | F_n] = 0$ only if $n \in \mathbb{Z}_+$ and consistently through "=" substituted via " $\leq$ " or " $\geq$ " for fantastic – or submartingales.

Lemma : 2.2

If (M_n) relates to a filter in a martingale (or super martingale) fashion (F_n) then

$$E[M_{n+k} | F_n] \stackrel{(\leq)}{=} M_n \quad P\text{-quite likely only if integer } n, k \geq 0.$$

Proof

Since M_n is F_n -measurable, the statement holds for $k=0$ by induction on k . On top of that, the claim for $k-1$

$$E[M_{n+k} | F_n] = E[E[M_{n+k} | F_{n+k-1}] | F_n]$$

$$= E[M_{n+k-1} | F_n] = M_n \quad P\text{-a.s.}$$

in return for assurances that the skyscraper would maintain its property.

Examples :2.3

a) Totals of randomly assigned numbers

The random walk

$$S_n = \sum_{i=1}^n \eta_i, \quad n = 0, 1, 2, \dots,$$





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By autonomous raises $\eta_i \in \mathcal{L}^1(\Omega, \mathcal{A}, P)$ is a martingale w. r. t to the separation

$$F_n = \sigma(\eta_1, \dots, \eta_n)$$

$$\sigma = (S_0, S_1, \dots, S_n)$$

centered random attributes must be present for the increments η_i to be true. The truth is that any $n \in \mathbb{N}$,

$$E[S_n - S_{n-1} | F_{n-1}] = E[\eta_n | F_{n-1}] = E[\eta_n]$$

using the increments independently. The same holds true, (S_n) is an (F_n) supermartingale if besides only if $E[\eta_i] \leq 0$ only if $i \in \mathbb{N}$.

b) Outputs of attributes that are autonomous and non-negative

The method of stochastic is follows

$$M_n = \prod_{i=1}^n Y_i, \quad n = 0, 1, 2, \dots,$$

In the presence of separate, opposing attributes $Y_i \in \mathcal{L}^1(\Omega, \mathcal{A}, P)$. Its fitted with a martingale or a super martingale according to the filtering

$$F_n = \sigma(Y_1, \dots, Y_n)$$

For any $E[Y_i] = 1$ only if $i \in \mathbb{N}$, $E[Y_i] \leq 1$ only if $i \in \mathbb{N}$ correspondingly. In detail, as M_n is F_n -assessable and Y_{n+1} is autonomous of F_n , we have

$$E[M_{n+1} | F_n] = E[M_n \cdot Y_{n+1} | F_n] = M_n \cdot E[Y_{n+1}] \text{ only if } n \geq 0.$$

Such martingales and super martingales seem to be a natural part of models of stochastic growth.

(c) Example

Assume a Random Walk $S_n = \sum_{i=1}^n \eta_i$ with additions η_i that are i.i.d also allow

$$Z(\lambda) = E[\exp(\lambda \eta_i)], \quad \lambda \in \mathbb{R}.$$

represent the function that generates the increases at the current instant. At that point, in the event that $\lambda \in \mathbb{R}$ by $Z(\lambda) < \infty$, the method

$$M_n^\lambda := e^{\lambda S_n} / Z(\lambda)^n = \prod_{i=1}^n (e^{\lambda \eta_i} / Z(\lambda))$$

is a martingale.

Theory: 2.4

Assume that $(M_n)_{n \geq 0}$ is an (F_n) The function $u: \mathbb{R} \rightarrow \mathbb{R}$ is convex and has a bottom limit; it is also martingale. What followed $(u(M_n))$ is an (F_n) sub martingale.

PROOF

Later u is lower constrained, $u(M_n)$ may be integrated for every. The discrepancy of Jensen for restricted expectations currently suggests

$$E[u(M_{n+1}) | F_n] \geq u(E[M_{n+1} | F_n]) = u(M_n)$$

Almost surely only if $n \geq 0$.

Definition :2.5

(1) A discrete time stochastic method $(X_n)_{n \geq 0}$ a (timehomogeneous) Markov Chain having shift kernel p w.r.t. the filtering $(\mathcal{C}_n)$ is defined as a set of states (S, B) specified on the probability space $(\Omega, \mathcal{A}, P)$.

a) (X_n) , is (F_n) adapted, and

b) $P[X_{n+1} \in B | F_n] = p(X_n, B)P$ - without a doubt only if $B \in \mathcal{B}$ and $n \geq 0$.

(2) The function i.e. $h: S \rightarrow \mathbb{R}$ determines whether an object is assumed superharmonic or subharmonic with respect to p .

$$(ph)(x) := \int p(x, dy) h(y), \quad x \in S,$$

exist, and

$$(ph)(x) \leq h(x) \text{ (respectively } (ph)(x) \geq h(x))$$

Holds, only if $x \in S$.

When a function h is super- and subharmonic, or when it satisfies both conditions, we say that it is harmonic.

$$(ph)(x) = h(x) \text{ only if } x \in S.$$

The tower property states that every Markov stochastic model with regard to conditional expectations is identical to a Markov stochastic model in regards to the canonical filtering that the process produces.





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Example:2.6

For typical random walk, $(X_n)_{n \geq 0}$ on $\mathbb{Z}^d$ is a Markov stochastic model in relation to the filtering $F_n^x = \sigma(X_0, \dots, X_n)$ through shift probabilities $p(x, x+e) = 1/2$ only if unit vector $e \in \mathbb{Z}^d$. The synchronize methods $(X_n^i)_{n \geq 0}$, $i=1, \dots, d$, belonging to the same filter, which are transition-probability Markov stochastic models

$$\bar{p}(x, x+1) = \bar{p}(x, x-1) = \frac{1}{2d}, \bar{p}(x, x) = \frac{2d-2}{2d}$$

The function i.e. $h: \mathbb{Z}^d \rightarrow \mathbb{R}$ is assumed superharmonic with respect to p only if

$$\Delta_{\mathbb{Z}^d} h(x) = \sum_{i=1}^d (h(x+e_i) - 2h(x) + h(x-e_i)) = 2d((ph)(x) - h(x)) \leq 0$$

only if $x \in \mathbb{Z}^d$.

A function $h: \mathbb{Z} \rightarrow \mathbb{R}$ does not deviate from p in any way until $h(x) = ax + b$ by $a, b \in \mathbb{R}$. Additionally, for h to be assumed superharmonic, it must be concave.

Theory:2.7

Assume that (X_n) is an (F_n) Markov chain. Moving on to the real numbers procedure

$$M_n := h(X_n), n = 0, 1, 2, \dots,$$

for all harmonic functions, is a martingale with respect to F_n . Hi there! Assuming that S is a subset of $\mathbb{R}$ $h(X_n)$ (resp. $h(X_n)^+$) is integrable for all n .

Proof

Obviously, (M_n) is another time (F_n) altered. Furthermore,

$$E[M_{n+1} | F_n] = E[h(X_{n+1}) | F_n] = (ph)(X_n) \quad P\text{-a.s.}$$

Example : 2.8

According to Wright's model, there is a limited number of potential kinds for a population of N people (replicas). Every member of generation $n+1$ takes on the type of an ancestor from a randomly selected one in generation n .

A Markov stochastic model that uses a transitional kernel and a state space $S = \{0, 1, \dots, N\}$ depicts the number X_n of a given sort of persons in generation n .

$$P(k, \bullet) = \text{Bin}(N, k/N).$$

In addition, the predicted number of people in generation is given by the harmonic function $h(x) = x$, and mean value of distribution in binomial is $kn+1$ given $X_0, \dots, X_n$ is

$$E[M_{n+1} | X_0, \dots, X_n] = X_n$$

Later, the method (X_n) is a boundary-limited martingale. Nowadays, the limit is implied by the Martingale Convergence theorem $X_\infty = \lim X_n$ most certainly exists, X_n as its values are discrete, we may deduce that $X_n = X_\infty$ with a chance of one in due time. In particular,

X_∞ is likely to be an engrossing condition. Hence

$$P[X_n = 0 \text{ or } X_n = N \text{ eventually}] = 1 \quad \dots (1)$$

The probability of $X_n = 0$ eventually" and $X_n = N$ eventually" may be calculated using the optional stopping theorem for martingales.

$$T := \min \{n \geq 0: X_n = 0 \text{ or } X_n = N\}, \min \emptyset := \infty,$$

The absorbing states' initial striking time is denoted. With the optional stopping theorem, if the starting number of persons of the specified type is k , then,

$$E[X_T] = E[X_0] = k.$$

Hence by (1) we get

$$P[X_n = N \text{ eventually}] = P[X_T = N] = \frac{1}{N} E[X_T] = \frac{k}{N}, \text{ and}$$

$$P[X_n = 0 \text{ eventually}] = 1 - \frac{k}{N} = \frac{N-k}{N}.$$

Therefore, in the end, everyone has the same type, and the likelihood of a particular type's final occurrence is proportional to its relative frequency in the population at the outset.





DOOB Decomposition

An example of a probability space is $(\Omega, \mathcal{A}, P)$, where $(F_n)_{n \geq 0}$ a Filtering on $(\Omega, \mathcal{A})$.

Definition : 3.1

A stochastic process $(A_n)_{n \geq 0}$ must be constant with respect to $\mathcal{A}_0$ and measurable with respect to $\mathcal{A}_n$ in order to be assumed predictable with respect to F_{n-1} only if $n \in \mathbb{N}$. Instinctively, the value $A_n(\omega)$ the results of a expected method may be estimated using the data that is now accessible $n-1$.

Theorem :3.2

Each (F_n) customized series of integrable random attributes $Y_n (n \geq 0)$ has a single disintegration.

$Y_n = M_n + A_n$ into an (F_n) martingale (M_n) as well as a structured procedure (A_n) such that $A_0 = 0$. For simplicity's sake, the breakdown is provided by.

$$A_n = \sum_{k=1}^n E[Y_k - Y_{k-1} | F_{k-1}] \text{ and } M_n = Y_n - A_n.$$

Conditional Variance Process

Take into account a martingale (M_n) that is square integrable only if $n \geq 0$. Next, according to Jensen's inequality, (M_n^2) may be broken down into martingales again; it is a submartingale $(\overline{M}_n)$ as well as a structured procedure $\langle M \rangle_n$ such that $\langle M \rangle_0 = 0$:

$$M_n^2 = \tilde{M}_n + \langle M \rangle_n \text{ only if } n \geq 0.$$

Process increments that are predictable are supplied by

$$\begin{aligned} \langle M \rangle_k - \langle M \rangle_{k-1} &= E[M_k^2 - M_{k-1}^2 | F_{k-1}] \\ &= E[(M_k - M_{k-1})^2 | F_{k-1}] + 2 E[M_{k-1} \cdot (M_k - M_{k-1}) | F_{k-1}] \\ &= \text{Var}[M_k - M_{k-1} | F_{k-1}] \text{ only if } k \in \mathbb{N}. \end{aligned}$$

In this case, we've made advantage of the fact that $E[M_k - M_{k-1} | F_{k-1}]$ vanishes then (M_n) is a martingale.

Definition : 4.1

The method that is expected to follow

$$\langle M \rangle_n := \sum_{k=1}^n \text{Var}[M_k - M_{k-1} | F_{k-1}], \quad n \geq 0,$$

is known as the square integrable martingale's conditional variance process (M_n) .

Example : 4.2

If $M_n = \sum_{i=1}^n \eta_i$ consists of a collection of center-free random attributes η_i and $F_n = \sigma(\eta_1, \dots, \eta_n)$ next, we have the conditional variance procedure, which is $\langle M \rangle_n = \sum_{i=1}^n \text{Var}[\eta_i]$. traditional upper bound from aggregates of independent random attributes to martingales, theories such as the law of massive numbers or the Central limit theorem are extended, then the conditional variance process is essential. An immediate consequence of the reality that $M_n^2 - \langle M \rangle_n$ is a martingale is that

$$E[M_n^2] = E[M_0^2] + E[\langle M \rangle_n] \quad \text{only if } n \geq 0.$$

It is often possible to utilize this to get L^2 -estimates for martingales.

Example :4.3

Reflect on a standard differential equation

$$\frac{dx_t}{dt} = b(X_t), \quad t \geq 0, \quad \dots(4.1.1)$$

Where $b : \mathbb{R}^d \rightarrow \mathbb{R}^d$ has a predetermined vector field. Researching random perturbations of the dynamics (4.1.1) of type is often of interest for accounting for unanticipated effects on a system.

$$dX_t = b(X_t)dt + \text{"noise"} \quad \dots(4.1.2)$$

Including a name for random noise. The answer $(X_t)_{t \geq 0}$ Operating in continuous time, a stochastic differential equation (SDE) is an algorithm that is defined on a probability space $(\Omega, \mathcal{A}, P)$. It also includes random attributes that describe the effects of noise. The (deterministic) "drift" describes the vector field b . Although we shall subsequently understand universal SDE, temporal discretizations may already be assumed.





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To keep things simple, let's say $d=1$, Let $b, \sigma : \mathbb{R} \rightarrow \mathbb{R}$ to functions that are continuous, and allow $(\eta_i)_{i \in \mathbb{N}}$ serve as a set of independently distributed attributes $\eta_i \in \mathcal{L}^2(\Omega, \mathcal{A}, P)$ specifying the impacts of background noise. It is our expectation

$E[\eta_i] = 0$ and $\text{Var}[\eta_i] = 1$ only if $i \in \mathbb{N}$.

It is crucial to note that the random attributes must be independent and have finite variances; However, it's important to note that the numbers between 0 and 1 are only to facilitate normalization. Using an initial value $x_0 \in \mathbb{R}$ with a fine discretization step size h , we will proceed to build a stochastic process $(X_n^{(h)})$ in discrete time through $X_0^{(h)} = x_0$, besides

$$X_{k+1}^{(h)} - X_k^{(h)} = b(X_k^{(h)}) \cdot h + \sigma(X_k^{(h)}) \sqrt{h} \eta_{k+1}, \text{ for } k=0,1,2, \dots \quad (4.1.3)$$

Everyone has to assume $X_k^{(h)}$ to estimate the method value (X_t) at time $t = k \cdot h$. Another way to rewrite equation (4.1.3) is as

$$X_n^{(h)} = x_0 + \sum_{k=0}^{n-1} b(X_k^{(h)}) \cdot h + \sum_{k=0}^{n-1} \sigma(X_k^{(h)}) \cdot \sqrt{h} \cdot \eta_{k+1} \quad \dots \quad (4.1.4)$$

Before delving into the scaling factors h and $\sqrt{h}$, it's important to remember that if $\sigma \equiv 0$, then the ordinary differential equation (4.1.1) may be expressed as (4.1.3) and (4.1.4), respectively, which represent the Euler discretization. In addition, the continuous time process is guaranteed by diffusive scaling in the second term by a factor $\sqrt{h}$ if $b \equiv 0$ and $\sigma \equiv 1X_{\lfloor t/h \rfloor}^{(h)}$, $t \in [0, \infty)$ is distributed so that it converges when $h = 0$. Indeed, the limit process in this case is a Brownian motion $(B_t)_{t \in [0, \infty)}$ as stated by Donsker's invariance principle, which is sometimes referred to as the functional central limit theorem. For stochastic differential equations of form, in general, (4.1.4) is an example of a Euler discretization.

$$dX_t = b(X_t)dt + \sigma(X_t)dB_t$$

Wherever $(B_t)_{t \geq 0}$ is a Brownian motion. Let $\mathcal{F}_n = \sigma(\eta_1, \dots, \eta_n)$ stand for the filtering that the random attribute produces η_i .

Martingale Problem

A Doob decomposition is obtained for a Markov stochastic model (X_n) .

$$f(X_n) = M_n^{[f]} + A_n^{[f]} \quad \dots \quad (5.1.1)$$

Finding an integrable function f on the state of space for each.

Theorem :5.1

Assume the measurable space $(S, \mathcal{B})$ with the stochastic kernel p . Next, given a stochastic process that has been adjusted for $(F_n)_{n \geq 0}$ by state space $(S, \mathcal{B})$ Here are some statements that are interchangeable:

- (i) (X_n) is a Markov stochastic model with a transition kernel p that is time homogeneous (F_n) .
- (ii) (X_n) Decomposition of the operator $\mathcal{L} = p - I$ into its component parts provides a solution to the martingale issue.

$$f(X_n) = M_n^{[f]} + \sum_{k=0}^{n-1} (\mathcal{L}f)(X_k), \quad n \geq 0,$$

Through an (F_n) martingale $M_n^{[f]}$ for every function $f : S \rightarrow \mathbb{R}$ like that $f(X_n)$, or expressed otherwise, only if restricted functions $f : S \rightarrow \mathbb{R}$, it is integrable regardless of the value of n . To be more precise, we see again that if $f(X_n)$ is integrable of f is harmonic ($\mathcal{L}f = 0$) then $f(X_n)$ Even in cases when f is superharmonic, is a martingale ($\mathcal{L}f \leq 0$), then $f(X_n)$ is a supermartingale.

Proof :

Just the Doob decomposition for $f(X_n)$ is what the implication "(i) $\Leftrightarrow$ (ii)" refers to. The predictable portion is really supplied by theorem (3.2).

$$\begin{aligned} A_n^{[f]} &= \sum_{k=0}^{n-1} E[f(X_{k+1}) - f(X_k) | \mathcal{F}_k] \\ &= \sum_{k=0}^{n-1} (p f(X_k) - f(X_k)) = \sum_{k=0}^{n-1} (\mathcal{L}f)(X_k) \\ \text{and } M_n^{[f]} &= f(X_n) - A_n^{[f]} \text{ is a martingale.} \end{aligned}$$

To demonstrate the contrary consequence "(ii) $\Rightarrow$ (i)" supposing that $M_n^{[f]}$ this is valid for all limited functions $f : S \rightarrow \mathbb{R}$. What followed

$$0 = E[M_{n+1}^{[f]} - M_n^{[f]} | \mathcal{F}_n]$$





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$$= E[f(X_{n+1}) - f(X_n) | F_n] - ((p f)(X_n) - f(X_n))$$

$$= E[f(X_{n+1}) | F_n] - (p f)(X_n)$$

In the case of any restricted function, it is quite likely. Thus, (X_n) is a Markov stochastic model having degree (F_n) and a transition kernel (p) . This is.

Example : 5.2

Assume that homogeneous model of Markov stochastic model i.e. $X_0 = x$ as its starting state, a transition kernel p , with a state space $S = \mathbb{R}$ or $\mathbb{Z}$. Let's say this process (X_n) is defined under P_x . In the event that $X_n \in \mathcal{L}^2(\Omega, \mathcal{A}, P)$ For all values of n , we describe the DRIFT and Fluctuate using follows,

$$A(x) = \text{Var}_x[X_1 - X_0, Bx] := E_x[X_1 - X_0]$$

For (X_n) , It is time to determine the Doob decomposition. We may deduce that

$$(p - I)f(x) = \int y p(x, dy) - x = E_x[X_1 - X_0] = b(x).$$

So, according to theorem (5.1),

$$X_n = M_n + \sum_{k=0}^{n-1} b(X_k) \quad \dots (5.1.2)$$

With an (F_n) martingale (M_n) . we calculate the procedure for variance: Using the Markov property and equation (5.1.2), we can deduce

$$\langle M \rangle_n = \sum_{k=0}^{n-1} \text{Var}[M_{k+1} - M_k | F_k] = \sum_{k=0}^{n-1} \text{Var}[M_{k+1} - X_k | F_k] = \sum_{k=0}^{n-1} a(X_k)$$

Therefore

$$M_n^2 = \tilde{M}_n + \sum_{k=0}^{n-1} a(X_k) \quad \dots (5.1.3)$$

With another (F_n) martingale $(\tilde{M}_n)$. Bounds for Markov stochastic models may now be efficiently derived using the functions $a(x)$ and $b(x)$ in conjunction with basic Martingale findings, such as the maximum inequality.

CONCLUSION

The essential fact in analysis is that every declining sequence of real numbers with lower bounds meets to its mean values. In contrast to this consequence in stochastic analysis, the super martingale theorem for convergent states that all less limited super martingale converges practically with assurance.

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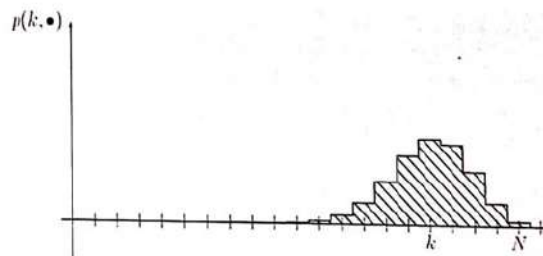


Figure.1: Transition function of (X_n) .





RESEARCH ARTICLE

Formation of Dio-3 Tuples Involving Some Figurate Numbers

P. Sangeetha^{1*} and G. Janaki²

¹Assistant Professor, Department of Mathematics, Cauvery College for Women (Autonomous), Annamalai Nagar, (Affiliated to Bharathidasan University), Tiruchirappalli, Tamil Nadu, India.

²Associate Professor, Department of Mathematics, Cauvery College for Women (Autonomous), Annamalai Nagar, (Affiliated to Bharathidasan University), Tiruchirappalli, Tamil Nadu, India.

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*Address for Correspondence

P. Sangeetha

Assistant Professor,
Department of Mathematics,
Cauvery College for Women (Autonomous), Annamalai Nagar,
(Affiliated to Bharathidasan University), Tiruchirappalli,
Tamil Nadu, India.
E.Mail: psangeethashree@gmail.com



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ABSTRACT

The Diophantine triples $\{a, b, c\}$, commonly known as $D(n)$ 3-tuples are the subject of this work. This may include developing new methods for analyzing and solving Diophantine equations or proving results about the existence or non-existence of solutions with certain properties. This paper takes a different strategy to the topic of Pythagorean triples. Although several techniques have been studied to generate Pythagorean triples, none of them manage to generate repeat-free triples frequently. In this article, Diophantine triple involving some figurate numbers such that the product of any two members adding with polynomial is a perfect square is discovered. These triples contain certain figurate numbers, such that any two of them multiplied and added with a suitable polynomial generates a perfect square. We additionally find out that MATLAB is used by the triples.

Keywords: Diophantine equation, Diophantine triples, centered pentagonal number, Heptagonal Number and Gnomonic number, and Integer triples.

INTRODUCTION

Janaki and Vidhya [3] analyzed the Construction of the Diophantine triple involving Stella Octangular number in 2017. In the same year Pandichelvi and Sivakamasundari [6] summarized the Formation of Triples Consist Some Special Numbers with Interesting Property. In 2018 Janaki and Saranya C [4] was presented Construction of the Diophantine triple involving Pentatope number. Also the same year Saranya P and Janaki [9] proposed Explication of Dio 3-tuples from truncated octahedral number-I. In 2019 Saranya C and Janaki [8] established Some Non-extendable





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Diophantine Triples involving centered square numbers. Cipu M *et al.* [1] Demonstrate that $\{a_1, a_2, b, c\}$ is a Diophantine quadruple and $\{a_1, b, c\}$ and $\{a_2, b, c\}$ are Diophantine triples with $a_1 < a_2 < b < c < 16b^3$. That is the largest two elements are common is proved in 2021. The authors of [2, 5 to 7] also developed the diophantine triples in linear recurrences and Using the Second Order Polynomials with Incisive Properties in the year 2023.

In this manuscript, the procedure for creating integer triples (p, q, r) consisting diophantine triple involving some figurate numbers such that the product of any two members adding with polynomial is a perfect square is studied.

METHODOLOGY

A specific diophantine triples (p, q, r) , is constructed from a pair (p, q) that meets the property $D(\lambda)$, where p, q , and λ are polynomials. In the following sections, we demonstrate the diophantine triples (p, q, r) that are created by

solving the system of equations $p = 2CP_n + Gno_n$ and $q = 2T_{7,n} + Gno_n$ applying the transformations $\phi = p + \sigma$ and $\psi = q + \sigma$.

Notations.

- $CP_n = \frac{5n^2 + 5n + 2}{2}$ be a centered pentagonal number of rank n
- $T_{7,n} = \frac{n(5n-3)}{2}$ be a Heptagonal Number of rank n .
- $Gno_n = (2n-1)$ be a Gnomonic number of rank n .

RESULTS AND DISCUSSION

Procedure-I

Let $p = 2CP_n + Gno_n$ and $q = 2T_{7,n} + Gno_n$

which correspond to the subsequent equations,

$$p = 5n^2 + 7n + 1, \quad q = 5n^2 - n - 1$$

Assume that,

$$pq + 26n^2 + 14n + 2 = \sigma^2$$

Let r be any non-zero integer such that,

$$pr + 26n^2 + 14n + 2 = \phi^2 \quad \dots\dots\dots (1)$$

$$qr + 26n^2 + 14n + 2 = \psi^2 \quad \dots\dots\dots (2)$$

Subtracting (1) and (2) the resulting equation is,

$$(p - q)r = \phi^2 - \psi^2 \quad \dots\dots\dots (3)$$

$$\text{Setting } \phi = p + \sigma \text{ and } \psi = q + \sigma \quad \dots\dots\dots (4)$$

Substituting (4) in (3), the value of r represented by

$$r = 20n^2 + 12n + 2$$





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Hence, $\{5n^2 + 7n + 1; 5n^2 - n - 1; 20n^2 + 12n + 2\}$ is a Diophantine triples with the property $D(26n^2 + 14n + 2)$.

Some numerical examples are found and illustrated in the below table 1.)

Procedure-II

Let $p_1 = 2CP_{n+1} + Gno_{n+1}$ and $q_1 = 2T_{7,n+1} + Gno_{n+1}$

which correspond to the subsequent equations,

$$p_1 = 5n^2 + 17n + 13, \quad q_1 = 5n^2 + 9n + 3$$

Assume that,

$$p_1 q_1 - 4n^2 - 12n - 3 = \sigma_1^2$$

Let r_1 be any non-zero integer such that,

$$p_1 r_1 - 4n^2 - 12n - 3 = \phi_1^2 \quad \dots\dots\dots (5)$$

$$q_1 r_1 - 4n^2 - 12n - 3 = \psi_1^2 \quad \dots\dots\dots (6)$$

Solving (5) and (6), leads to

$$(p_1 - q_1)r_1 = \phi_1^2 - \psi_1^2 \quad \dots\dots\dots (7)$$

$$\text{Setting } \phi_1 = p_1 + \sigma_1 \text{ and } \psi_1 = q_1 + \sigma_1 \quad \dots\dots\dots (8)$$

Applying (8) in (7), one may get

$$r_1 = 20n^2 + 52n + 28$$

Hence $\{5n^2 + 17n + 13; 5n^2 + 9n + 3; 20n^2 + 52n + 28\}$ is a Diophantine triples with the property $D(-4n^2 - 12n - 3)$.

Some numerical examples are determined and illustrated in the below table 2.

Procedure-III

Let $p_2 = 2CP_{n+2} + Gno_{n+2}$ and $q_2 = 2T_{7,n+2} + Gno_{n+2}$

which correspond to the subsequent equations,

$$p_2 = 5n^2 + 27n + 35, \quad q_2 = 5n^2 + 19n + 17$$

Assume that,

$$p_2 q_2 - 4n^2 - 20n - 19 = \sigma_2^2$$

Let r_2 be any non-zero integer such that,

$$p_2 r_2 - 4n^2 - 20n - 19 = \phi_2^2 \quad \dots\dots\dots (9)$$

$$q_2 r_2 - 4n^2 - 20n - 19 = \psi_2^2 \quad \dots\dots\dots (10)$$

Solving (9) and (10), given

$$(p_2 - q_2)r_2 = \phi_2^2 - \psi_2^2 \quad \dots\dots\dots (11)$$

$$\text{Setting } \phi_2 = p_2 + \sigma_2 \text{ and } \psi_2 = q_2 + \sigma_2 \quad \dots\dots\dots (12)$$





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Substituting (12) and (11), the values of r_2 is represented by

$$r_2 = 20n^2 + 92n + 100$$

Hence $\{5n^2 + 27n + 35 ; 5n^2 + 19n + 17 ; 20n^2 + 92n + 100\}$ is a Diophantine triples with the property $D(-4n^2 - 20n - 19)$.

Some numerical examples are obtained and explored in the table 3 below.

Procedure-IV

Let $p_3 = 2CP_{n+3} + Gno_{n+3}$ and $q_3 = 2T_{7,n+3} + Gno_{n+3}$

which correspond to the subsequent equations,

$$p_3 = 5n^2 + 37n + 67, \quad q_3 = 5n^2 + 29n + 41$$

Assume that,

$$p_3 q_3 + 20n^2 - 28n - 43 = \sigma_3^2$$

Let r_3 be any non-zero integer such that,

$$p_3 r_3 + 20n^2 - 28n - 43 = \phi_3^2 \quad \dots\dots\dots (13)$$

$$q_3 r_3 + 20n^2 - 28n - 43 = \psi_3^2 \quad \dots\dots\dots (14)$$

Subtracting (13) and (14) we get

$$(p_3 - q_3)r_3 = \phi_3^2 - \psi_3^2 \quad \dots\dots\dots (15)$$

$$\text{Setting } \phi_3 = p_3 + \sigma_3 \text{ and } \psi_3 = q_3 + \sigma_3 \quad \dots\dots\dots (16)$$

Substituting equations (16) in (15) the values of r_3 represented by

$$r_3 = 20n^2 + 132n + 212$$

Hence $\{5n^2 + 37n + 67 ; 5n^2 + 29n + 41 ; 20n^2 + 132n + 212\}$ is a Diophantine triples with the property $D(20n^2 - 28n - 43)$.

Some numerical examples are determined and illustrated in the below table 4.

Some numerical examples are determined and illustrated using MATLAB are given below Fig.1,2.

CONCLUSIONS

It has been interesting to study how different features and relationships can generate triples and quadruples. In this paper, the triples involving some special numbers are located in such a way that the triples product of any two of its parts with added a suitable polynomial is a perfect square. In this way, one may found various triples and quadruples with different attributes.

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Table 1: Some Numerical Examples are Found and Illustrated in the Below Table.

n	Dio-3 Tuples	$D(26n^2 + 14n + 2)$
1	(13,3,34)	42
2	(35,17,106)	134
3	(67,41,218)	278
4	(169,75,370)	474

Table 2: Some Numerical Examples are Determined and Illustrated in the Below Table.

n	Dio-3 Tuples	$D(-4n^2 - 12n - 3)$
1	(35,17,100)	-19
2	(67,41,212)	-43
3	(109,75,364)	-75
4	(161,119,556)	-115

Table 3: Some numerical examples are obtained and explored in the table below.

n	Dio-3 Tuples	$D(-4n^2 - 20n - 19)$
1	(67,41,212)	-43
2	(109,75,364)	-75
3	(161,119,556)	-115
4	(223,173,788)	-163

Table 4: Some numerical examples are determined and illustrated in the below table.

n	Dio-3 Tuples	$D(201n^2 - 28n - 43)$
1	(109,75,364)	130
2	(161,119,556)	705
3	(223,173,788)	1682
4	(295,237,1060)	3061





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```

3/2/24 7:36 PM C:\Users\premk\OneDrive\D...\triples.m

clc;
clear;
close all;
n = 1:4;
p = 5.*n.^2 + 7.*n + 1;
q = 5.*n.^2 - n - 1;
r = 20.*n.^2 + 12.*n + 2;
triple1 = [p;q;r];
p1 = 5.*n.^2 + 17.*n + 13;
q1 = 5.*n.^2 + 9.*n + 3;
r1 = 20.*n.^2 + 52.*n + 28;
triple2 = [p1;q1;r1];
p2 = 5.*n.^2 + 27.*n + 35;
q2 = 5.*n.^2 + 19.*n + 17;
r2 = 20.*n.^2 + 92.*n + 100;
triple3 = [p2;q2;r2];
p3 = 5.*n.^2 + 37.*n + 67;
q3 = 5.*n.^2 + 29.*n + 41;
r3 = 20.*n.^2 + 132.*n + 212;
triple4 = [p3;q3;r3];
disp('Formation of Dio-3 Tuples Involving Some Figurate numbers')
disp('Case 1:some numerical examples for rank n')
disp(' (p,q,r)')
fprintf('%d\t%d\t%d\n',triple1);
disp('Case 2:some numerical examples for rank n+1')
disp(' (p1,q1,r1)')
fprintf('%d\t%d\t%d\n',triple2);
disp('Case 3:some numerical examples for rank n+2')
disp(' (p2,q2,r2)')
fprintf('%d\t%d\t%d\n',triple3);
disp('Case 4:some numerical examples for rank n+3')
disp(' (p3,q3,r3)')
fprintf('%d\t%d\t%d\n',triple4);

```

Fig. No. 1: Some numerical examples are determined and illustrated using MATAB are given below.

```

MATLAB Command Window

Formation of Dio-3 Tuples Involving Some Figurate numbers
Case 1:some numerical examples for rank n
(p,q,r)
13   3   34
35   17  106
67   41  218
109  75  370
Case 2:some numerical examples for rank n+1
(p1,q1,r1)
35   17  100
67   41  212
109  75  364
161  119 556
Case 3:some numerical examples for rank n+2
(p2,q2,r2)
67   41  212
109  75  364
161  119 556
223  173 788
Case 4:some numerical examples for rank n+3
(p3,q3,r3)
109  75  364
161  119 556
223  173 788
295  237 1060
>>

```

Fig. No. 2: Some numerical examples are determined and illustrated using MATAB are given below.





RESEARCH ARTICLE

Influence of Alkali Treatment and Cenosphere Filler on the Mechanical and Electrical Properties of Coir Fibre Reinforced Composites

Kavya N¹, Nagaraja N^{2*}, Ashok R B³ and Narendra Babu R N⁴

¹Research Scholar (Reg. No.: 857/2021), Department of Physics, Sahyadri Science College, (Autonomous), (Affiliated to Kuvempu University), Shivamogga, Karnataka, India.

²Associate Professor, Department of Physics, Sahyadri Science College, (Autonomous), (Affiliated to Kuvempu University), Shivamogga, Karnataka, India.

³Assistant Professor, Department of Mechanical Engineering, PES Institute of Technology and Management (Affiliated to Visvesvaraya Technological University, Belagavi), Shivamogga, Karnataka, India.

⁴Lecturer, Department of Physics, Alva's PU College, Moodbidre, Dakshina Kannada, (Affiliated to Mangalore University), Karnataka, India.

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*Address for Correspondence

Nagaraja N

Associate Professor,

Department of Physics,

Sahyadri Science College, (Autonomous),

(Affiliated to Kuvempu University),

Shivamogga, Karnataka, India.

E.Mail: nnkadur@gmail.com



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ABSTRACT

Presently, the emphasis in research and development is on finding eco-friendly, sustainable materials to lessen reliance on traditional petroleum based products. As a result, due to their beneficial characteristics, the usage of composite materials reinforced with natural and synthetic fibers is expanding quickly in engineering and technology. Ongoing research is dedicated to creating coir fiber-reinforced polyester composites with different ratios of cenosphere, which have a wide range of potential uses. With cenosphere as a filler, the mechanical and electrical characteristics of the untreated and NaOH-treated composites are the main focus of the investigation. The hand layup technique was used in the specimen's production. The mechanical properties are evaluated using the tensile, impact, flexural strength, and hardness tests. The electrical characteristics of the composites were analysed by dielectric constant, dielectric loss, and ac conductivity. The addition of cenosphere as a filler was shown to improve the mechanical and insulating qualities of coir reinforced composites, which could potentially find application in the automotive and aerospace industries as well as in insulating laptop covers and electric boards.

Keywords: Coir, Natural fiber Cenosphere, Dielectric Constant, AC conductivity, Electrical Insulating material.





INTRODUCTION

Researchers and engineers are under increasing pressure to find eco-friendly materials that offer high performance at reasonable costs due to the growing environmental consciousness. Natural fiber-reinforced composites represent one such material. The utilization of natural fibers in composites is widely recognized due to their innate characteristics, including lignocellulose composition, renewable superior strength, abundant availability, and capacity to generate clean energy[1,2,3]. The importance of natural fiber composites is increasing, leading to a growing significance of the electrical properties in natural fiber-reinforced polymer composites. The dielectric constant, volume resistivity, and loss factor have been identified as crucial determinants for the electrical applications of composites[4]. Within the electronic industry, these composites find application in the production of panels, switches, and insulators[5]. Coconuts are cultivated in numerous countries around the world, especially in tropical and sub-tropical regions, and they significantly contribute to economic development. Coir is robust, dense, and highly resistant to abrasion, making it a preferred material in composite applications[6]. Coir has been employed to improve the strength of concrete by utilizing it as a reinforcing fiber material[7,8,9]. Bagasse and coir epoxy composites showed better electrical resistivity as compared to jute and sisal fibres composites due to their lower densities[10]. The cenosphere consists of spherical, hollow particles obtained from flyash. When 5. % cenosphere is added to the jute-epoxy composite, it leads to an increase in tensile strength, flexural strength, hardness, and interlaminar shear strength, while also reducing water absorption properties [11]. According to the response surface analysis, adding cenosphere as a filler in epoxy resin significantly decreases thrust and hole surface roughness for the developed composite [12]. This research aims to investigate the impact of NaOH treatment on fiber and the incorporation of cenosphere with varying weight percentages in coir-reinforced composites. The composites' X-ray diffraction (XRD), mechanical, and electrical properties were examined.

MATERIALS AND METHODOLOGY

The coir fibers, which were dried, were sourced from Shivamogga. Cenosphere CIL-100 was acquired from Cenosphere India Pvt. Ltd., situated in Chennai, Tamil Nadu. The dried coir fibers underwent a 24-hour soaking period in water to facilitate easier extraction. After soaking, the fibers were washed twice with water to eliminate impurities and then left to dry at room temperature. These coir fibres were subjected to a 5% NaOH (Sodium Hydroxide) treatment, using the entire volume of the solution. After being immersed in the alkaline solution for 60 minutes at room temperature, the coir was gently rinsed with deionized water. To obtain alkali-treated fibers, the fibers were then allowed to air dry for three days at room temperature.

Preparation of the composites

The composites were developed by reinforcing randomly distributed coir short fibers with polyester resin and hardener as shown in fig.a. The treated coir fibers and cenospheres of varying percentages (0%, 10%, 20%, 30%, and 40%) were added, while the matrix consisted of polyester and hardener Methyl Ethyl Ketone Peroxide (MEKP). A mild steel mold with dimensions of 200mm x 200mm x 10mm was used to cast the composite panels. In order to prepare the composite, the hand layup method was used. After being prepared, the composites were dried at 30 °C for 72 hours. The resulting composites were then cut to the specified dimensions in the ASTM standard for various tests. Subsequently, the mechanical and electrical properties of the composites were analyzed.

Characterization of coir fibre reinforced composites

X-ray diffraction of untreated and 5% NaOH treated coir fibers was performed using the Rigaku Smart Lab, with a wavelength of 1.54 Å, to determine their crystallinity. The crystallinity index of both untreated and treated fibers was determined using Segal's method. Tensile and flexural tests of untreated and treated composites were conducted using a universal testing machine. Five specimens were tested for each composite. Tensile strength of the areca fiber composites were tested according to ASTM D3039 and flexural test of the composites were performed with ASTM D 790. The impact test was carried out using charpy impact tester, ZWICK ROELL HIT 50P according to ASTM D 256.





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Rockwell hardness test is conducted according to the ASTM D 785 for composites. The dielectric properties and electrical conductivity were measured with Agilent 4294A precision impedance analyzer at frequencies 40Hz to 5MHz.

RESULT AND DISCUSSION

X-ray diffraction (XRD)

The figure 1. illustrates the impact of chemical modification on the crystallinity of lignocellulosic materials. A strong peak at 22.3° represents the crystalline fractions, while a weak peak at 15.7° indicates the presence of amorphous material. The treated fibers exhibit a crystallinity index of 29%, whereas untreated coir has a crystallinity index of 25%. The treated fiber's crystallinity index surpasses that of the untreated fiber, indicating the partial elimination of amorphous hemicellulose, non-crystalline components, and wax from the fibres[13,14]. A higher crystalline structure leads to reduced moisture absorption and improved mechanical properties of the fibres[15].

Tensile Strength

In the fig.2 Provided, it is evident that the enhancement in tensile strength of treated fibre composites resulted from the elimination of hemicellulose, lignin, wax, and other impurities through fibre treatment, leading to an increase in cellulose content [16]. The composites reinforced with 10% and 20% cenosphere-coir exhibited the superior tensile strength. The addition of filler contributes to the strength of the composites up to a certain threshold.

Flexural Strength

The flexural strength fig.3 of untreated composites is inferior when compared to other developed composites. The application of chemical treatment enhances the flexural strength of the composites by modifying the surface, thereby improving the adhesion properties between coir fibers [17]. It has been observed that the flexural strength of the composites increases with the inclusion of cenosphere from 10 to 20%. However, with further addition of cenosphere up to 40%, there is a decrease in flexural strength. This decrease is attributed to a chemical reaction occurring at the interface between the cenosphere particles and the polyester matrix, which weakens the transfer of flexural stress.

Impact Strength

As tensile and flexural strength, the impact strength of the treated composite also has better strength. Filler clusters are created when the resin goes through a discontinuous phase as the filler amount increases. As a result of this clustering, the impact strength of the composite diminishes with increasing filler concentration, leading to local phase inversion and eventual failure. Figure 4. indicates that the composites with 10% cenosphere filler-reinforced had the highest strength.

Hardness

The treated fiber composite exhibits a high level of hardness due to the chemical modification of the fibres as shown in the fig.5. Through the chemical treatment [16], non-cellulose components and other impurities on the fiber surface are minimized, while the surface roughness of the fiber is enhanced to improve the interlocking of the fiber and matrix [18]. Additionally, the hardness the cenosphere filler varies with filler content, increasing and decreasing up to 20%.

Dielectric Property

Dielectric constant, (ϵ') = $C_p \times d / (\epsilon_0 \times A)$

Where, C_p - Parallel capacitance, d - Thickness of the sample, A - Area of the sample, ϵ_0 - Permittivity of free space 8.854×10^{-12} F/m.

The figure 6 and 7, depicts the change in the dielectric constant and dielectric loss of the composites with respect to frequency. The dielectric loss is observed to be highest at lower frequencies for the 10% cenosphere and untreated composites. As frequency increases, the dielectric loss decreases substantially [19]. This suggests that the dielectric



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properties are influenced by the treatment and filler content of the composites. The Dielectric constant and loss decreases with rise in concentration of cenosphere in the composites. At lower frequencies, complete molecule orientation is attainable, and the attainment of equilibrium static field values for polarization takes longer compared to electronic and atomic polarizations [19]. Consequently, the dielectric constant decreases with increasing frequency due to a delay in the polarization orientation [20].

Ac Conductivity

Electrical conductivity of the composite is given by: $\sigma_{ac} = \epsilon \epsilon_0 \omega$, here ω is the angular frequency. Dielectric materials, despite being primarily insulators with a significant energy gap, may demonstrate some degree of conductivity [21]. The occurrence of conduction can be associated with dipolar and interfacial polarization, even at low levels of polarization [22]. As shown in Figure 8, the AC conductivity of the composites changes with frequency. The increased electrical conductivity in the composites containing 10% cenosphere may be due to the presence of moisture content and crystalline components in the composite [23]. The AC conductivity decreases as the cenosphere filler percentages increase, indicating a property of electrical resistance.

CONCLUSION

This research involved an investigation into the effects of chemical treatment and the addition of cenosphere at different weight percentages on the performance of coir fiber-reinforced composites. The investigation of mechanical characteristics, including hardness, impact resistance, tensile strength, and flexural strength indicated that composites treated with chemicals and cenosphere exhibited greater strength compared to untreated composites. Composites containing 10% and 20% cenosphere showed improved strength. In addition, the treated composites showed improved electrical characteristics such as dielectric constant, dielectric loss, and ac-conductivity. A higher concentration of cenosphere resulted in better insulation, with 40% cenosphere proving to be the most effective. The composite material developed in this study provides good electrical insulation and superior mechanical properties, making it suitable for use in insulating electric boards, laptop or mobile device covers, and the automotive and aerospace industries. This will aid in transforming agricultural by product into beneficial products while also being environmentally friendly.

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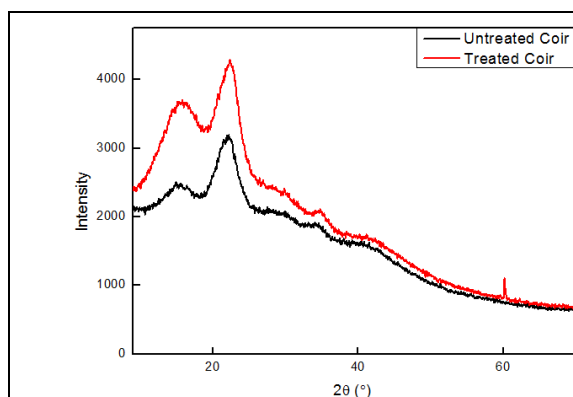


Figure 1: XRD of untreated and treated fibre

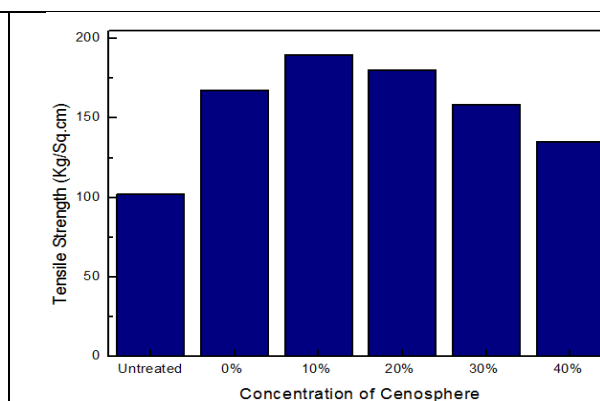


Figure 2: Tensile strength of the coir reinforced composites.





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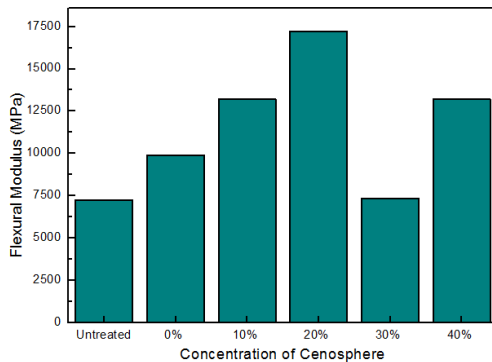


Figure 3: Flexural modulus of the coir reinforced composites.

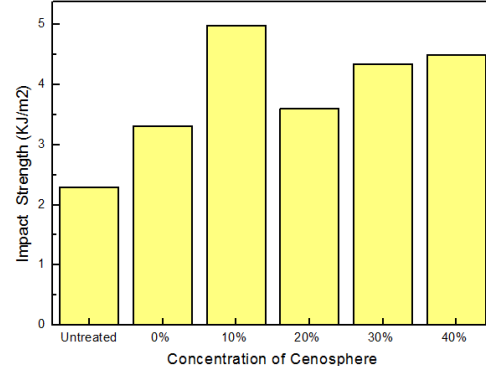


Figure 4: Impact strength of the coir reinforced composites.

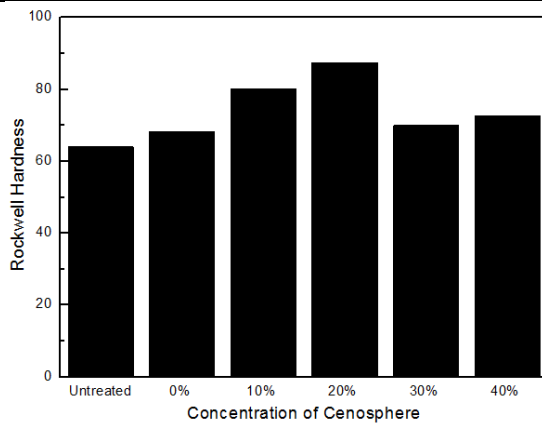


Figure 5: Hardness of the coir reinforced composites.

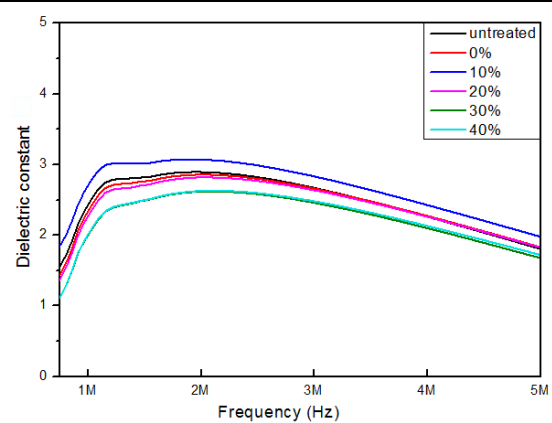


Figure 6: Dielectric Constant of the coir reinforced composites.

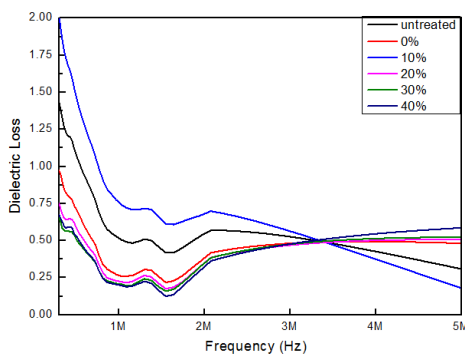


Figure 7: Dielectric loss of the coir reinforced composites.

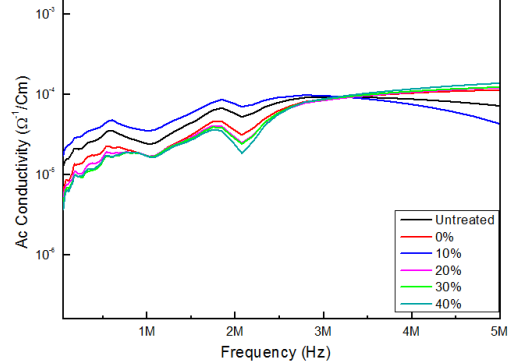


Figure 8: AC Conductivity of the coir reinforced composites.





RESEARCH ARTICLE

Production of Anthracyclines with the Mutant Species of *Streptomyces peucetius*

R. Kamalambigeswari^{1*} and Kamalesh .A²

¹Assistant Professor, Department of Industrial Biotechnology, Bharath Institute of Higher Education and Research (Deemed to be University), Selaiyur, Chennai, Tamil Nadu, India.

²Student, Department of Industrial Biotechnology, Bharath Institute of Higher Education and Research (Deemed to be University), Selaiyur, Chennai, Tamil Nadu, India.

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*Address for Correspondence

R. Kamalambigeswari

Assistant Professor,

Department of Industrial Biotechnology,

Bharath Institute of Higher Education and Research

(Deemed to be University), Selaiyur, Chennai,

Tamil Nadu, India.

E.Mail: kamali1203@gmail.com



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ABSTRACT

Anthracyclines, including doxorubicin and daunorubicin, are potent chemotherapeutic agents primarily produced by *Streptomyces peucetius*. Enhancing their industrial-scale production requires strain improvement through genetic modifications and process optimization. In this study, a mutant strain of *S. peucetius* was developed to enhance anthracycline yield. The mutant strain was obtained through (mention mutation method, e.g., UV mutagenesis, EtBr, hydrogen peroxide), leading to improved biosynthetic pathway efficiency. High-performance liquid chromatography (HPLC) analysis confirmed a significant increase in anthracycline production compared to the wild-type strain. These findings highlight the potential of strain improvement and process optimization in maximizing anthracycline yields for industrial-scale pharmaceutical applications. Further, downstream extraction and purification processes were evaluated for improved recovery and cost efficiency. The results indicate that the mutant strain exhibits superior anthracycline production compared to the wild-type, making it a promising candidate for industrial-scale applications. This study highlights the potential of strain engineering and process optimization in enhancing the biotechnological production of high-value antibiotics.

Keywords: *Streptomyces peucetius*, Anthracyclines, Doxorubicin, Daunorubicin, Mutant Strain, Fermentation Optimization, Industrial Production





INTRODUCTION

ANTHRACYCLINES

Anthracyclines represent one of the most potent and widely used classes of chemotherapeutic compounds in clinical oncology. Discovered in the 1960s, these drugs, e.g., doxorubicin and daunorubicin, are isolated from *Streptomyces* species, particularly *Streptomyces peucetius*, and characterized by a tetracyclic ring system with a sugar moiety that contributes to their DNA-binding ability [1]. Their primary mode of action is that they insert themselves into the DNA and disrupt topoisomerase II, disrupting DNA replication and transcription, thus causing cell death in rapidly dividing tumor cells [2].

Biotechnological developments have also made it possible to explore the biosynthetic pathways in *S. peucetius* more, offering opportunities for metabolic engineering and anthracycline overproduction on a large scale [3]. Clarification and regulation of these microbial pathways not only allow for cost-effective large-scale production but also allow for the production of new anthracycline derivatives with improved pharmacological profiles.

STRUCTURE OF ANTHRACYCLINES

Anthracyclines are polyketide antibiotics with a tetracyclic quinone-hydroquinone core linked to a central sugar moiety. Their structural characteristics are responsible for their anticancer and antimicrobial actions, especially by DNA intercalation and topoisomerase II inhibition (Fig1)

TYPES OF ANTHRACYCLINES

Anthracyclines are a group of chemotherapeutic antibiotics from *Streptomyces* species. They are commonly used to treat cancer because they have broad antitumor activity. The most widely used anthracyclines are

First-Generation Anthracyclines

They were the first to be discovered and are still very much used in cancer treatment.

Second-Generation Anthracyclines

Altered structures of first-generation drugs with changed pharmacokinetics and toxicities.

Liposomal Anthracyclines

Formulated to reduce toxicity, particularly cardiotoxicity, by altering drug distribution in the body.

Novel and Experimental Anthracyclines

Newer anthracyclines with improved efficacy and reduced side effects.

MICROORGANISMS USED IN THE PRODUCTION PROCESS

Anthracyclines are a group of effective antibiotics that are commonly employed in the treatment of cancer, mainly because they can disrupt DNA replication and transcription [4]. The compounds are synthesized by different bacterial species, most notably members of the *Streptomyces* genus. Some of the most important bacterial species responsible for the synthesis of anthracyclines include:

STREPTOMYCES

Streptomyces is a Gram-positive, filamentous bacterial genus of the phylum Actinobacteria. They are most famous for their production of antibiotics and bioactive metabolites, and hence are one of the most valuable microorganisms for medicine and biotechnology. They are present in soil and rotting organic material, where they have an important role in breaking down complex organic compounds. Their characteristic earthy odour is a result of geosmin production, a chemical responsible for the distinctive smell of soil following rain. [5]





MATERIALS AND METHODS

Isolation of *Streptomyces peucetius*

Samples are collected from various environments such as decomposing organic matter, compost, etc. The pre-treatment of the soil is taken by air drying for 48 hrs and incubating the soil at 55°C for 15-30 minutes. Then serially dilute the 1g of soil sample (10^{-1} to 10^{-6}) and 0.1 ml of dilution was plated on selective agar medium [6]. For isolation of *Streptomyces peucetius* isp-4, agar medium is used, which is composed of starch soluble 10g/l, di-potassium phosphate 1 g/l, magnesium sulphate 1g/l, sodium chloride 1g/l, calcium chloride 2g/l, agar 20g/l, and the pH is adjusted to 7.2. The inoculated plates are incubated at 28–30°C for 7–14 days. Further, the plates are maintained by actinomycetes isolation agar (AIA), which consists of starch soluble 10g/l, di-potassium phosphate 2g/l, magnesium sulphate 0.05g/l, sodium chloride 1g/l, casein hydrolysate 0.3g/l, agar 15g/l. The pH is adjusted to 7.2. The inoculated plates are incubated at 28–30°C for 3–4 days. The colonies were distinct Streptomyces-like colonies and streaked onto new subcultured plates of ISP-4 or SCA

Gram staining for identification

A sterile glass slide was taken away and labelled. A sterile loop was used to drop a drop of distilled water onto the slide [7]. Aseptically, a little of the bacterial culture was picked up and added to the water to make a thin smear. The smear was left to air-dry completely.

Fermentation media preparation

The Fermentation medium (g/L): glycerol 20, soy flour 10, yeast extract 5, CaCO_3 5, L-tyrosine 0.5, MgSO_4 0.5; pH 7.0. 7–9 days of incubation at 28–30 °C, 250 rpm agitation. Seven flasks (Control, 10 min, 15 min, 20 min, 5 μM , 10 μM , 15 μM) were arranged, sterilized, marked, inoculated with seed culture, and incubated on standardized conditions [8].

Solvent extraction

The fermentation broth was acidified to pH 2.5–3.0 with 1N HCl to improve anthracycline solubility in organic phase. An equal volume of broth and organic solvent (such as ethyl acetate or butanol) was combined in a separating funnel, shaken intensely for 10–15 minutes, and permitted to settle [9]. The organic phase was separated and re-extracted 2–3 times to ensure maximum yield. Solvent was evaporated under reduced pressure at 40–50 °C to recover crude anthracycline extract.

Thin layer chromatography

TLC plates were scored with a baseline 1 cm below the bottom, and anthracycline extracts (in methanol) were spotted in 1–2 μL per spot. Plates were dried and developed in a pre-saturated chamber with mobile phase and filter paper for 5–10 min [10]. The solvent front was allowed to move ~80% of the plate height. Plates were air-dried and examined under UV light at 254 nm and 365 nm to see fluorescent anthracycline bands.

Liquid chromatography and mass spectrometry

Crude anthracyclines were obtained by acidifying the fermentation broth to 2.5–3.0 pH using HCl, and then centrifuging at 10,000–12,000 rpm for 15–20 min. The supernatant was analyzed further [11]. RP-HPLC/UHPLC was conducted on a C18 column with a gradient of water (0.1% formic acid) and acetonitrile (0.1% formic acid), flow 0.3–0.5 mL/min, and column temperature 30–40 °C. ESI-MS analysis utilized nitrogen as nebulizer gas (35–50 psi), drying gas 300–350 °C, capillary voltage 3.5–4.5 kV, and collision energy 15–35 eV.

FTIR Analysis

Anthracycline samples were dried thoroughly to remove moisture. For the KBr method, 1–2 mg purified sample was ground with 100–200 mg anhydrous KBr and pressed into a pellet. Alternatively, powdered samples



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were applied directly to the ATR crystal. Spectra were collected on an FTIR spectrophotometer [12] (4000–400 cm^{-1} range, 4 cm^{-1} resolution, 16–32 scans).

Antimicrobial analysis

Pathogenic bacterial strains (*E. coli*, *S. aureus*, *P. aeruginosa*, *B. subtilis*) were grown on Nutrient Agar and incubated at 37 °C for 18–24 h. Anthracycline extracts were dissolved in DMSO or ethanol (10 mg/mL) for testing. Agar plates were swabbed with microbial suspensions, and wells (6–8 mm) were filled with 50–100 μL of test solutions at different concentrations. Controls were solvent (negative) and standard antibiotics (positive). Plates were incubated for 18–24 h at 37 °C, and zones of inhibition were quantified in mm to determine antimicrobial activity.

RESULT AND DISCUSSION**Isolation of *Streptomyces peucetius***

The strain *S. peucetius* forms dry powdery or chalky colonies with a velvety texture on ISP-2 and ISP-4 media (Fig.2 and 3). The aerial mycelium is well-developed and white to grayish. In comparison, the ISP-2 substrate mycelium is reddish to red-colored due to the production of anthracycline antibiotics such as doxorubicin [13]. Red pigments are also produced, which are usually seen on the reverse side of the culture slabs, and a pungent earthy odor due to the production of geosmin. The spore chains are typically straight to flexuous and non-motile, one of the most important features employed in differentiating *S. peucetius* from other *Streptomyces* species.

Gram Staining

Streptomyces peucetius, as with other members of the *Streptomyces* genus, is Gram-positive. Under Gram staining, the cells were filamentous with a branched, mycelial structure and held the crystal violet stain, showing that there is a thick peptidoglycan layer in the cell wall (Fig4). The typical Gram-positive reaction is in line with its taxonomic position in the phylum Actinobacteria, which comprises high G+C gram-positive bacteria renowned for the production of secondary metabolites like antibiotics. The filamentous structure observable under the microscope upon Gram staining also fits with the identification of *S. peucetius* as an actinomycete.

Inoculum Preparation

Inoculum of *Streptomyces peucetius* was successfully prepared by streaking spores on ISP-2 agar plates and incubating at $28 \pm 2^\circ\text{C}$ for 5–7 days. The white to gray aerial mycelium and reddish substrate mycelium indicated the establishment of a mature culture. A loopful of the grown colony was aseptically inoculated into 50 mL of sterile ISP-2 broth in a 250 mL Erlenmeyer flask [14]. The culture was incubated at 28°C on a rotary shaker at 180 rpm for 48 hours. The optical density (OD_{600}) measured between 0.8 and 1.0, indicating active growth.

Mutation of *Streptomyces peucetius***UV Mutagenesis**

The inoculum of *Streptomyces peucetius* was exposed to UV mutagenesis with a UV transilluminator (254 nm). Spore suspension (about 10^8 CFU/mL) was irradiated with UV at a distance of 15 cm for different periods (10, 15, and 20 minutes). After irradiation, the tubes were placed in the dark for 1 hour to avoid photoreactivation (Fig 5). A progressive reduction in colony-forming units was noted with increasing duration of exposure.

The formula to calculate Colony Forming Units (CFU) is as follows

$\text{CFU/ml} = \text{Number of colonies} \times \text{dilution factor/volume plated (in ml)}$ The original spore concentration was ca. 1.0×10^8 CFU/mL.

- For 10 minutes of UV irradiation, the CFU dropped to 4.5×10^7 CFU/mL, i.e., ~45% survival.
- For 15 minutes of exposure, CFU dropped to 1.8×10^7 CFU/mL (~18% survival),
- At 20 minutes, the drop was sudden to 3.0×10^6 CFU/mL (~3% survival). These findings verified UV radiation dose-dependent lethality, and the range of exposure of 10–15 minutes provided enough mutant colonies for screening with a compromise between mutagenic effect and survival [15].



**Kamalambigeswari and Kamalesh****ETBR Mutagenesis**

Inoculum of *Streptomyces peucetius* was subjected to Ethidium Bromide (EtBr) to induce mutations. Spore suspension ($\sim 10^8$ CFU/mL) was treated with EtBr at 1, 5, 10, and 15 $\mu\text{g/mL}$ concentrations for 30 minutes in the dark. Treated suspensions were washed and plated on sterile ISP-2 agar plates, and the plates were incubated at 28°C for 5–7 days.

- At 5 $\mu\text{g/mL}$, survival was reduced to approximately 50%, yielding 5.0×10^7 CFU/mL. Many of the colonies showed novel pigmentation and distorted colony morphologies, indicative of successful mutagenesis.
- At 10 $\mu\text{g/mL}$, survival was decreased to 25%, with a CFU value of 2.5×10^7 CFU/mL. The majority of colonies showed aberrant morphology, including color shifts and distorted growth patterns.
- Reduced to 15 $\mu\text{g/mL}$, the survival rate declined further to about 10% by CFU count $\times 10^7$ CFU/mL. Most of the colonies showed severe morphological alterations in that they were irregular in shape and size, while some were smaller or defective in growth, reflecting an increased mutagenic effect.

Fermentation Media Preparation**Shake Flask Fermentation**

Initial fermentation was performed in 250 mL Erlenmeyer flasks with 50 mL of production medium (Fig.6). The engineered strain (*S. peucetius* $\Delta\text{dnrU}/\text{drrC}$) had reached a titer of 1128 mg/L doxorubicin on day 7. Carbon and nitrogen source optimization by response surface methodology (RSM) and improved the yield to 1406 mg/L under the following parameters. Growth was uniform, and the pH level was between 6.8–7.2 throughout the fermentation.

Bioreactor Fermentation

Scale-up was carried out in a 10-liter stirred-tank bioreactor with an operating volume of 7 liters. The conditions were 28°C , pH 6.8, 300 rpm agitation, and 1vvm aeration (Fig7). Under these conditions, the maximum production of doxorubicin was 1461 mg/L on day 7 [16]. Biomass accumulation followed a linear rise up to day 6, followed by a plateau phase, signifying entry into the stationary phase.

Solvent Extraction

Liquid-liquid extraction of the fermentation broth of *Streptomyces peucetius* was done to recover a blend of anthracyclines (Fig 8) (e.g., doxorubicin and daunorubicin) with chloroform as solvent. Extraction efficiency was evaluated using UV-Vis spectrophotometry at 480 nm, and quantitation of anthracycline concentration was accomplished by HPLC.

Extraction Efficiency with Chloroform

The clarified fermentation broth was stirred with chloroform in a 1:1 solvent-to-broth ratio. Room temperature extraction for 30 minutes was used. The yield of anthracycline was 82.4%, as indicated by the concentration of doxorubicin and daunorubicin in the organic phase. Efficient extraction occurred under pH 5.5 with maximum efficacy and increased organic-phase solubility of anthracyclines

Final Product Recovery

After the evaporation of chloroform, the anthracyclines were recovered as a reddish-brown powder. The final yield from the 3.5 liters of fermented broth, produced in the pilot-scale bioreactor, was approximately 2.56 g of anthracyclines. This represents the total product obtained after solvent extraction and evaporation. For comparison, the production levels from other mutated species are listed in the table 1 below.

UV Spectroscopy Analysis

Chloroform-extracted anthracyclines were scanned in the 200–600 nm region using a UV- Vis spectrophotometer to determine the absorbance. There was a characteristic absorbance peak at 480 nm, as is expected from the established spectral properties of anthracycline drugs like doxorubicin and daunorubicin. The compounds have intense absorbance in the visible spectrum because they contain extended conjugated quinone ring systems, which account for their intense red coloration and fluorescence [17].



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Doxorubicin generally possesses a dominant absorbance peak between 476–480 nm in organic media, and daunorubicin displays a comparable spectrum [18]. The sample's UV spectrum was consistent with these profiles, corroborating the identification of the isolated compound as an admixture of anthracyclines (Fig. 9 and 10).

Thin Layer Chromatography

Thin Layer Chromatography (TLC) was used to establish the presence of anthracyclines in the samples extracted from *Streptomyces peucetius*. The samples were applied on silica gel 60 F254 TLC plates, and the chromatograms were developed in a solvent system of Chloroform: Acetone: Methanol: Ammonia (80:10:5:5, v/v/v), a solvent system already used with success for the separation of anthracyclines. After development, the plates were dried in air and observed under UV light at 254 nm and 366 nm. The anthracycline-containing samples revealed clear red-orange fluorescent bands typical of compounds such as doxorubicin and daunorubicin (Fig 11). The R_f values of the bands seen varied from 0.42 to 0.48, following literature-reported R_f values for the compounds using the same solvent systems [19].

R_f = Distance traveled by the compound (spot) / Distance traveled by the solvent front

R_f Values of TLC (Table 2)

Antimicrobial Analysis

The Agar Well Diffusion method measured the antimicrobial activity of the anthracycline extracts from the UV rays and ethidium bromide (EtBr)-induced mutated strains of *Streptomyces peucetius*. Inhibition zones were quantified in millimeters (mm) for bacterial and fungal test strains (Fig 12).

LC-MS Analysis

Electrospray Ionization Mass Spectrometry (ESI-MS) analysis was performed to detect and compare anthracycline compounds produced by the wild-type *Streptomyces peucetius* and mutant strains produced by UV irradiation and treatment of ethidium bromide (EtBr) [20]. The chloroform extracts were dried to constant weight, dissolved in methanol, and subjected to positive ionization mode analysis. The mass spectra showed clear molecular ion peaks corresponding to known anthracyclines like doxorubicin and daunorubicin, along with other peaks indicative of structural analogues or derivatives in the mutant strains. LC-MS Analysis (Table 3)

- All strains yielded doxorubicin (m/z 544.6) and daunorubicin (m/z 528.4) as principal products.
- The UV-mutated strain also yielded a low-intensity peak at m/z 562.3, which could represent hydroxylation or glycosylation variants.
- The EtBr-induced mutant strain yielded the widest variety of products, including two other molecular ions at m/z 576.5 and 590.4, which could represent over-glycosylated anthracyclines or biosynthetic intermediates.

FTIR Analysis

Fourier Transform Infrared Spectroscopy (FTIR) was carried out to determine the functional groups in the anthracycline extracts of wild-type and mutant (UV and EtBr-treated) strains of *Streptomyces peucetius*. The powders extracted using chloroform were scanned using an FTIR spectrometer from 4000 to 400 cm^{-1} . All strains had characteristic core functional groups of anthracyclines: phenol O–H, ketone C=O, aromatic C=C, (C–O–C) ether, and glycosidic sugar signs. Mutant strains, specifically the EtBr-induced mutant strain, showed amplified or extra peaks in the ~ 1710 cm^{-1} region (denoting extra carbonyl functionalities), and a more prominent glycosidic signal (~ 1200 – 1150 cm^{-1}), indicating structural variations in the anthracycline molecule—apparently due to increased oxidation or glycosylation. FTIR Analysis (Table 4)

CONCLUSION

The current research showed failure anthracycline yield improvement through mutagenesis of *Streptomyces peucetius* with UV light and ethidium bromide (EtBr) as the mutagenic agents. Some of the mutants do not show enhanced





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yields of anthracyclines relative to the wild-type. These decreases are due to genetic alterations that likely overexpress the polyketide biosynthesis pathway responsible for anthracycline production. The mutagenized strains not only demonstrated intensified pigment in fermentation broth but also produced lower amounts of purified anthracyclines, as validated by TLC, UV-Vis spectroscopy, LC-MS, and FTIR analysis. In general, the results indicate that targeted mutagenesis with UV and EtBr is not a viable approach to strain improvement and large-scale production of pharmaceutically valuable compounds like doxorubicin and daunorubicin.

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Table1: Final product recovery amount

Si No	Mutated Species	Concentration and Time (μ m and Min)	Recovery Amount (Mg)
1.	CONTROL	-	187.254
2.	EtBr	5	90.4285
3.	EtBr	10	50.7142
4.	EtBr	15	22.2857
5.	UVrays	10	80.2859
6.	UVrays	15	38.5714
7.	UVrays	20	7.2952

Table 2: Rf Values of TLC

Si No	Mutated Species	Concentration And Time (Mm and Min)	Rf VALUES
1.	CONTROL	-	0.44
2.	EtBr	5	0.42
3.	EtBr	10	0.42
4.	EtBr	15	0.43
5.	UV rays	10	0.45
6.	UV rays	15	0.44
7.	UV rays	20	0.43

Table 3: LC-MS Analysis

SI NO	Strain Type	Conc	Detected m/z Peaks	Putative Compound(s)	Ion Type
1.	CONTROL	-	544.6, 528.4	Doxorubicin, Daunorubicin	[M+H] ⁺
2.	UV rays	10MIN	544.6, 562.3	Doxorubicin, Daunorubicin, Hydroxylated derivative	[M+H] ⁺
3.	UV rays	15MIN	562.3, 562.3	Doxorubicin, Daunorubicin, Hydroxylated derivative	[M+H] ⁺
4.	UV rays	20MIN	562.3	Doxorubicin, Daunorubicin, Hydroxylated derivative	[M+H] ⁺
5.	EtBr	5 μ m	544.6, 528.4,	Doxorubicin, Daunorubicin, Extended- glycosylated forms	[M+H] ⁺
6.	EtBr	10 μ m	528.4, 576.5	Doxorubicin, Daunorubicin, Extended- glycosylated forms	[M+H] ⁺
7.	EtBr	15 μ m	576.5, 590.4	Doxorubicin, Daunorubicin, Extended glycosylated forms	[M+H] ⁺

Table 4: FTIR Analysis

SI NO	Wavenumber (cm ⁻¹)	Functional Group	Assignment	Observed In
1.	~3400–3300	O–H stretching (broad)	Phenolic and alcoholic groups	All strains
2.	~2920–2850	C–H stretching	Aliphatic –CH ₂ and –CH ₃ groups	All strains
3.	~1720–1700	C=O stretching	Quinone/Ketone group	All strains
4.	~1610–1580	C=C stretching (aromatic)	Anthraquinone ring	All strains





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5.	~1260–1200	C–O–C stretching	Ether or glycosidic linkage	All strains
6.	~1070–1030	C–O stretching	Alcoholic and sugar OH groups	All strains
7.	~800–750	C–H bending (aromatic)	Substituted aromatic ring	All strains
8.	~1710–1685	New or intensified C=O	Additional oxidized derivatives	UV and EtBr mutants (enhanced)
9.	~1200–1150	More intense C–O–C signal	Possible sugar modifications	EtBr mutant strain

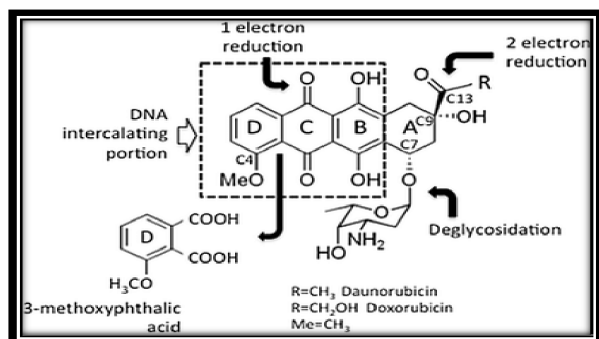


Fig 1: Structure of anthracyclines

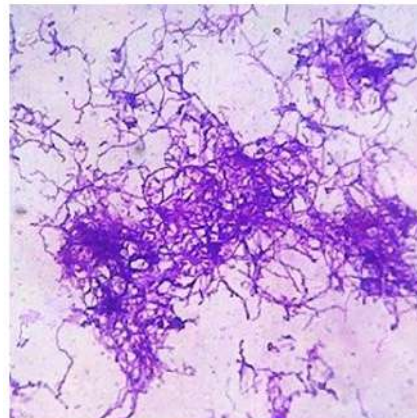
Fig 2: Pure plate culture of *Streptomyces peucetius*Figure 3: Red Pigmentation of *Streptomyces peucetius*Figure 4: Gram Staining of *S. peucetius*.

Figure 5: Mutation of Inoculum by UV rays in UV Transilluminator



Figure 6: shake flask fermentation of anthracyclines production





Figure 7: Bioreactor Fermentation of Anthracycline Production

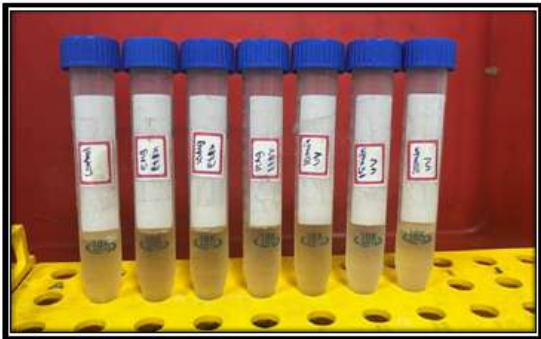


Figure 8: Solvent Extraction of Anthracyclines of Various Mutated Species of *Streptomyces peucetius*

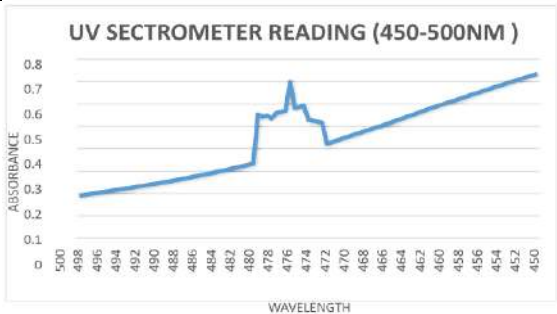


Figure 9: UV Spectrometer Graph from the Wavelength of 450 nm to 500 nm

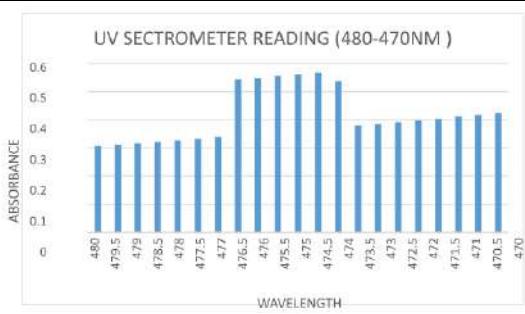


Figure 10: UV Spectrometer Graph from the Wavelength of 480 nm to 470 nm





RESEARCH ARTICLE

A Comprehensive Review on Kidney Stones: Understanding the Formation of Kidney Stones, Types, Common Risk Factors, and Comparative Study of Therapeutic Approaches

Mohibul Haque^{1*}, Dariphilin Ramde², Md Zafar Sadik Ahmed², Dondime Biachi R Marak²

¹Assistant Professor, Department of Pharmacy, School of Pharmaceutical Sciences, University of Science and Technology, Baridua, Ri-Bhoi, Meghalaya, India.

²B.Pharm Student, Department of Pharmacy, School of Pharmaceutical Sciences, University of Science and Technology, Baridua, Ri-Bhoi, Meghalaya, India.

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*Address for Correspondence

Mohibul Haque

Assistant Professor,
Department of Pharmacy,
School of Pharmaceutical Sciences,
University of Science and Technology,
Baridua, Ri-Bhoi, Meghalaya, India.
E.Mail: haquem425@gmail.com



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ABSTRACT

A comprehensive review on kidney stones, understanding the mechanism of formation, its type, common risk factors and comparative study of their therapeutic approaches. Kidney stones or renal calculus is worldwide problem which convey significant ailment with very high recurrence rate. Kidney stones also known as, nephrolithiasis or urolithiasis or renal calculi, are mineral deposits in the renal tube and renal pelvis that are connected to the renal papillae. Calcium stones, struvite stones, cystine stones, uric acid stones are the four main types of kidney stones. Among these, calcium oxalate is the most common type of kidney stones. Increase in urinary super saturation due to hyperoxaluria, hypercalciuria, low urine volume and increase urine pH which involves multiple steps including crystal nucleation, crystal growth, crystal aggregation, crystal retention within the kidney or renal collecting duct eventually leading to stone formation. Obesity, dehydration, hyperparathyroidism, diabetes are considered as risk factors for kidney stone. Kidney stone mostly affect kidney ureters and urethra of the body. There are various treatments are available for the kidney stone like allopathic treatment, ayurvedic treatment and homoeopathy treatment etc. But commonly used treatments are being used in India are allopathic and ayurvedic. In this generation kidney stones disease become very normal because of life style and food habit. But in case of treatment most of the people get scared because of surgery. In India, people believe on ayurvedic treat because it has minimal side effect. But most of the people go for allopathic treatment because of the immediate response. In this study we tried to understand which way of treatment is better



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for the common people and important point is that some people do not even know that they have kidney stone until it become large in size so patient had to go through surgery. After reviewing of multiple research and review article it has been found that improper diet and unhealthy life style is the main reason behind kidney stone and in case of treatment, allopathic treatments are popular than the ayurvedic treatment but ayurvedic medicine has less side effect as compare to allopathic. Nowadays ayurvedic treatments are becoming popular in India as well as whole world because of its minimal side effect with affordable price.

Keywords: Kidney stone, Calcium stone, Diet, Nephrolithiasis.

INTRODUCTION

Kidney stones are hard mineral deposits that form in the kidneys when substances like oxalate, calcium, uric acid and their concentration become high in the urine and form crystals. Kidney stones are also known as nephrolithiasis or urolithiasis. Kidney stone disease is one of the common and oldest disease and still people are searching for its best treatment without surgery and to get proper idea how to avoid risk factors which are responsible for kidney stone. There are different types kidney stones are available but calcium oxalate stone is the most common form of kidney stone. Randall's plaques are considered as the main source of calcium oxalate stone formation. Sex hormones play crucial role in the formation of kidney stones. It is found that 1 to 15 % of individuals encounter with kidney stone formation at some point of time in their life. The process of kidney stone formation is a critical process that involves nucleation, crystal growth, epitaxial, crystal retention, and crystal aggregation. Kidney stones symptoms include loin or groin pain, dysuria, hematuria (blood in the urine), urinary frequency, fever. The common risk factors of kidney stones are obesity, diabetes, hypertension, diet, dehydration, family history, alcohol consumption. 5 to 10% of stones formation risk has been reported. Since kidney stone is a worldwide rising ailment affecting millions of people around the world, hence this article aims to provide a comprehensive understanding of its formation, types, risk factors and therapeutic approaches. [1, 2, 3, 4]

Types of kidney stones

There are four types of kidney stones

Calcium stones: Calcium is the element of renal stones formation in an individual. Environmental and metabolic abnormalities change the urinary environment leading to super saturation of stone forming salt resulting in the formation of calcium stones. Dietary alteration plays an important role in minimizing calcium stone diseases in patients. More than 200mg of urine calcium levels at a daily rate can increase stone risk resulting in calcium imbalance. Calcium oxalate and calcium phosphate are the two types of calcium stones. About 85% of stone in human beings are calcium stone consisting of oxalate and phosphate. [5, 14]

Struvite stone: Struvite is a crystalline substance comprising of magnesium ammonium phosphate ($\text{MgNH}_4\text{PO}_4 \cdot 6\text{H}_2\text{O}$). Struvite stones are also known as "Infection stones" and "Triple phosphate" stones as they are related with urinary tract infections. Struvite stone is formed in the presence of urease producing bacteria. These stones occur mostly in women, infants, and the elderly patients since they are more likely to get urinary tract infections. [1, 2, 5]

Cystine stone: Cystine stones are uncommon as compared to other stones. The incapability of renal tubules to reabsorb filtered cysteine results in cystinuria. Cystinuria is a rare genetic renal stone ailment having no cure. Treatments may include high diuresis, alkalization, and pharmacological interventions with constant observation of urinary pH, cysteine levels, cystine crystal volume and solubility.

Uric acid stones: Uric acid is the final product of purine degradation in humans. Some of the risk factors of uric acid are acidic urine, hyperuricosuria (presence of excessive amount of uric acid in the urine), and low urine volume.



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Climate changes and diet plays major role in uric acid stone formation. Consumption of excessive meats results in increase in uric acid excretion. Uric acid stones are more common among kidney stone patients with Type2 diabetes, obesity, and metabolic syndrome.

Risk factors of kidney stone

Obesity: Obesity is one of the risk factor of kidney stones diseases. Stone formation in obese patients is considered to be link with insulin resistance, dietary factors, and lithogenic urinary profile. Mostly in these patients uric acid stones and calcium oxalate stones are often observed. Weight loss is considered as primary treatment for obese patients with nephrolithiasis. Two well defined metabolic circumstances considered for patients with metabolic syndrome are when abdominal obesity prone to insulin resistance at renal level decreasing the excretion of urinary ammonium leading to a low urinary ph resulting in greater risk of uric acid stone formation. Bariatric surgery helps in weight loss in obese people however it carries a significant risk of calcium oxalate stone formation. [27, 28]

Diet: Diet plays a major role in urinary stone formation. Nutritional factors such as protein, carbohydrates, oxalate, calcium and sodium chloride can balance the risk of kidney stone formation. Daily consumption of calcium can avoid secondary hyperoxaluria. Recommendation like increase in fluid intake, maintaining a balanced calcium intake, reducing sodium and animal protein intake and increasing intake of fruits and fibers can reduce the formation of kidney stone. [30, 31]

Dehydration: Dehydration is considered to be one of the important risk factor for kidney stone formation which can be treated by increasing the intake of water and dietary advice. Prolonged heat exposure and dehydration may lead to kidney stone formation. Lower estimate glomerular filtration rate (eGFR) changes urine chemistry and risk factors of kidney stones differ by stone type. [33, 34]

Diabetes: Diabetes may increase the risk of kidney stone formation. Evidence shows that physical activity may decrease the risk of Type 2 diabetes. Urolithiasis is the most recurrent cause of hospitalization in diabetic patients as compared to non-diabetic patients. [36]

Inflammatory bowel disease: Kidney stones are considered to be the cause of inflammatory bowel diseases. The pace of stone formation is slightly higher in patients with Crohn's disease as compared to the patients with ulcerative colitis. [37]

Family history: Family history of kidney stones considerably increases the risk of stone formation and it is more common in male than in female. Decrease in urinary volume is one major component related with risk of stone formation. [42]

Hyperparathyroidism: Kidney stone is the main clinical abstract of primary hyperparathyroidism (PHPT) and this is usually asymptomatic. Increase serum calcium level in nephrolithiasis patients generally indicates hyperparathyroidism so the serum calcium level should be measured. [43, 44]

Formation of kidney stones

The formation of kidney stone occurs through super saturation of the urine with calcium and oxalate salts after which crystalline particle are formed. These crystalline particles are the major reason of kidney stone formation. [26]
Mechanism of kidney stone formation (Figure 1)

Therapeutic approaches

Ayurvedic treatment: Medicinal plants or herbal plants have been recognized to have therapeutic compounds that are useful for the treatment and prevention of various diseases such as kidney stone, medicinal plants are being used for decades as they are safer, more effective, and culturally acceptable and have fewer side effects as compared to modern medication. [45]



**Mohibul Haque et al.,****Allopathic treatment:**

Treatment through allopathic medications: [50] (Table 2)

Surgical treatment

Extracorporeal shock wave lithotripsy (ESWL): Extracorporeal shock wave lithotripsy (ESWL) breaks stones in the kidney and upper urinary tract by using shock waves. It is considered to be a safe method in the treatment of kidney stones if proper demonstration is ensured. This treatment is suggested in upper urinary tract calculi less than 2cm in diameter due to its efficacy and low morbidity. [51, 52]

Nephrolithotomy: It has been considered to be the most effective treatment for the removal of kidney stones. It is a surgical protocol for the treatment of large or complex kidney stones. Nephrolithotomy has considered being a successful and safe treatment that has been used for centuries. This treatment is used for patients of different groups such as children, obese patients, and patients with previous surgery. [51, 54]

Ureteroscopy: Ureteroscopy is being used as a primary treatment for renal stones as compared to shock wave lithotripsy and nephrolithotomy. Prolonged duration of this treatment may lead to ureteral perforation. For stones greater than 2 cm ureteroscopy procedure is suggested which is suitable for pregnant and obese patients. This treatment is effective with low morbidity for most kidney stones. [58, 59]

Comparative analysis between allopathic and ayurvedic treatment of kidney stones

Effectiveness of ayurvedic treatment: Ayurvedic medicines show potential compatible method to the treatment and prevention of kidney stones. Ayurvedic formulations are considered to be an effective treatment in reducing kidney stone size and flank pain. Some of the examples of herbal medicinal plants used for the treatment of kidney stones are *Asparagus racemosus* which reduces calcium oxalate stone formation, *Phyllanthus niruri* which helps to prevent kidney stone formation, *Crataeva nurvala* helps in regulating the excretion of metabolites and waste, and prevents stone formation. [47, 61, 62]

Effectiveness of allopathic treatment

Medication: Level of adherence to medication such as thiazides diuretics, alkaline citrate and allopurinol among patients diagnosed with kidney stones is considered to be low and due to this lack of adherence may reduce the effectiveness of these medications. [63] Loop diuretics and potassium sparing diuretics are used to treat kidney stones. Some medications such as nifedipine have been demonstrated to be effective and safe medicine for increasing the stone expulsion rate of kidney stone. [65]

Surgery: Shock wave lithotripsy has considered being less effective than Ureteroscopy. Nephrolithotomy is considered to be effective treatment for large renal stones.

Success rate

ESWL -75 to 80 % success rate for stones smaller than 2cm.

PCNL -90 to 95 % success rate for stones larger than 2cm .

Ureteroscopy -95 to 100% success rate for stones less than 1cm.

Safety

Ayurvedic treatment: Herbal medications are being used for centuries and it has been recognized to be more effective and has fewer side effects as compared to allopathic medications. It has been believed that herbal medicines are free from undesired side effects and are considered to be safe and effective. [70]

Allopathic treatment: Nephrolithotomy is considered to be a safe and successful treatment for treating patients with kidney stones which has been using for decades. ESWL surgery is an effective treatment for treating patients with urinary calculi with a safe reliable performance and minimal risk of side effects as it decreases the side effects and



**Mohibul Haque et al.,**

promotes quicker recovery of patients which improves their day to day life. Ureteroscopy is found to be a safe and effective procedure for pregnant and as well as non pregnant patients. [56]

Cost: Patients suffering from kidney stones rely on surgeries even though they are expensive and may have difficulties while on the other hand herbal medications are cost effective and have fewer difficulties. [73]

DISCUSSION

In this generation kidney stones disease become very common because of sedentary life style and food habit. One of the important point is found that kidney stone formation occur due to people don't drink enough water because of their busy life. Nowadays people become more addicted to fast food and improper diet. But in case of treatment most of the people depend on allopathic treatments and some people depend on ayurvedic treatment. Most of the people believe on allopathic because of their immediate response and some people don't even know that they have kidney stone until it become larger in size ultimately patient had to go through surgery. When a kidney stone patient experienced pain they think it is because of gastric or others so they don't take action immediately and in India lower middle class people don't visit doctor easily because of their financial issues eventually they deals with major disease or disorder but nowadays ayurvedic treatment grabbing people's attention because of its herbal formula with fewer side effects. Ayurvedic medicines are cost effective also and it's very easy to use also. So, tradition medicine is becoming first choice for the rural Indian people.

CONCLUSION

In conclusion, as kidney stone disease remains to be growing problems all over the world, and there are some emerging techniques also arising for the treatment of stones. But common treatment includes allopathic and ayurvedic treatments. After comparing ayurvedic and allopathic treatment for kidney stones it has been found that ayurvedic treatment is more effective, has less side effects and less expensive when the stone size is very small than allopathic treatment. Allopathic treatments shows result immediately so its better in case of emergency. After reviewing of multiple research and review article it has been that improper diet and unhealthy life style is the main reason behind kidney stone and in case of treatment allopathic treatments are popular than the ayurvedic treatment but ayurvedic medicine has less side effect as compare to allopathic. Nowadays ayurvedic treatments are becoming popular in India as well as whole world because of no side effect, herbal drugs and affordable price. Kidney stone can be overcome by changing the life style as per the different research article.

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Table 1. Ayurvedic treatment

SI NO	BOTANICAL NAME	FAMILY	PART OF THE PLANT USED	USES
1	<i>Celosia argentea</i>	Amaranthaceae	Seed	For the dissolution and excretion of stones
2	<i>Trigonella foenum-graecum</i>	Fabaceae	Seed	Reduce calcification in the kidney
3	<i>Asparagus racemosus</i>	Asparagaceae	Root	Reduces calcium oxalate formation
4	<i>Phyllanthus niruri</i>	Phyllanthaceae	Whole plant	Helps to prevent kidney stone formation
5	<i>Tribulus terrestris</i>	Zygophyllaceae	Root, fruit	Treatment of urinary tract disease and helps



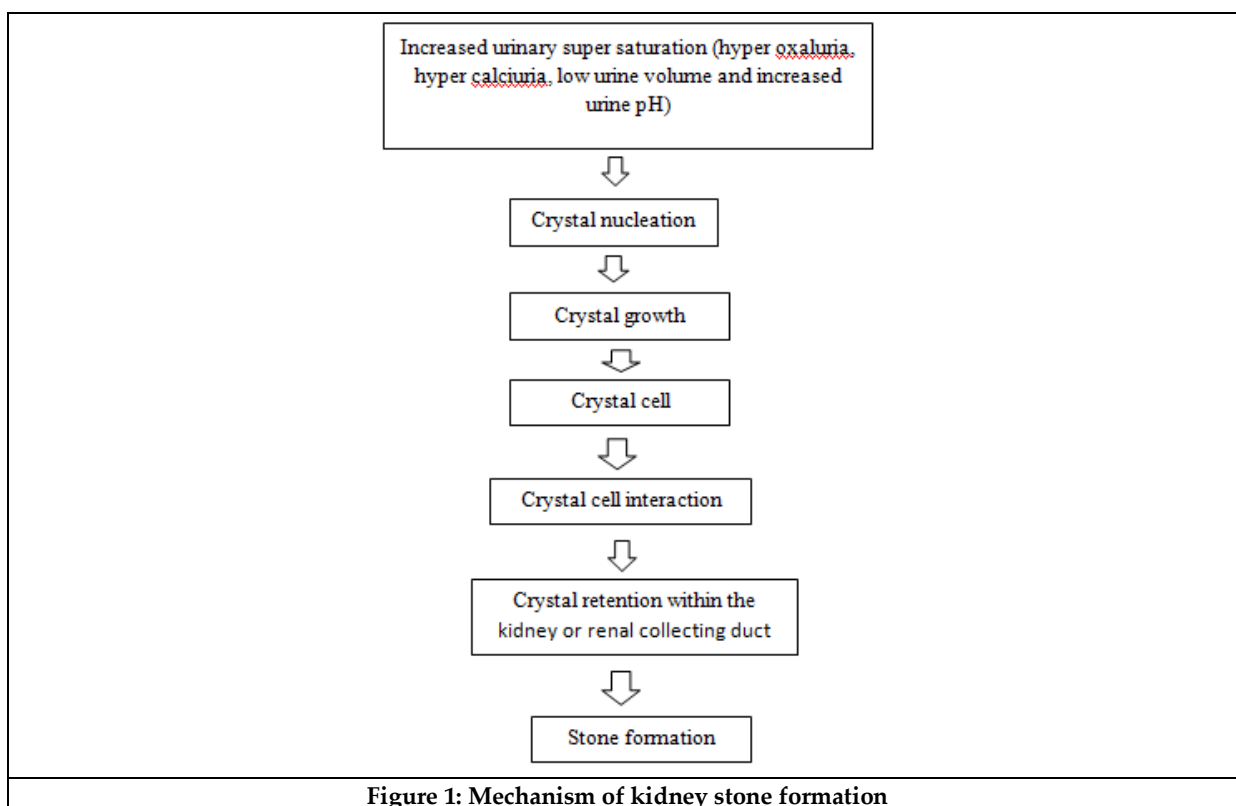


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				to reverse early stage urolithiasis
6	<i>Crataeva nurvala</i>	Capparaceae	Bark	Regulating the excretion of metabolites and waste, metabolic error and prevent stone formation.
7	<i>Berberis vulgaris</i>	Berberidaceae	Root, Bark	Inhibit calcium oxalate crystallisation.
8	<i>Zingiber officinale</i>	Zingiberaceae	Rhizome	Reduce the formation of Kidney stones.
9	<i>Curcuma longa</i>	Zingiberaceae	Rhizome, Root	Reduce the formation of Kidney stones.
10	<i>Mimosa pudica</i>	Mimosaceae	Leaves	Reduces the pain.

Table 2: Treatment through allopathic medications: [50]

SI NO	MEDICINES	USES
1	Thiazide diuretics	Helps to reduce high calcium level in urine
2	Potassium citrate	Helps makes urine more alkaline which reduces the formation of cystine and uric acid stone
3	Allopurinol or febuxostat	Reduces uric acid content in the blood and urine
4	Acetohydroxamic acid(AHA)	Reduces the formation of struvite stones or infection in the UTIs
5	Nifedipine	Expulsion of the stone from the body by relaxing the smooth muscles of urinary tract
6	Corticosteroid	Reduces the inflammation caused by urinary stone





RESEARCH ARTICLE

Optimization of Process Parameters and Mechanical Characteristics in Friction Stir Welding of Different Aluminium Alloys using Taguchi Approach

Sayon Dey*, Nityanando Mahato and Gourab Chakraborty

Assistant Professor, Department of Mechanical Engineering, Brainware University, Barasat, Kolkata, West Bengal, India.

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*Address for Correspondence

Sayon Dey

Assistant Professor,
Department of Mechanical Engineering,
Brainware University, Barasat, Kolkata,
West Bengal, India.

E.Mail: deysayon@gmail.com



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ABSTRACT

Friction stir welding is a process where plastic deformation takes place at solid state to join two similar or dissimilar metallic pieces by plunging a rotating tool into the workpiece. The factors influencing the weld ability and other mechanical characteristics of friction stir welding (FSW) joints are the FSW parameters like tool rotational speed, welding speed, tool tilt angle, tool pin profile, axial force etc. Previous research has extensively investigated how FSW parameters affect the quality and weld ability of aluminium alloys welded with both similar and dissimilar metals. This review emphasizes the findings of these studies. The majority of comparative research has determined that critical factors such as welding speed, rotational speed, base material, pin profile etc. play a substantial role in the weld ability of aluminium joints when utilizing the FSW technique. In this study, Taguchi optimization (L9) is employed to analyze mechanical strength, specifically the tensile strength of different aluminium alloys based on various experimental data from the literature. Friction stir welding (FSW) parameters selected for investigation include tool rotational speed, welding speed, and axial force. The analysis of tensile strength reveals a strong correlation with tool rotational speed.

Keywords: Friction Stir Welding, Welding Speed, Tool Rotational Speed, Tensile strength, Pin profile, Optimization.



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INTRODUCTION

Aluminium alloy is widely utilized across various applications due to its ease of shaping into diverse structures through simple mechanical actions. This material is commonly employed in vehicle body fabrication, as well as in aerospace applications. Additionally, aluminium alloy finds extensive use in the construction of thermal unit boilers, heat exchangers, and related accessories. Aluminium alloy is categorized into two main types: wrought alloy and cast alloy. There are different combinations and series of aluminium alloys available, including those designated as 1xxx, 2xxx, 3xxx, 4xxx, 5xxx, 6xxx, 7xxx, and 8xxx. Welding procedures are employed to permanently join different materials, with significant research attention focused on welding aluminium and magnesium alloys, both in similar and dissimilar combinations. Currently, there is a significant focus on using Friction Stir Welding (FSW) to replace heavy alloys with lighter ones, aiming to achieve weight reduction and improve fuel efficiency in automobiles. FSW is also utilized to create high-strength joints in electric tools, maritime equipment, space shuttles, turbines, and agricultural machinery. This solid-state welding process results in materials that exhibit superior mechanical and microstructural properties in comparison to those produced using conventional methods. The cause and effect diagram[1] is shown in Figure 1.

Ahmed *et al.*[2] optimized the process parameters in FSW of AA5451 alloy for marine applications. The highest tensile strength value of 160.6907 MPa was attained under optimal welding conditions, including a tool rotation speed of 1400 rpm, a feed rate of 18 mm/min, and utilizing a threaded tool pin. Similarly, the maximum hardness value of 81.056 HV was achieved with optimal conditions of a tool rotation speed of 1200 rpm, a feed rate of 18 mm/min, and a threaded tool pin profile. Furthermore, the analysis of variance (ANOVA) was used to determine the contribution percentage of each input parameter. Sefene and Tsegaw[3] carried out a study on parameter optimization of AA6061 alloy using the Taguchi method. A steady-state heat transfer analysis was conducted using a transient thermal workbench to predict and determine the optimal parameters based on the simulated welding temperature results. With a 95% confidence interval, rotational and traverse speeds exhibit noteworthy characteristics. The joint efficiency achieved 92.25% of the base metal's strength at the peak welding temperature. Furthermore, the microstructure of the stir weld zone was examined using a Scanning Electron Microscope (SEM).

Anbuechziyan *et al.*[4] used a straight cylindrical pin profile with threads, featuring an 18 mm shoulder diameter, a rotational speed (R_s) of 710 rpm, and a welding speed (W_s) of 28 mm/min, was utilized to achieve sound joints. It was found that a tapered cylindrical pin profile was unsuitable for Friction Stir Welding (FSW) of the Mg alloy AZ91. Plates of magnesium alloy (AZ31B) and aluminium alloy (AA6061), each with a thickness of 6 mm, were joined using FSW. Joints with a shoulder diameter of 21 mm exhibited higher tensile strength (89%) compared to those with a lower-strength base material. FSW was employed by Karthikeyan *et al.*[5] to join Mg AZ31B-H24 and AA6061-T6 aluminium alloys using pin diameters ranging from 3.25 mm to 3.75 mm and welding speeds (W_s) between 600 and 1000 rpm. Tunnel defects were observed at a 4.25 mm pin diameter and welding speeds of 800 and 1000 rpm. The development of intermetallic phases during dissimilar welding using conventional methods poses integrity risks depending on the material thickness.

Heramo and Workneh[3] choose the combined Taguchi and Grey relation analysis experimental method for experiments on AA6061-T6 and AA5052-H32 alloys. It was found that the 1400 rpm tool rotational speed and the 40 mm/min tool transverse speed are the optimum parameters for joining these dissimilar joints. Elnabi *et al.*[6] conducted a statistical optimization through experimental work to analyze the ultimate tensile strength (UTS) and elongation of dissimilar joints between AA5454 and AA7075 using friction stir welding (FSW). The maximum ultimate tensile strength (UTS) achieved is 221 MPa using the optimal levels determined from L16OA, and the highest elongation reached is 12.83% based on the optimal levels obtained from L12OA. Lakshminarayanan and Alasubramanian[1] utilized the Taguchi method to identify the key control factors that significantly enhance the tensile strength of friction stir welded joints in RDE-40 aluminium alloy. The findings suggest that rotational speed, welding speed, and axial force are critical parameters that influence the tensile strength of the joint in friction stir



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welded RDE-40 aluminium alloy. The predicted optimal value for the tensile strength of this friction stir welded alloy is 303 MPa.

MATERIALS AND METHODOLOGY

The experimental results of different combinations of aluminium alloys are studied from the literature to find out the suitable parameters for the FSW process using the Taguchi method. Friction stir welding (FSW) tools come in various profiles such as straight cylindrical, tapered cylindrical, square, triangular, threaded, etc., and different studies have been conducted considering these tool profiles. The FSW tool consists of two main parts: the shoulder diameter and the pin diameter, with the shoulder diameter larger than the pin diameter. Different zones within the welded area are identified as the Heat Affected Zone (HAZ), Thermo-Mechanically Affected Zone (TMAZ), and Weld Nugget Zone (WNZ)[1], [3]. This investigation focuses on joining similar and dissimilar joints, analyzing mechanical strength such as tensile strength using the Taguchi L9 Orthogonal Array. All specimens are prepared according to ASTM E8 standards.

RESULTS AND DISCUSSION

In this study, the process parameters for increasing the tensile strength of welded samples after friction stir welding (FSW) were optimized using the Taguchi method. Signal-to-noise ratios were generated through various experimental measurements of different alloys using the Taguchi method. Larger-is-better signal-to-noise ratio (S/N ratio) criteria were employed to maximize responsiveness. The major effect plot for means, the S/N ratios, the contour plot and surface plot for the different aluminium alloys based on different experimental data for literature are shown in Figure 2, 3, 4, 5, 6, and 7. Furthermore, these figures indicate that the tool rotational speed plays a crucial role in determining the tensile strength of individual alloys. This can be attributed to the effectiveness of the threaded pin profile in ensuring a strong connection, as the material around the pin was sufficiently stirred during the process. The combined study considering different alloys, the major effect plot, the main effect plot for S/N ratio and the contour plot for tensile strength vs welding, rotational speed are shown in Figure 8.

CONCLUSION

This paper explores the application of friction stir welding (FSW) for joining similar and dissimilar aluminium alloy components in structural applications for marine and other high-tech industries. The Taguchi method was employed to identify the optimal process parameters for FSW and evaluate the contribution of each factor. Successful production of dissimilar aluminium alloy joints was achieved through friction stir welding, and the tensile strength was analyzed. The key findings of this study are as follows,

- For the joining of AA7020 and AA8014 alloys under optimal conditions, the maximum tensile strength was achieved with a tool speed of 1200 rpm, welding speed of 300 mm/min, and axial force of 8 kN.
- Experimental testing of AA5451 alloy specimens under optimal conditions yielded a tensile strength of 157 MPa, confirming and validating the computed results.
- Based on the ANOVA results for the AA6061 alloy, rotational speed and welding speed contribute significantly to the joint quality of the weld, with contributions of 64.2% and 27.4%, respectively. A higher tool rotational speed, lower welding speed, and tapered tool pin profile were found to enhance the quality of the weld. The effectiveness and suitability of Taguchi-based Grey Relational Analysis (GRA) for investigating the conformity of projected results in friction stir welding of AA6061 are demonstrated. The experiment achieved the highest efficiency of 92.25% when utilizing the optimum values of the input parameters.
- The optimal process parameters for RDE-40 aluminium alloy were determined to be 1400 rpm for rotational speed, 45 mm/min for traverse speed, and 6 kN for axial force.



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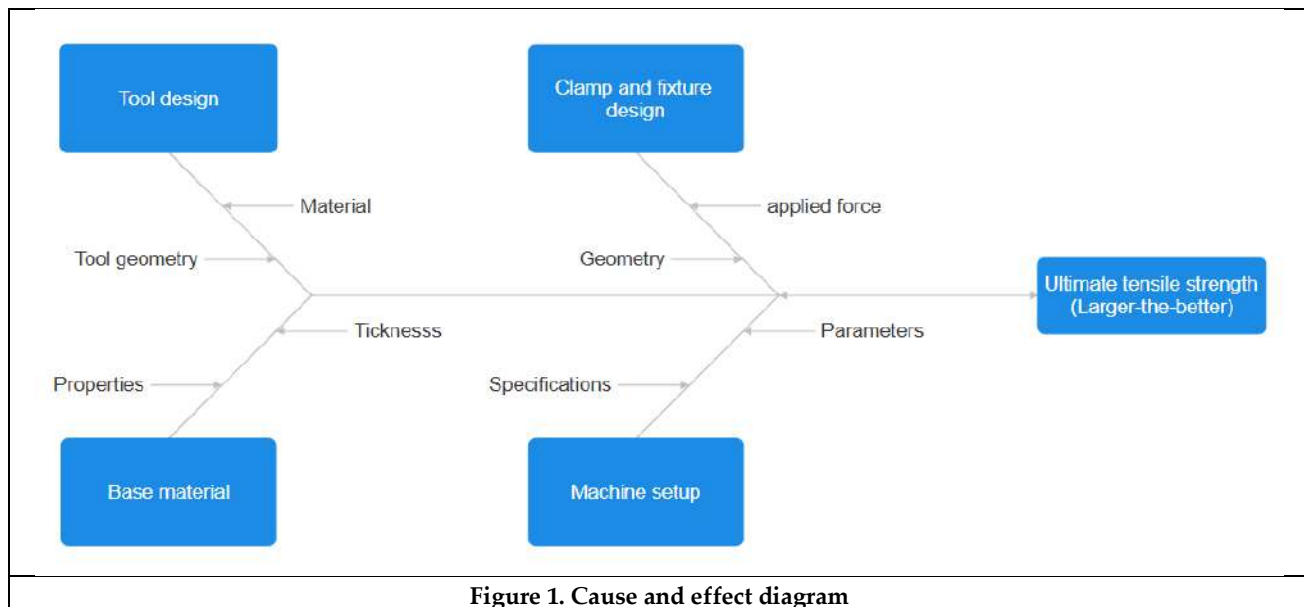
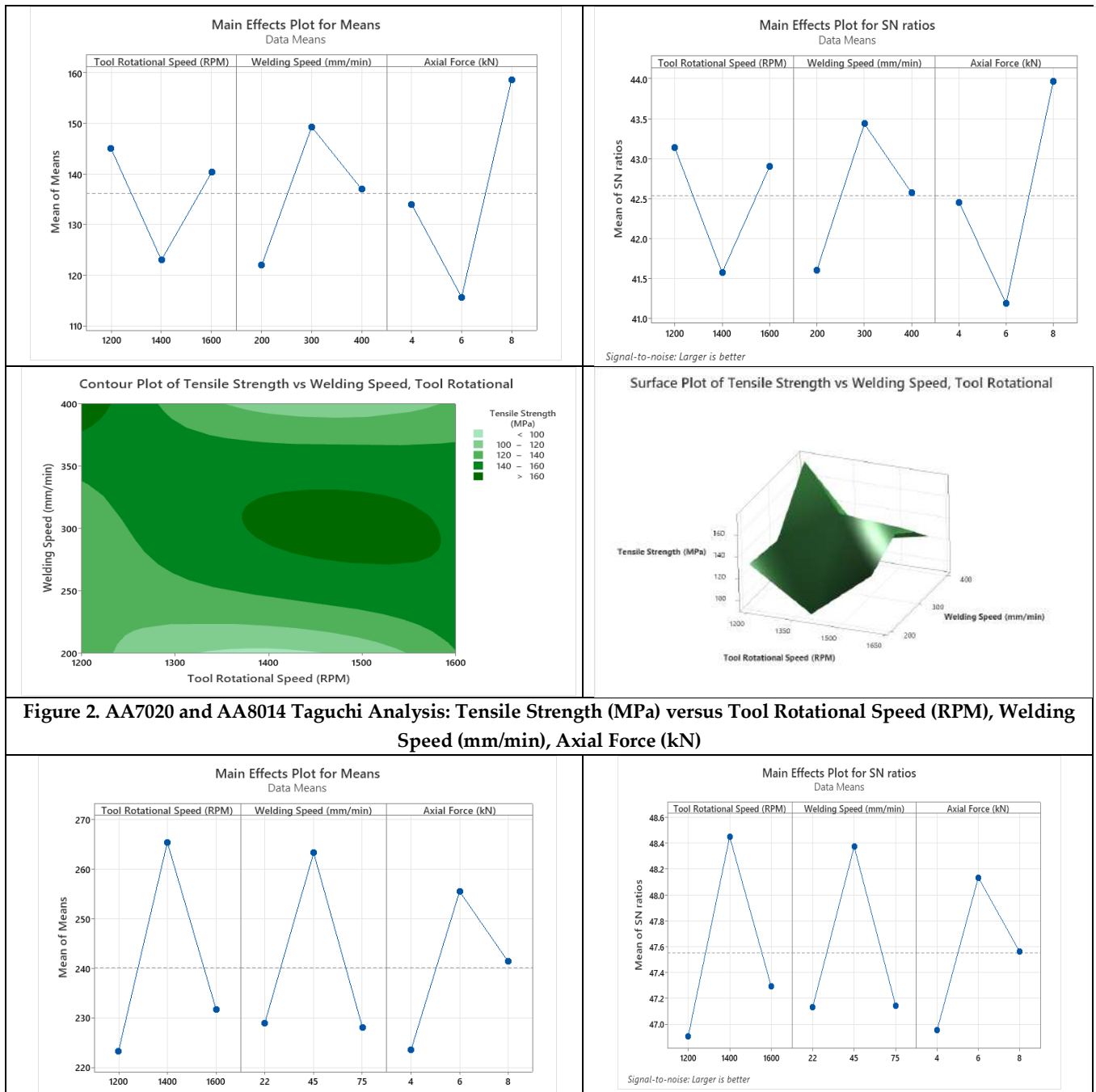


Figure 1. Cause and effect diagram



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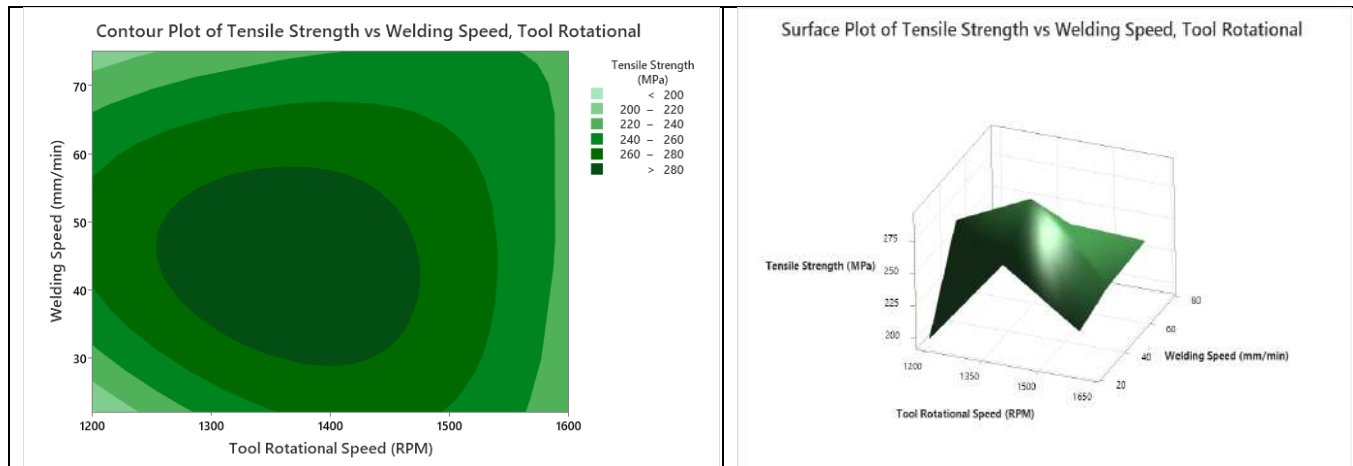


Figure 3. RDE-40 Taguchi Analysis: Tensile Strength (MPa) versus Tool Rotational Speed (RPM), Welding Speed (mm/min), Axial Force (kN)

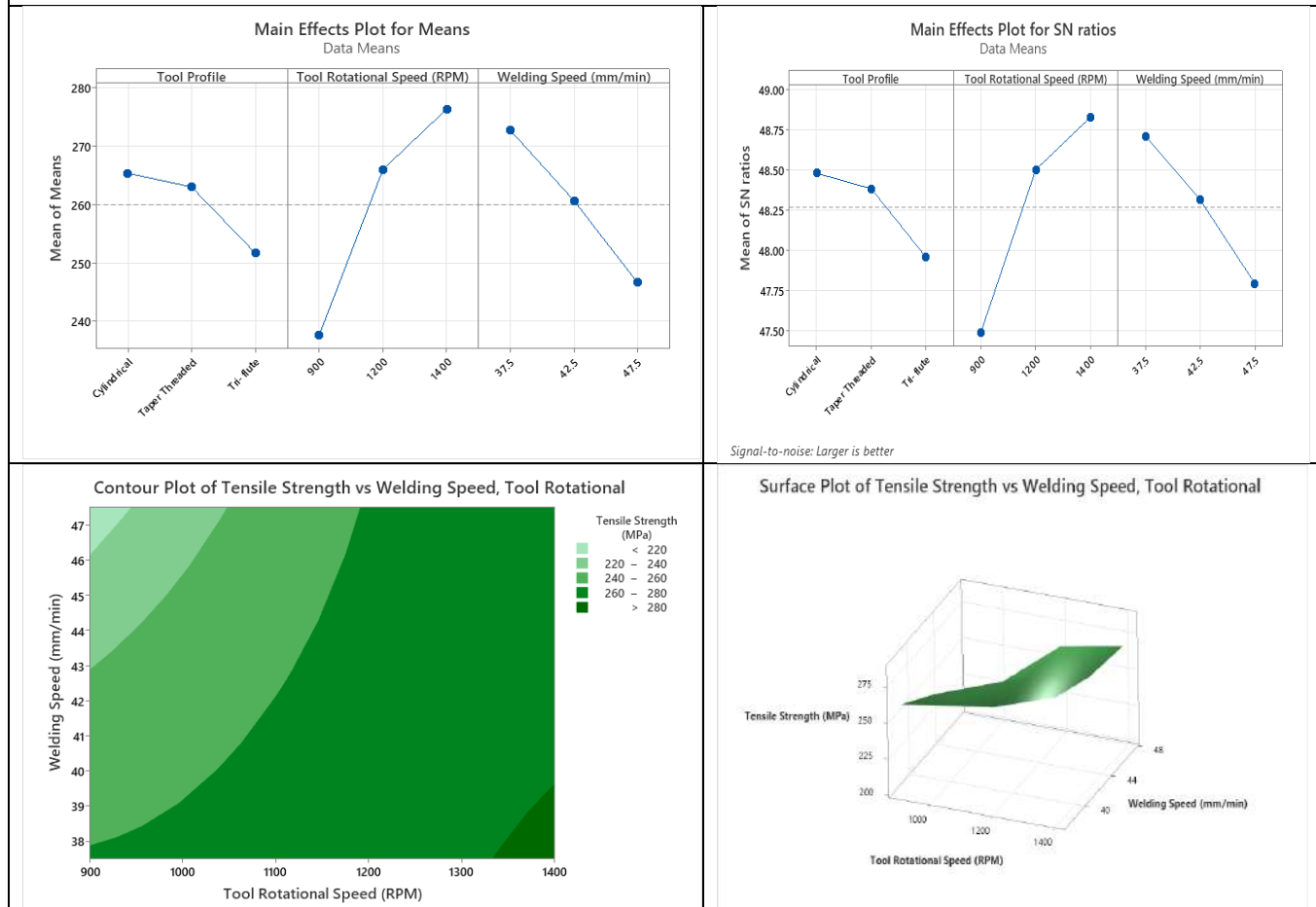


Figure 4. AA6061 Taguchi Analysis: Tensile Strength (MPa) versus Tool Profile, Tool Rotational Speed (RPM), Welding Speed (mm/min)





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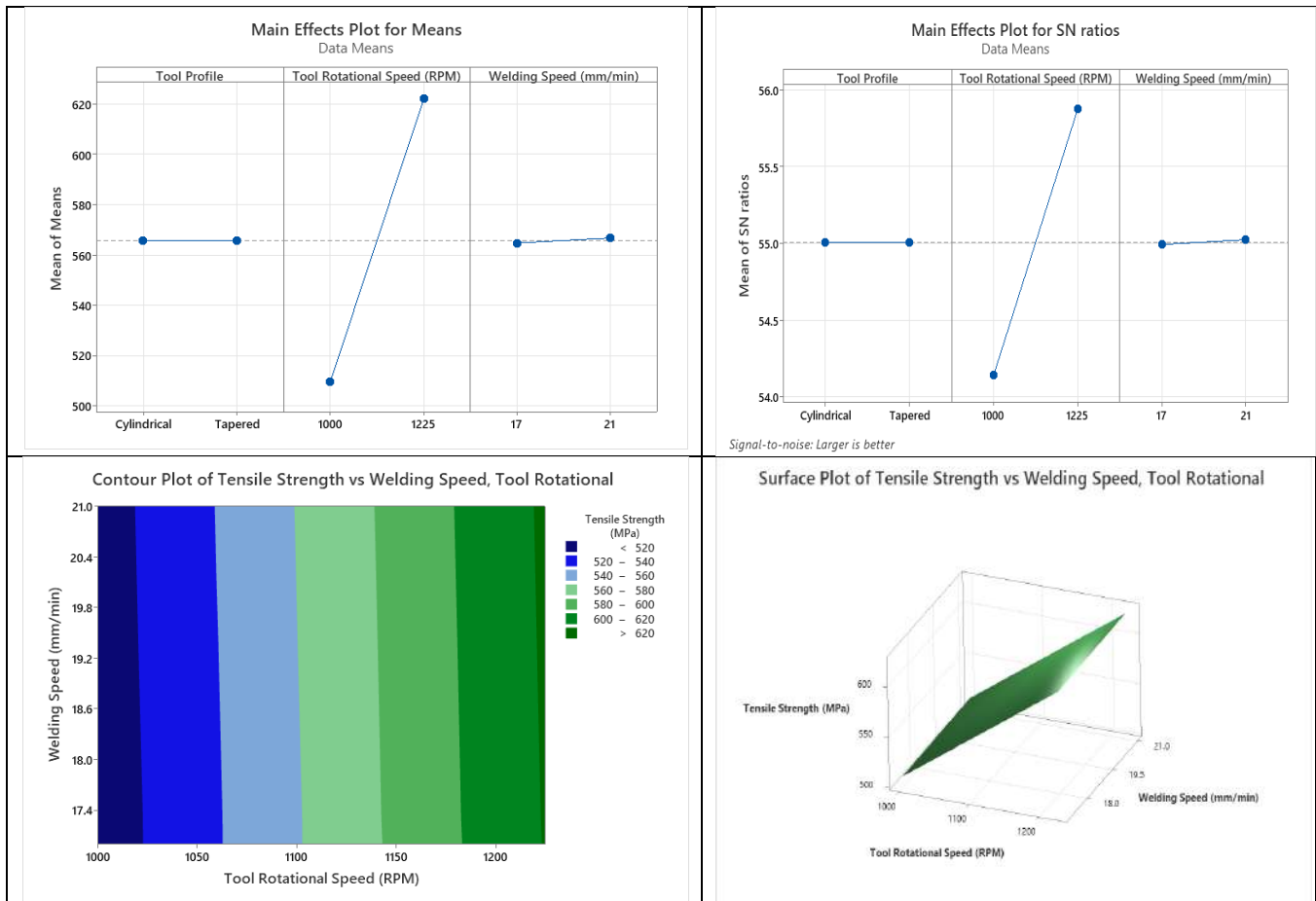
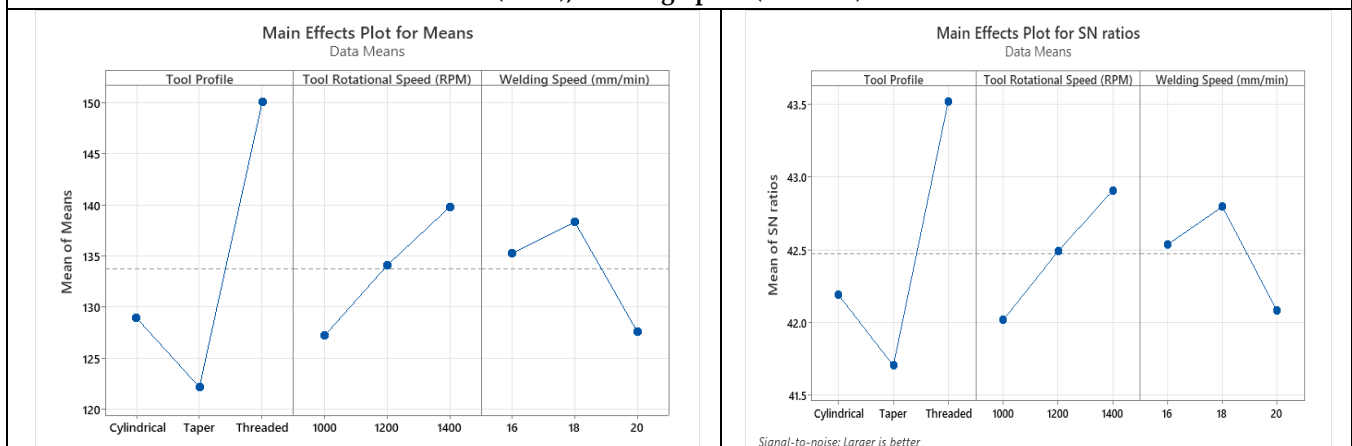


Figure 5. AA5454 and AA7075 Taguchi Analysis: Tensile Strength (MPa) versus Tool Profile, Tool Rotational Speed (RPM), Welding Speed (mm/min)





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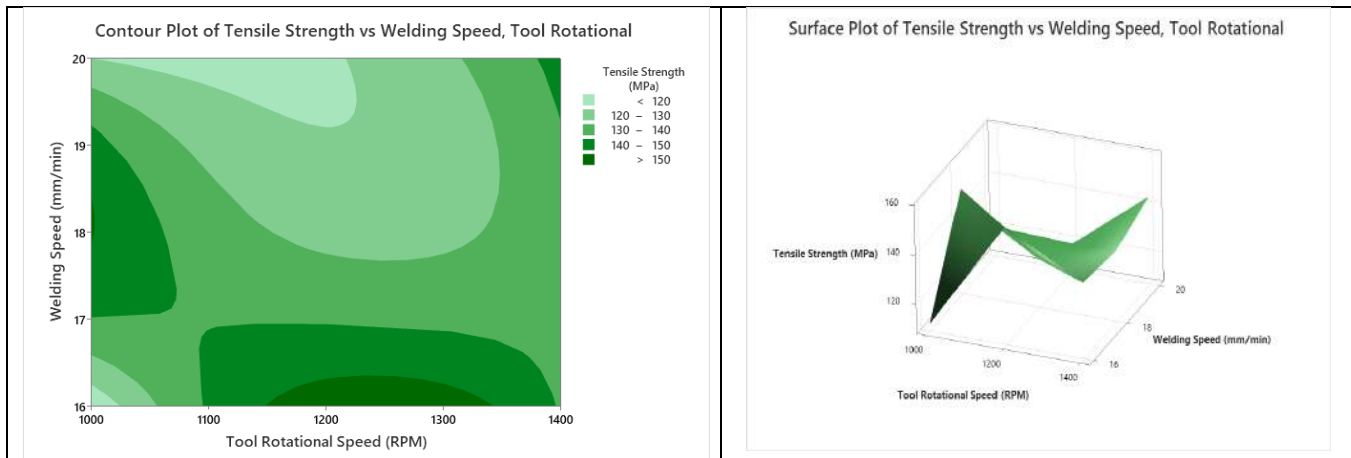


Figure 6. Aluminium 5451 Taguchi Analysis: Tensile Strength (MPa) versus Tool Profile, Tool Rotational Speed (RPM), Welding Speed (mm/min)

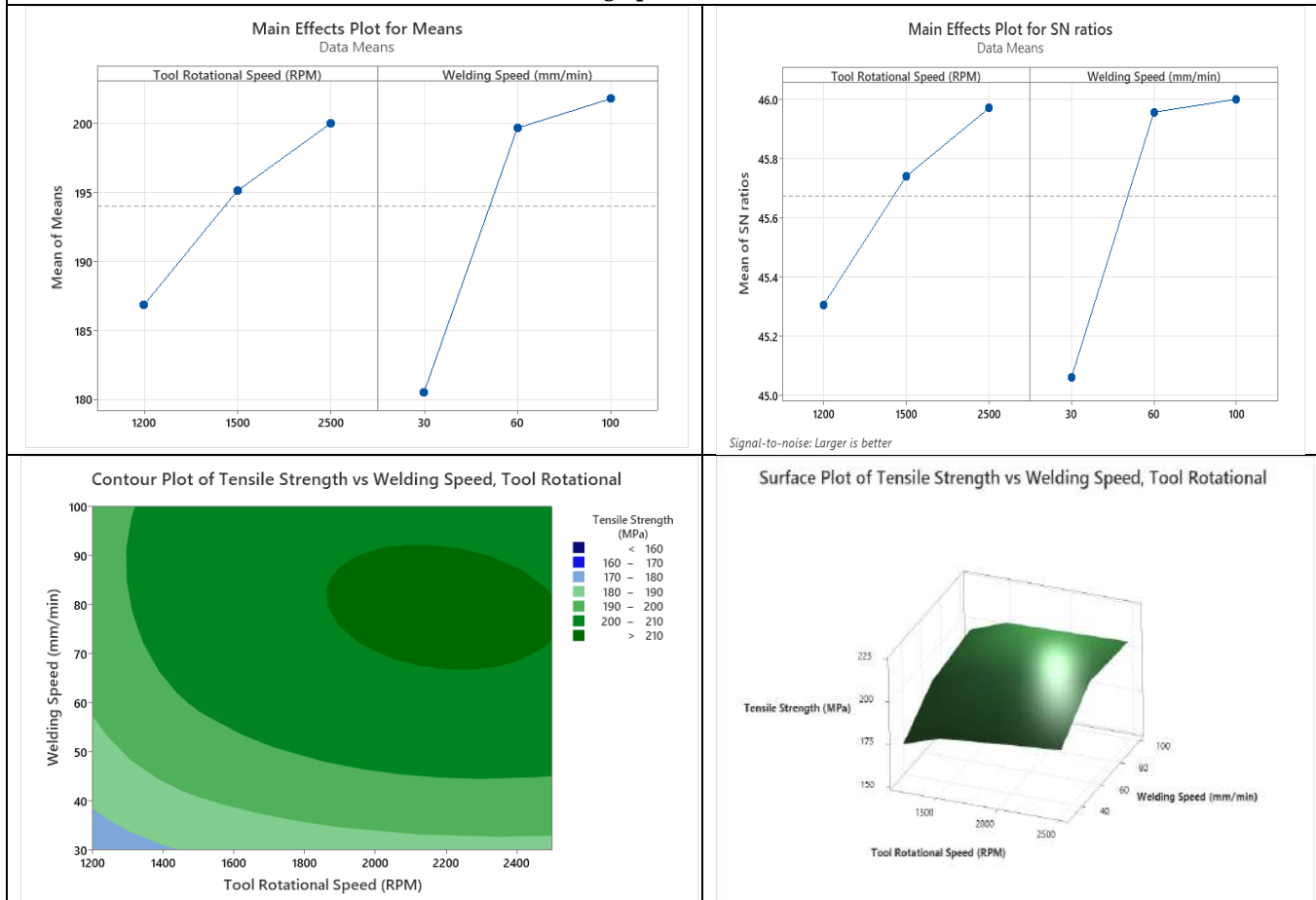


Figure 7. AA6082-T6 Taguchi Analysis: Tensile Strength (MPa) versus Tool Rotational Speed (RPM), Welding Speed (mm/min)





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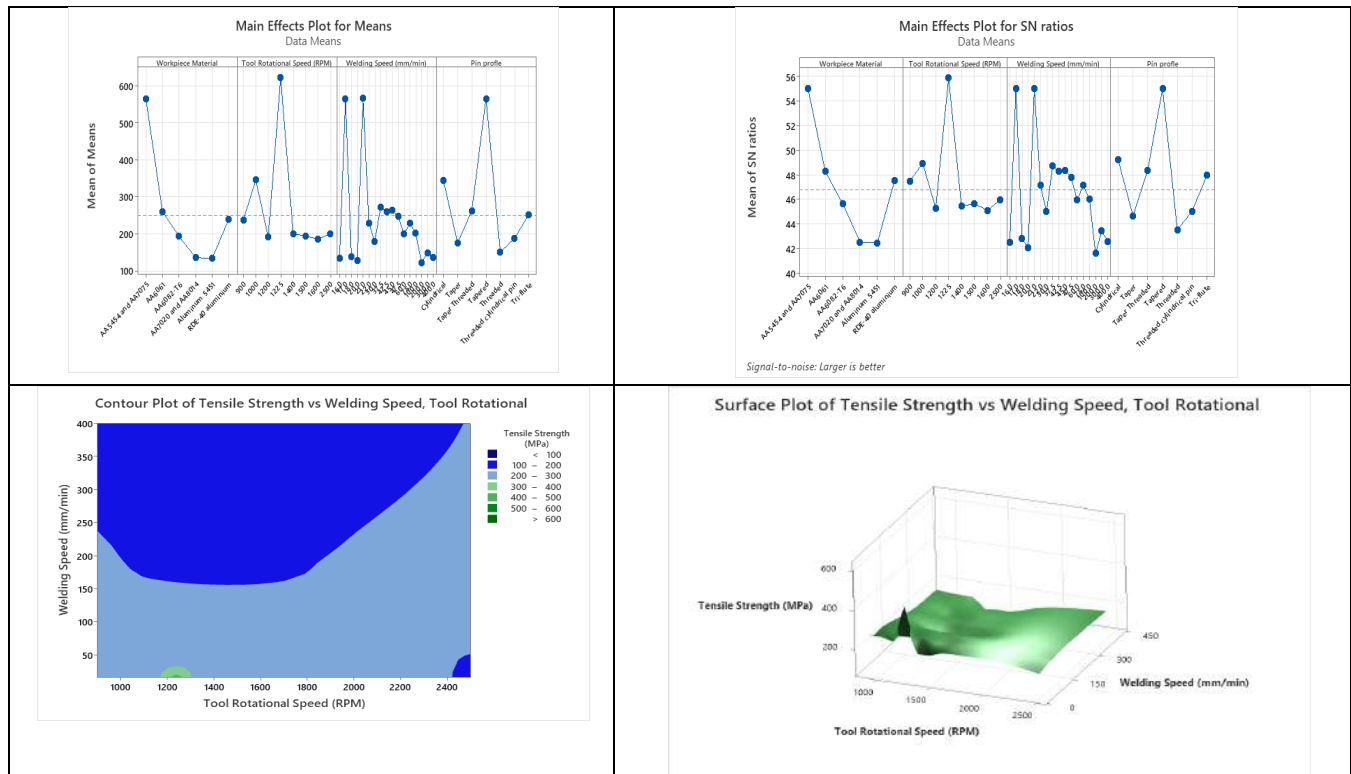


Figure 8. Taguchi Analysis: Tensile Strength (MPa) versus Workpiece Material, Tool Rotational Speed (RPM), Welding Speed (mm/min), Pin profile





RESEARCH ARTICLE

Assessment and Delineation of Groundwater Potential Zones in the Semi-Arid Region of Challakere, Chitradurga District using Geospatial Techniques and Analytic Hierarchy Process (AHP)

Vinay C^{1*}, Nagendra P², Samarth .URS .M¹, and B. V. Suresh Kumar³

¹Research Scholar, Department of Studies in Earth Science, University of Mysore, Mysuru, Karnataka, India.

²Guest Faculty, Department of Studies in Earth Science, University of Mysore, Mysuru, Karnataka, India.

³Professor, Department of Studies in Earth Science, University of Mysore, Mysuru, Karnataka, India.

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*Address for Correspondence

Vinay C

Research Scholar,

Department of Studies in Earth Science,

University of Mysore, Mysuru,

Karnataka, India.

E.Mail: geovinay95@gmail.com



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ABSTRACT

This research investigates groundwater availability in the water-stressed, semi-arid Challakere region of Chitradurga district. Recognizing the escalating need for water in such areas, the study aims to map and categorise zones with varying groundwater potential. It achieves this by combining geospatial analysis with the Analytic Hierarchy Process (AHP). Using spatial data layers representing factors like topography, land use, soil, and rainfall, the research pinpoints areas likely to hold significant groundwater resources. The AHP method further refines this understanding by assigning weighted importance to each factor influencing groundwater recharge. The resulting map of groundwater potential zones offers a practical tool for local officials and stakeholders to improve water resource management and planning.

Keywords: Remote Sensing, Groundwater Potential, Water Security, and Analytic Hierarchy Approach.

INTRODUCTION

Groundwater plays a pivotal role in sustaining livelihoods, agriculture, and industrial activities, especially in semi-arid regions where surface water sources are limited, seasonal, and unreliable. The increasing dependency on groundwater in such terrains has led to significant depletion, necessitating scientific approaches for its sustainable assessment and management. In hard rock regions like Challakere Taluk of Chitradurga district, Karnataka, the



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occurrence and movement of groundwater are highly heterogeneous due to the intricate subsurface lithology, structural controls, and low porosity of the geological formations. As a result, traditional exploration methods often yield suboptimal results. Current advancements in geospatial technologies, particularly GIS and remote sensing, have enabled the integration of multidisciplinary datasets to assess groundwater potential with improved spatial accuracy. When coupled with decision-support models like the AHP, these tools offer a systematic, objective, and reproducible methodology for delineating GWPZ. The AHP approach facilitates pair wise comparison of influencing factors and assigns relative weights based on expert judgment and consistency measures. This study aims to delineate GWPZ in the semi-arid region of Challakere by integrating twelve key thematic layers: land use/land cover, lithology, soil type, slope, geomorphology, rainfall, groundwater level, drainage density, lineament density, topographic wetness index, terrain ruggedness index, and curvature. These factors were standardized, weighted through AHP, and subjected to weighted overlay analysis in a GIS environment. The resultant GWPZ map, classified into five categories from very poor to excellent, is further validated using well yield data and ROC analysis. The outcomes are expected to aid in informed groundwater development planning, especially in hard rock terrains facing hydrological stress.

Study Area

Challakere is a town located in the Chitradurga district of Karnataka, India. It is known for its significant agricultural activities and is surrounded by a diverse landscape that includes rocky terrains and flat plains. This area is characterised by a semi-arid climate, contributing to its unique hydrological and geomorphological features. The study area of Challakere is marked by its complex drainage patterns, which can be influenced by factors such as geological composition, vegetation cover, and climatic conditions. With a primary focus on drainage density, it is observed that the terrain exhibits a low drainage density, indicative of poor surface drainage and limited stream development. The lithology in the area predominantly consists of hard rock formations, which affect the runoff characteristics. Additionally, vegetation cover is likely sparse due to the semi-arid conditions, and rainfall patterns are relatively low, which further contributes to the landscape's hydrology. The transition from gentle slopes to flat plains in Challakere also plays a crucial role in determining the flow patterns of water and the overall drainage network density. Understanding these aspects is vital for managing water resources and planning for sustainable development in the region. Locationmap of the study area (Figure 1).

METHODOLOGY

Using geomatic techniques, we mapped groundwater potential zones in the Vedavathi River basin (Challakere taluk). Our analysis integrated ten key information layers: geology, geomorphology, land use, land cover, drainage density, lineaments, rainfall, soil characteristics, slope, and curvature. Remote sensing data was pre-processed with image processing and GIS methodologies (ArcGIS 10.3). Basin boundaries were delineated using 30-meter SRTM data and the ArcGIS hydrology tool. We created LULC and geomorphological maps through visual interpretation of 24-meter IRS LISS-III satellite data within a GIS environment, using thematic layers from the NRSC as a guide. Digitized geological and soil maps from the GSI and National Bureau of Soil Survey provided geological and soil information. Slope, curvature, and roughness were derived from SRTM data. Spatial rainfall distribution was generated from Indian Meteorological Department data using IDW interpolation. Automated extraction techniques identified drainage and lineaments from SRTM and IRS LISS-III data, and their densities were calculated using the GIS spatial analyst's line density function. Data Table (Table 1). Methodology (Figure 2).

RESULTS AND DISCUSSION

Thematic Layers of Challakere Taluk

Drainage Density

Drainage density (Dd) serves as a key geomorphological indicator reflecting the degree of dissection within a watershed and is primarily influenced by lithology, vegetation cover, topography, and climatic conditions. Typically,



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low Ddsignifies poor surface drainage and is commonly associated with impervious subsurface materials, sparse vegetation, and rugged or undulating terrain. According to Strahler, such conditions lead to the development of a coarse drainage texture, in contrast to high Dd, which results in a finer drainage pattern. In the present study area, the calculated Dd is 0.39 km (Fig. 6), indicating a relatively low density of the drainage network. This low value suggests a predominantly hardrock terrain with minimal structural deformation, limited vegetation cover, low rainfall, and a landscape transitioning from gentle slopes to flat plains, all of which contribute to reduced surface runoff and limited stream development. Drainage Density map of Challakere (Figure 3).

Land Use and Land Cover

Most of the area is used for agriculture, followed by rangeland, with limited areas covered by vegetation, built areas, and shrubs. These factors play a crucial role in groundwater recharge.

Earth Surface Use and CoverMap of Challakere (Figure 4).

Geology Map

Geological context plays a significant role in the occurrence and distribution of groundwater. High permeability and porosity in geological units improve groundwater storage and yield. The area primarily consists of granite and gneiss rocks (Fig. 3). The infiltration rate is low due to the area's geology, as most of it is covered by relatively young, less weathered subsurface rocks. Geology Map of Challakere (Figure 5).

Soil Map

Challakere Taluk in Chitradurga district has red, black, and mixed soils. Red soil, rich in iron but low in fertility, is typical in many areas. Black soil, known for its moisture retention, is suitable for crops like cotton and jowar. Some areas also have mixed sandy and loamy soils supporting crops like groundnuts and millets. Due to the semi-arid climate, soil fertility and water retention are important factors for agriculture in the region. Soil map of Challakere (Figure 6).

Rainfall Maps

Soil map of Challakere (Figure 7). There are noticeable differences in rainfall between the two seasons in Challakere Taluk in the Chitradurga district of Karnataka. During the pre-monsoon season, the area receives about 55 mm of rainfall from March to May, which accounts for about 12.6% of the yearly total. Rainfall peaks at 39 mm in May after progressively increasing from 6 mm in March to 20 mm in April. On the other hand, because of retreating monsoons and cyclonic activity, a more significant proportion of rainfall occurs during the post-monsoon season. These variances are essential to the region's agricultural practices, groundwater recharge, and water resource management.

Elevation and Slope Map of Challakere.

Challakere has an average elevation of 585 meters (1,919 feet) above mean sea level. The elevation ranges from a minimum of 559 meters (1,834 feet) to a maximum of 616 meters (2,011 feet), resulting in comparatively level topography. This slight change in elevation impacts regional agricultural techniques and contributes to the area's semi-arid climate. The area's slope is also the least, varying from generally gently sloping to steep. Elevation and Slope map of Challakere (Figure 8).

Assessment of groundwater potential zones

GWP maps serve as valuable tools for identifying zones within a region that are more suitable for groundwater development. In this study, twelve influential factors were analysed using a GIS-based AHP to delineate GWPZ. The selected parameters included land use/land cover, soil type, lithology, slope, geomorphology, lineament density, drainage density, groundwater level, rainfall, topographic wetness index, and terrain ruggedness index. These factors were evaluated using a PCM, and their relative importance was incorporated through a weighted overlay analysis guided by the AHP framework. The resulting GWPZ map classified the region into five categories: excellent, good, moderate, poor, and very poor, with spatial extents of 11.72 km², 1455.56 km², 828.46 km², and 1.67 km², respectively. Areas identified as having excellent groundwater potential are typically associated with gentle terrain,



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loamy soils, and plantation-covered land, all of which support high infiltration rates. These zones also receive substantial rainfall and exhibit low runoff, high lineament density, and low drainage density, indicating a favorable hydrological setup with well-connected aquifers near surface water sources. Regions with moderate groundwater potential tend to have average slopes and moderately vegetated land, resulting in more surface runoff and less infiltration compared to areas with higher potential. These regions often have medium lineament density, rocky outcrops, and ridge features, highlighting the need for a balanced approach to water resource planning that considers both surface and groundwater resources. In contrast, zones classified as poor and very poor in groundwater potential are characterised by steep slopes, thin soils, and urban development, all of which contribute to high surface runoff and limited infiltration. These areas typically exhibit low lineament density, high drainage density, and minimal recharge, and are often located far from surface water bodies, factors that collectively restrict groundwater availability and recharge capacity.

Area of GWPZ (Table 2).

Groundwater potential zone map of Challakere (Figure 9).

Percentage Area of GWPZ of Challakere (Figure 10).

Ground Truth Verification of GWPZ Map

The good inventory of the study area also shows its potential. From the data, we can easily understand that most of the places are in the "Fair" category. We have carried out a well inventory of nearly 200 bore wells in the taluk, and five wells in each Panchayat. (Table 4). Graph yield vs Depth (Figure 11).

Validation of Model by ROC Curve

The GWPZ map developed using the AHP was validated for its predictive accuracy through ROC analysis, a recognised technique for model evaluation. This validation compared the GWPZ classifications with actual well yield data. The Receiver Operating Characteristic (ROC) curve illustrates the trade-off between the true positive rate and the false positive rate across a range of threshold values. The Area Under the Curve (AUC) quantifies the model's ability to distinguish between classes, with values approaching 1.0 indicating strong predictive performance and high classification accuracy. According to standard benchmarks, an AUC between 0.5 and 0.6 reflects poor performance, while values between 0.9 and 1.0 indicate excellent predictive strength. In this study, the AHP-based GWPZ map yielded an AUC of 0.75 (Fig. 12), signifying a 75% prediction accuracy and confirming that the AHP approach, while not flawless, is a reliable tool for delineating groundwater potential zones. Validation of Spatial Prediction Using ROC Curve Analysis (Figure 12).

CONCLUSION

Groundwater is a vital resource for human survival, providing drinking water to billions and supporting agriculture, industry, and ecosystems. It is my region's primary source of fresh water, especially where surface water is scarce. Unlike surface water, it is stored underground in aquifers, making it more resilient to droughts and contamination. In Karnataka, groundwater primarily exists under water table conditions and predominantly flows through fractures within the underlying hard rock. Geological characteristics, possible recharge regions, and groundwater flow patterns can all be mapped using geospatial techniques. A multi-criteria analysis based on AHP is conducted to determine the GWPZ of the Vedavathi basin, incorporating the eight most pertinent themes. These state-of-the-art technologies enable a comprehensive evaluation of groundwater resources, supporting informed decision-making and sustainable management practices. A thorough understanding of groundwater potential was achieved using ground data. The results demonstrated that the Vedavathi River watershed's groundwater resources have significant potential for sustainable development. The prominent factors controlling groundwater in the study area are overuse and infrequent rainfall. According to Table 2, most of the study area falls into the "Fair" category, covering approximately 1456 square kilometres, while the "Excellent" category encompasses a smaller area, at 1.67 square kilometres. Challakere Taluk is classified as "Fair," reflecting the state of the taluk's groundwater. From this study,





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we learned that, whereas Nayakanahatti and Taluku Hoblis show "Fair" and "Poor" groundwater potential, most areas around the Vedavathi River basin exhibit good and fair potential. Given the local geology and lack of precipitation, it is evident that the aquifer in the Taluku and Nayakanahatti Hobli is less suitable. Numerous Managed Aquifer Recharge (MAR) initiatives are being implemented in the study region through watershed programs, such as Atal Bhujal Yojana and REWARD (Rejuvenating Watersheds for Agricultural Resilience through Innovative Development). These projects aim to enhance agricultural sustainability, improve water availability, and recharge groundwater. They encompass interventions like check dams, percolation tanks, agricultural ponds, and recharge wells to foster water conservation and effective long-term groundwater management. Research findings have a significant impact on the strategic and effective use of groundwater resources, especially for agricultural and urban uses. The results give policymakers and planners vital information on how to prioritise, conserve, and use groundwater resources sustainably, particularly in the low and moderate GWPZ of the Vedavathi Catchment. This is crucial for supporting drinking water, agribusiness, and industrial needs to meet the 2030 SDGs.

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Table 1: Data Table

Dataset	Spatial resolution	Acquisition date	Source
LULC	10x10 m	21 January 2023	Bhuvan
Lithology	-	-	Bhukosh
Geomorphology	-	-	Bhuvan
Soil	-	-	Bhuvan
Lineaments density	30 m	-	Bhuvan
Rainfall map	GP Wise Data	-	KSNDMC and
Slope	30 m	-	Bhuvan
Well Inventory	-	-	From Field Work

Table 2: Area of GWPZ.

Sl.No	GWPZ	Area(Sq Km)
01	Poor	11.72
02	Fair	1455.56
03	Good	828.46
04	Excellent	1.67



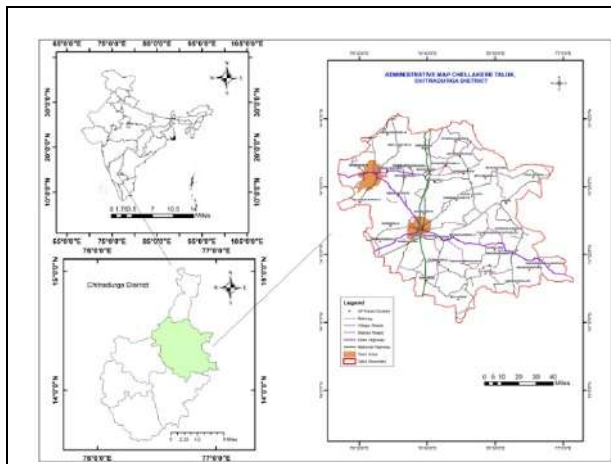


Figure 1: Locationmap of the study area.

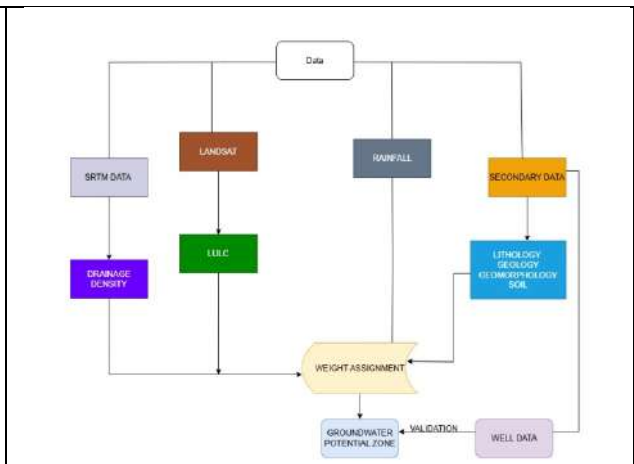


Figure 2: Methodology.

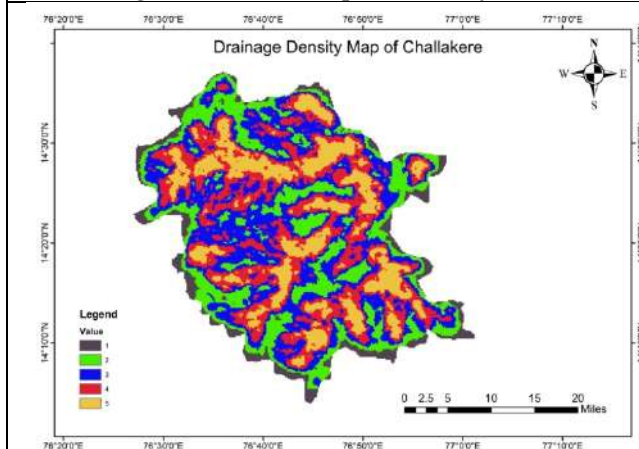


Figure 3: Drainage Density map of Challakere.

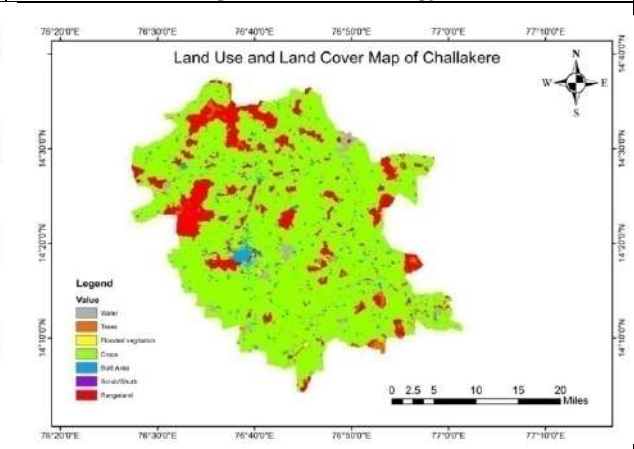


Figure 4: Earth Surface Use and CoverMap of Challakere.





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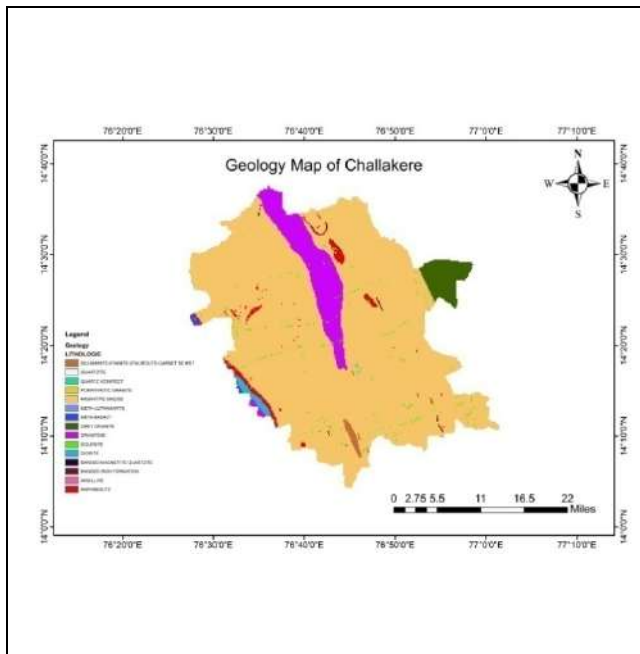


Figure5: Geology Map of Challakere

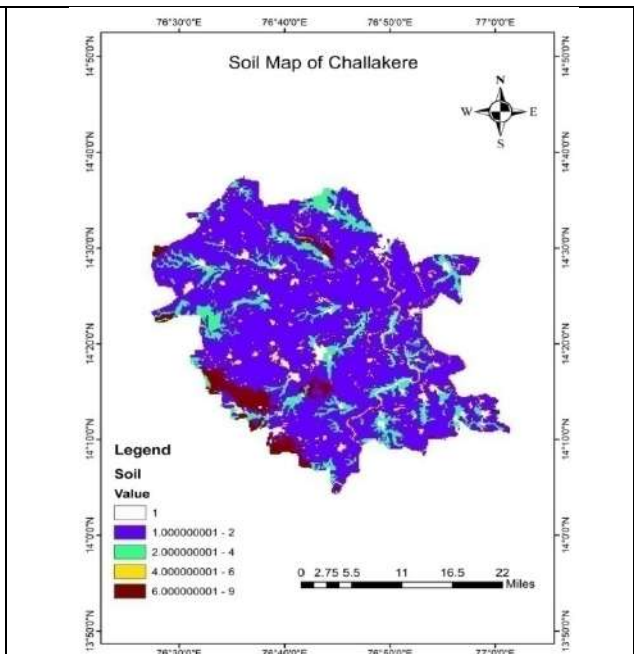


Figure 6: Soil map of Challakere

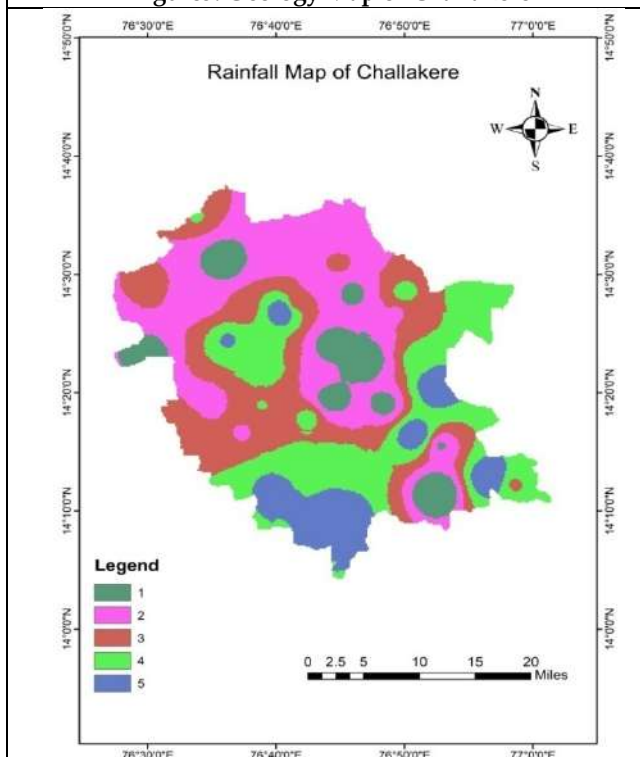


Figure 7: Soil map of Challakere

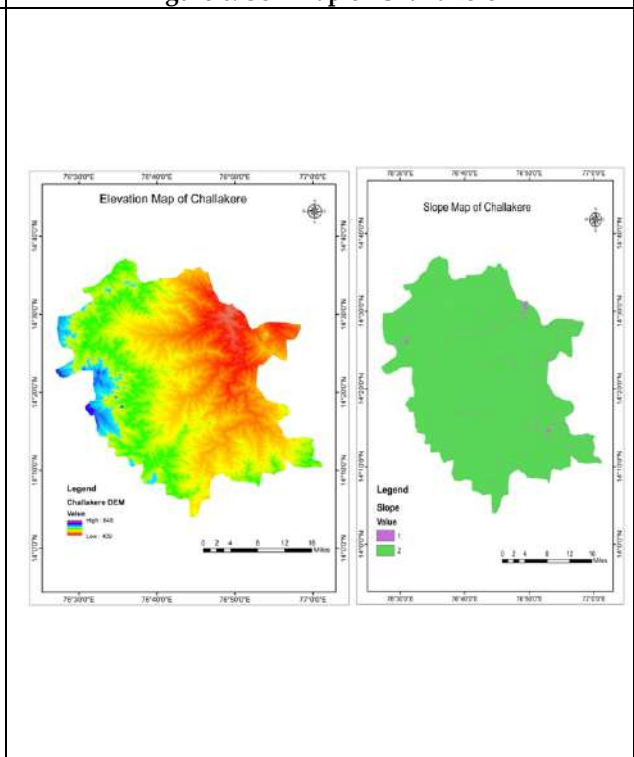


Figure 8: Elevation and Slope map of Challakere





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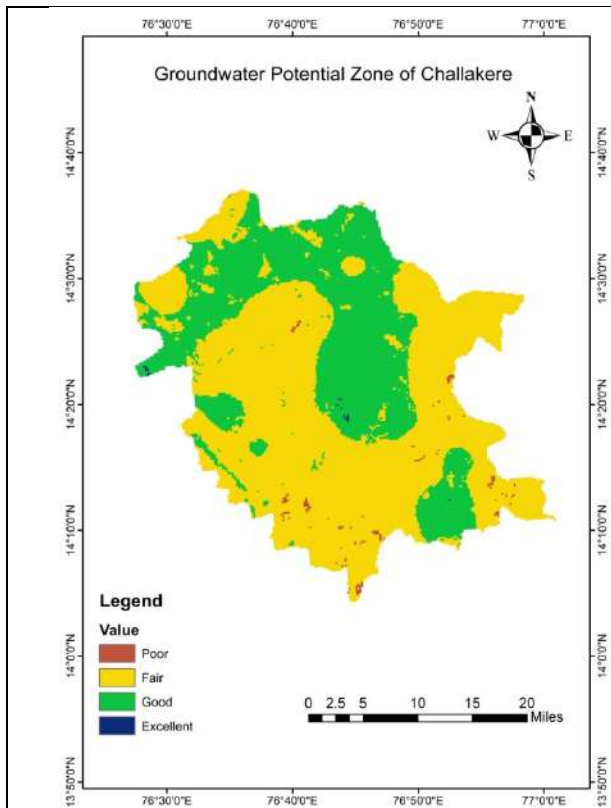


Figure 9: Groundwater potential zone map of Challakere

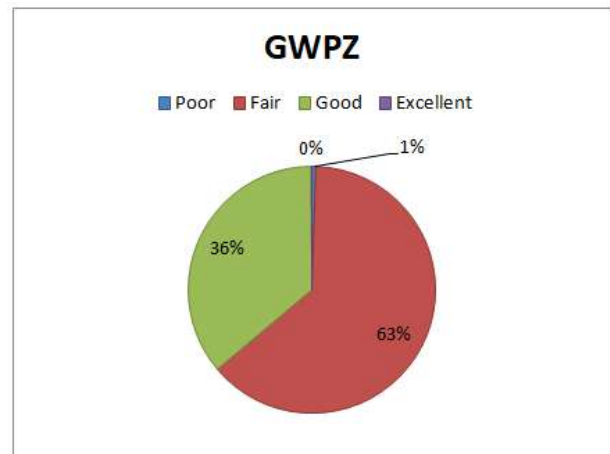


Figure 10: Percentage Area of GWPZ of Challakere.

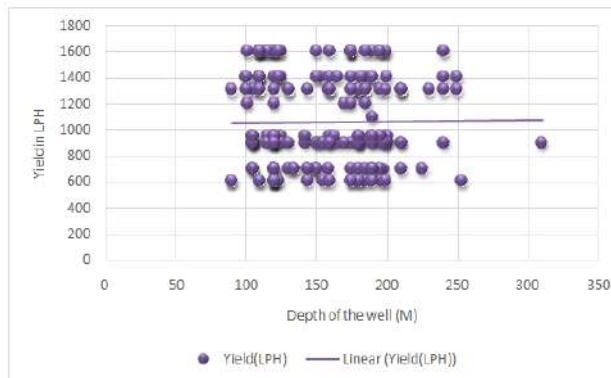


Figure 11: Graph yield vs Depth.

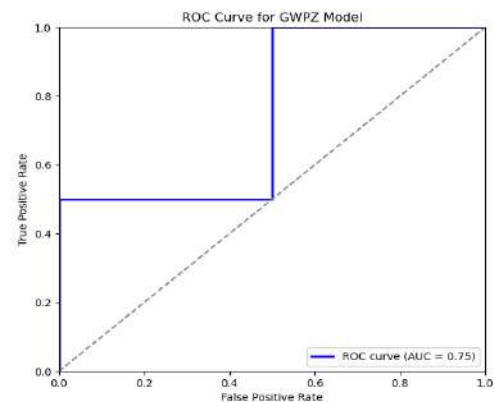


Figure 12: Validation of Spatial Prediction Using ROC Curve Analysis





RESEARCH ARTICLE

Efficacy of Methanolic Extract of *Muntingia calabura* L. Stem Bark on Improving Liver Functions Against Paracetamol Induced Hepatic Damage

Mohanavamsi Yemineni^{1*}, Venkata Ramana Kancharlapalli² and N Subrahmanyaswari P³

¹Assistant Professor, Department of Pharmaceutical Chemistry, A.S.N Pharmacy College, Tenali, (Affiliated to Acharya Nagarjuna University), Andhra Pradesh, India.

²Professor and Principal, Department of Pharmaceutical Chemistry, A.S.N Pharmacy College, Tenali, (Affiliated to Acharya Nagarjuna University), Andhra Pradesh, India.

³Assistant Professor, Department of Pharmacology, Vignan Pharmacy College, Vadlamudi, Guntur, (Affiliated to Jawaharlal Nehru Technological University, Kakinada), Andhra Pradesh, India.

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*Address for Correspondence

Mohanavamsi Yemineni

Assistant Professor,

Department of Pharmaceutical Chemistry,

A.S.N Pharmacy College, Tenali,

(Affiliated to Acharya Nagarjuna University),

Andhra Pradesh, India.

E.Mail: vamsiyemineni@gmail.com



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ABSTRACT

Medicinal plants have long served as foundational resources in the treatment of various human illnesses. The current study was undertaken to assess the preclinical pharmacological properties and hepatoprotective efficacy of methanolic extracts obtained from the stem bark of *Muntingia calabura* L. Wistar albino rats (n = 6 per group) were utilized for both acute and sub-acute toxicity evaluations. In the acute toxicity study, the control group received a vehicle (2 ml/kg, p.o.), while treatment groups were administered increasing oral doses (100–2000 mg/kg) of the extract. For the sub-acute toxicity study, the control group was given 3 ml/kg of vehicle daily, and the test group received 500 mg/kg of the methanolic extract orally for 14 days. For hepatoprotective assessment, rats received either 50 mg/kg or 100 mg/kg of the methanolic extract daily for 30 days. On the 30th day, paracetamol (2 g/kg, s.c.) was administered 4–5 hours following the final dose to induce liver damage. Paracetamol toxicity was fully induced by the 30th day. The animals were then evaluated 24 hours post-treatment for changes in liver function biomarkers, lipid and protein profiles, and hepatic histology. Statistical analysis was performed using one-way ANOVA followed by Tukey–Kramer's post hoc test. Among the tested doses, the 100 mg/kg group showed the most significant hepatoprotective effect, demonstrating a highly significant reduction ($P < 0.001$) in serum liver enzyme levels and a marked reduction in hepatic necrosis compared to the paracetamol-only group, indicating substantial liver protection.

Keywords: Acute toxicity, Sub-acute toxicity, Hepato protective, Paracetamol, silymarin



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INTRODUCTION

Liver Diseases and the Significance of Traditional Medicine

According to recent data from the World Health Organization (WHO), liver-related illnesses claim approximately 18,000 lives annually. The liver was anatomically enumerated to be one of the body's big, largest and most vital organs, which plays a pivotal role in metabolic and excretory functions[1]. It is essential for regulating internal balance (homeostasis) and is involved in various biochemical processes related to growth, energy production, immune defense, reproduction, and nutrient storage.

Ayurvedic Approach and the Use of Medicinal Plants

India has a long-standing tradition of using natural remedies, including herbs, spices, and medicinal plants, many of which fall under the practice of Ayurveda. Ayurveda, tend to translate itself as to “science of life” from Sanskrit, it is considered as one of the oldest comprehension of healing systems of the world. Originating over 5,000 years ago, this system focuses on promoting longevity and well-being by harmonizing the mind, body, and spirit. The foundational concepts of Ayurveda are documented in ancient Indian scriptures, particularly the *Atharvaveda*, which outlines the use of plants and natural therapies for healing.

MATERIALS AND METHODS

Collection of Plant Material

The bark of *Muntingia calabura* which was used in this protocol of study was collected from the basic coastal regions or areas of the Guntur district, Andhra Pradesh, India. The actual plant material was authenticated from the Department of Botany, Acharya Nagarjuna University, Guntur. The bark was alligned to be cut into smaller pieces and was shade-dried[2].

Preparation of the Methanolic Extract

The coarse powder was then packed into an Soxhlet apparatus and was extracted with 2000 mL of methanol over about the period of 10 days. The extract obtained was finally concentrated with the help of an evaporator which is namely called to be as an rotary flash evaporator and was further subsequently tend to be dried by the help of desiccator until used for further use.

Experimental Animals

Swiss albino mice (19–25 g) of male/female (either) sex were meant to be used for acute toxicity study, whilst the adult Wistar albino rats (70–220 g) of any sex were generally used for certain studies[3]. All the experimental protocols were initially approved by the Institutional Animal Ethics Committee (Approval No: 13/02/B/CPCSEA).

Toxicological Evaluation of Methanolic Extract of *Muntingia calabura* Bark

Acute Toxicity Study (LD₅₀ Determination)

The acute toxicity study was actually conducted on the Wistar albino rats (110–260 g, n = 6). The control group initially is received saline (2 mL/kg, p.o.), while the remaining test groups were originally administered with the increasing doses of the prepared methanolic extract of various doses like (100, 200, 300, 600, 800, 1000, and 2000 mg/kg, p.o.).

Sub-Acute Toxicity Study

Wistar albino rats (125–150 g) were divided into two groups (n = 6 per group)

Group I (Control): Received the distilled water as vehicle (2-3 mL/kg, p.o.)

Group II (Test Group): Received methanolic extract of *M. calabura* bark (500 mg/kg, p.o.)

The extract was actually administered once every day for next 14 consecutive days [Ganapaty *et al.*, 2002; Oduola *et al.*, 2007]. On the 15th day, the animals were completely anesthetized with general anaesthetic namely ketamine (10



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mg/kg, i.v.), (Dissociative Anaesthetic) and the blood was collected via or by cardiac puncture (6-8 mL per animal): 2-4 mL into K₂EDTA tubes for the basic hematological analysis and 2-4 mL into the lithium containing heparin tubes for the observation of biochemical analysis.

Selection and Preparation of Doses for Pharmacological Studies

Wistar albino rats (150–200 g) of any sex were randomly selected and divided into five groups (n = 6 per group). Then the methanolic extracts were evaluated at the two basic dose levels: 50 mg/kg and 100 mg/kg body weight.

Paracetamol-Induced Hepatoprotective Activity

The hepatoprotective potentiality of the methanolic extract was actually assessed using a paracetamol-induced liver injury model [4]. The taken animals were collaboratively or eventually divided further into the defined following groups:

Experimental Procedure**Animal Grouping and Treatment**

Adults the Wistar albino rats of any sex, weighing 180–220 g, were allocated randomly which were divided into the basic five groups (n = 6 each or per group)

Group I (the Normal Control): Which was received with saline (1 mL/kg, p.o.) daily for period of 30 days.

Group II (the Toxic Control): which was received with one dose of induced paracetamol (1-2 g/kg, s.c.) on 30th day.

Group III (the Standard Control): Which is initially Pre-treated with the standard drug silymarin (10-15mg/kg, p.o.) for next seven consecutive days and on day 30, the induced paracetamol (2 g/kg, s.c.) was observed to be administered.

Group IV (the Low Dose Test): Which is primarily Pre-treated with basic methanolic extract of *Muntingia calabura* targeted bark (50 mg/kg, p.o.) everyday for 28 days and on day 30, paracetamol (2 g/kg, s.c.) was preferred to be administered for 4–5 hours after the last dose.

Group V (the High Dose Test): Which is actually pre-treated with basic methanolic extract of *M. calabura* targeted bark (100 mg/kg, p.o.) per/day of about 28 days; on day of 30, paracetamol (2 g/kg, s.c.) was preferred to be administered.

Liver Sample Collection, Identification and Analysis

After the blood collection, the animals were allowed to be separated; sacrificed by slight increase in the dose of chloroform. Livers were properly allowed to be dissected and excised for analyzing the following ideal parameters were Wet Liver Volume; Wet Liver Weight; Histopathology; Liver Homogenate Preparation.

Histopathological Studies: Tissue Processing, Embedding and Sectioning followed by Staining was done.

Toxicity Studies**Acute Toxicity Study**

The extracted methanolic extract of *Muntingia calabura* bark was given administered orally to the mice at basic doses ranging from 150 to 2000 mg/kg. Observations included sedation, purgation, and analgesia at all doses, but no mortality occurred during the 14-day observation period. This analyzes to indicate the extract was preferably non-toxic to 2000 mg/kg.

Sub-Acute Toxicity Study**Experimental Design**

Wistar albino rats (125–150 g) were arranged to be divided into 2 groups (n = 6 per group)

Group I: Control which (received vehicle only, 3 mL/kg, p.o.)

Group II: Which is treated with methanol extract of *M. calabura* (500 mg/kg, p.o.)

The extract was administered once daily for 14 consecutive days. On day 15, rats were anesthetized with ketamine (10 mg/kg, i.v.) and 6 mL of blood was collected via cardiac puncture. Animals were euthanized by cervical



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dislocation. Hematological, biochemical, and histopathological assessments were conducted using standard protocols [Dacie JV *et al.*, 2001; Norbert WT, 1986; Ji Su Kim *et al.*, 2006].

RESULTS

Investigation of haematological parameters

Certain Haematological parameters like total or basic count (TC) of WBC and RBC, platelet count differential count (DC), and estimation of Hb haemoglobin were observed and performed. For DC, TC and platelet count the original blood smears were prepared on typical glass slides which were followed by staining with reagent namely called as Leisman reagent.

Histopathological Investigation

Histopathology involves the microscopic examination of tissue samples obtained via biopsy or autopsy for the purpose of disease diagnosis[5]. The tissues were preserved in 10% formalin prepared in normal saline and processed as outlined below.

Preparation of Slides

To examine tissues microscopically, appropriate preparation is necessary. The process begins with **fixation**, followed by dehydration, clearing, embedding, sectioning, mounting, and staining.

Microscopic Findings

Liver

Multiple liver sections exhibited well-preserved lobular architecture. No signs of lobular hepatitis, bile stasis, granuloma formation, dysplasia, or malignancy were observed at the tested dose levels of the extract (Fig. 1a).

Kidney

Renal sections showed normal morphology of glomeruli, renal tubules, interstitial tissue, and blood vessels. There was no evidence of acute tubular necrosis, glomerulonephritis, or any glomerular abnormalities (Fig. 1b).

Pancreas

Pancreatic sections demonstrated intact and preserved glandular architecture. No histopathological abnormalities such as inflammation, granulomas, dysplasia, or neoplastic changes were noted (Fig. 1c).

Effect on Physical Parameters: Wet Liver Weight and Volume

Paracetamol administration significantly increased wet liver weight and liver volume, indicating hepatic swelling due to toxicity. Treatment with MEMC, which were especially at 200 mg/kg, classified to be demonstrated as a notable reduction in various parameters, relating to a restorative effect.

DISCUSSION

Histopathological Evaluation of Liver in Paracetamol-Induced Hepatotoxicity

Control Group (Normal)

Microscopic analysis of liver tissue from the control group revealed well-preserved hepatic lobular architecture. Hepatocytes appeared predominantly normal, with occasional mild nuclear polymorphism and visible nucleoli

Paracetamol-Exposed Group

Tissue sections demonstrated significant hepatic architectural distortion. Evidence of hemorrhage, necrosis, and both micro- and macrovesicular steatosis was found throughout the liver lobules.



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Sections showed localized disruption of liver architecture. Some hepatocytes in perivenular and midzonal regions exhibited fatty changes.

Methanolic Extract (100 mg/kg) + Halothane Group

Partial disruption of hepatic tissue was observed. Select hepatocytes, particularly in perivenular and midzonal areas, showed necrosis and fat accumulation.

Methanolic Extract (200 mg/kg) + CCl₄ Group

Liver architecture appeared partially compromised, with noticeable fatty degeneration in perivenular and midzonal hepatocytes. Inflammatory infiltration, predominantly mononuclear, was observed in the same areas.

Plate 1: Liver Histopathology

(Histological images referenced here)

Evaluation of Hepatoprotective Properties

The liver is central to various metabolic functions and is frequently subjected to xenobiotic-induced injury. Halothane was employed in this study as a hepatotoxin due to its known hepatotoxic potential in both clinical and experimental contexts[6].

Mechanism of Paracetamol-Induced Hepatic Damage

Paracetamol is metabolized in the liver via cytochrome P450 enzymes to form the reactive metabolite trichloromethyl radical (CCl₃•), which reacts with oxygen to produce trichloromethyl peroxy radicals. These radicals deplete glutathione (GSH) and initiate lipid peroxidation, leading to extensive cellular damage and necrosis.

Physical Assessment Parameters**Liver Weight and Volume**

Toxic liver injury often results in increased hepatic mass and volume due to intracellular water retention and lipid accumulation. These physiological changes serve as reliable indicators of liver health. In this study, administration of the methanolic bark extract of *Muntingia calabura* significantly reduced liver weight and volume, supporting its hepatoprotective efficacy.

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**Table 1: Effect of the intake of methanol extracts of *Muntingia calabura* barks on some Important haematological parameters**

Hb (%)	13.21±0.65	13.10±0.92
RBC (Cells/mm ³)	701.99±13.48	651.43±9.97
Platelet (Cells/mm ³)	82,000.93±48.48	76,000.44±56.75
Neutrophils (%)	21.22± 5.11	14.61±1.53
Lymphocytes (%)	76.21±5.88	80.19±5.55
Eosinophils (%)	3.02± 0.29	4.06± 0.51
Monocytes (%)	1.90±0.23	2.18±0.20
Basophils (%)	0.00	0.00

Table 2: Biochemical parameters for the Liver function tests on rats for methanol extracts of *Muntingia calabura* barks at doses of 500 mg/kg, p.o.

Parameter	Control	Methanol extract of <i>M. calabura</i>
Total bilirubin (μmol/l)	5.83±1.98	12.86±1.25
Total protein (g/l)	68.76±4.66	71.42±5.86
Total cholesterol (mg/dL)	46.51±6.56	64.99±3.56
Triglyceride (mg/dL)	82.01±4.41	151.93±12.43
ALT (IU/l)	151.43±12.18	202.95±2.98
AST (IU/l)	267.91±10.85	300.02±13.01

Table 3: Wet Liver Weight and Volume in Halothane-Induced Hepatotoxic Rats^[7]

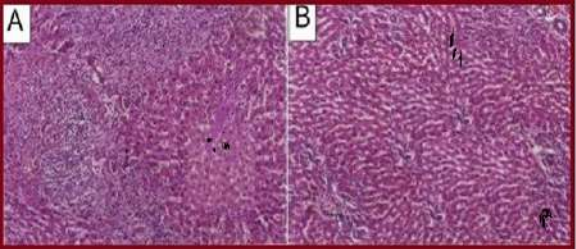
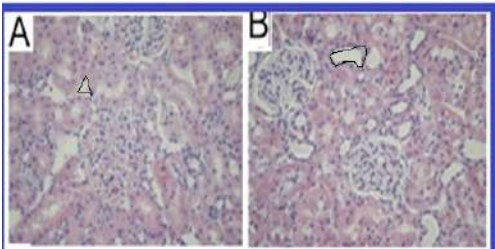
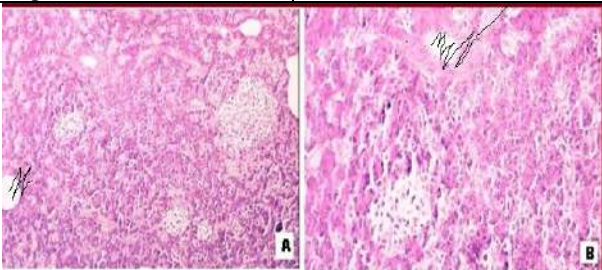
Group	Treatment	Dose	Liver Weight (g/100g)	Liver Volume (ml/100g)
A	Normal Control	10 ml/kg p.o	2.75 ± 0.475	2.85 ± 0.20
B	Toxic Control (Paracetamol)	600 mg/kg p.o	5.45 ± 0.25	4.5 ± 0.25
C	Standard (Silymarin)	100 mg/kg p.o	**3.25 ± 0.4	3.2 ± 0.25 **
D	MEMC	100 mg/kg p.o	4.25 ± 0.20 *	*3.865 ± 0.05
E	MEMC	200 mg/kg p.o	**3.75 ± 0.5	**3.40 ± 0.50

*p<0.001 (One-way ANOVA with Tukey-Kramer's post-hoc test)

**Fig.1 Stem****Fig. 2. Fruit with Flower**



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Fig 3.a: Histopathological image of rat's liver A: Histopathological image of rat liver of Control[8] B: Histopathological image showing rat liver of methanol extract of <i>Muntingia calabura</i> barks		Fig 3.b: Histopathological image of rat's kidney. A: Histopathological image of rat kidney of Control B: Histopathological image of rat kidney of methanol extract of <i>Muntingia calabura</i> barks.	
		Fig 3.c: Histopathological image of rat's pancreas. A: Histopathological image of rat pancreas of Control. B: Histopathological image of rat pancreas of methanol extract of <i>Muntingia calabura</i> barks.	





RESEARCH ARTICLE

Predicting Pattern among Drugs Prescribed to Patients of a Drug Store Using Association Rule Mining

Sujit Chakraborty¹, Niyasha Patra^{2*}, Pritha Chakraborty² and Suraj Sharma³

¹Assistant Professor, Department of CSE AIML, RCC Institute of Information Technology, Canal South Road, Kolkata, (Affiliated to Maulana Abul Kalam Azad University of Technology, Nadia), West Bengal, India.

²Assistant Professor, Department of Computational Sciences, Brainware University Ramkrishnapur Road, Barasat, Kolkata, West Bengal

³Assistant Professor, Department of Commerce, Adamas University, Jagannathpur, Kolkata, West Bengal, India.

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*Address for Correspondence

Niyasha Patra

Assistant Professor,

Department of Computational Sciences,

Brainware University Ramkrishnapur Road,

Barasat, Kolkata, West Bengal

E.Mail: niyasha.patra@gmail.com



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ABSTRACT

Currently, healthcare systems such as pharmacies and drugstores are known to generate substantial amounts of data. As a result, the application of data mining techniques in healthcare systems has now become a standard procedure. The present study involves the utilization of the Apriori algorithm for conducting data mining on data sourced from prescriptions issued at a pharmacy. Through the application of the Apriori algorithm, a total of ten Association Rules were derived based on the pharmaceutical drugs prescribed in these orders. Furthermore, the accuracy of these rules is meticulously examined and assessed by a medical professional. Within the identified Association Rules, it was found that Vitamin D and Calcium supplements exhibit the strongest correlation, whereas Omeprazole and Metronidazole are ranked second in terms of association. The outcomes of this investigation furnish valuable insights into the relationships between different medications which can lead a pharmacy to store their drugs accordingly and help to enhance their business.

Keywords: Data Mining, Association Rules, Apriori Algorithm, Prescription, Healthcare, Pharmaceutical.



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INTRODUCTION

The expansion of data growth across various sectors and the necessity for data analysis to derive valuable insights have presented researchers with a myriad of challenges. Mere data collection is insufficient to yield meaningful outcomes; hence, it is imperative to view data as a raw material that requires an analytical approach for information extraction. The manual or visual extraction of the outcome from the collected data source is arduous in absence of the assistance of computers or robust analytical tools [11]. Knowledge discovery in databases (KDD) serves as a comprehensive method for analyzing and extracting valuable information from databases through fully automated techniques [18]. KDD involves the procedure of uncovering valuable knowledge from a dataset, encompassing data preparation, cleansing, integration of prior knowledge, and explanation of detailed results built on pragmatic outcomes. Key usefulness of KDD includes marketing, telecommunications, and manufacturing. The notion of KDD has evolved to encompass 360 degree of knowledge discovery, with data mining representing a crucial phase where training algorithms are put to data. This evolution has extended to encompass the entirety of knowledge discovery stages, wherein data mining may refer to the complete process of strategy building by knowledge extraction [5 and 6]. Data mining has found diverse applications in healthcare systems, particularly in the realm of pharmaceutical data [13,14,16 and 21]. Medical data, distinguished by their uniqueness, demand heightened precision due to the sensitive nature of personal information in prescriptions, where minor errors can lead to significant ethical dilemmas [2]. Challenges have arisen with the increasing reliance on technology, notably Internet-based prescriptions, necessitating careful consideration of their implications to mitigate associated issues [4]. The World Health Organization has highlighted the inadequate fulfilment of prescriptions in developing nations. Additionally, misconceptions leading to incorrect or excessive drug usage are often rooted in individuals' beliefs that higher consumption equates to faster recovery or improved medical treatment [9]. This study endeavors to elucidate the interdependence of drug items in medical prescriptions dispensed at pharmacies [1]. To achieve this objective, access to a comprehensive and authentic database is essential. Regrettably, such a readily available database for researchers is currently unavailable in Iran, leading to the manual collection of drugstore information, a highly time-consuming endeavor. Within this article, the data mining strategy utilized in this study are elucidated in the initial phase. Subsequently, the application of this strategy rules on the dataset is described, and ultimately, the derived rules and outcomes are examined.

LITERATURE REVIEW

In recent years, numerous studies have depicted regarding purchase portfolio analysis, and novel approaches have been suggested for the efficient sale of pharmaceutical products in pharmacies [8]. Various methods have also been developed to determine the maximum profit achievable through sales discrepancies [3]. For instance, ChEMBL represents a vast repository of medical data that has been meticulously curated [20]. In order to extract valuable insights, hypotheses need to be validated within databases, followed by the identification of any existing errors [7]. The challenges that need to be addressed can be viewed as data mining problems, highlighting the significance of pattern recognition in this context [15 and 19]. While the majority of the aforementioned studies have focused on purchase portfolio analysis, Lv *et al.* introduced a specialized software system where user or patient symptoms served as input data. This system was capable of recommending medications based on the reported symptoms, and customers can participate in the initial evaluation of newly suggested drugs with volunteer assistance [12]. The Food and Drug Administration (FDA) in the United States has leveraged data mining techniques to incorporate information on drug side effects into its database. In this regard, the multi-item gamma poison shrinker (MGPS) method was utilized, enabling the early detection of drug side effects up to five years in advance compared to conventional approaches, achieving a success rate of 67% [17].





OBJECTIVE OF THE STUDY

The objective of the study carried out in this article is to develop and execute a system aimed at identifying the correlation among pharmaceuticals in a pharmacy. The identification of such relationships among the pharmaceuticals presents several benefits:

1. Facilitating the internal organization and proper arrangement of pharmaceuticals in pharmacies;
2. Taking into account potential discounts provided by insurance firms for pharmaceuticals within a specific group;
3. Preparing relevant pharmaceuticals to reduce or prevent instances of missing pharmaceutical prescriptions; as a large number of customers typically obtain pharmaceuticals from pharmacies where all the prescribed pharmaceuticals are in stock.

RESEARCH METHODOLOGY

Data

In order to identify the connections between various medications, a comprehensive database is essential for extracting the pertinent data. This database must encompass details such as the “Name”, “Classification”, “Code”, “Dosage”, and “Indications of Each Drug”. Specifically, the database utilized in this investigation comprises a total of 3444 drug entries. The compilation of this database involved the manual collection of prescriptions from a pharmacy, followed by the development of software code tailored for the input of these prescriptions into the database. Subsequently, the information within the database was standardized into a unified format to facilitate the utilization of data mining software in the research. Subsequent to this standardization, Association Rules were derived from the datasets, using Python 3.8, which integrates various data mining algorithms. Notably, the Apriori algorithm, recognized for its efficacy in identifying Association Rules, was employed in this study. A key advantage of this algorithm lies in its ability to streamline search complexities to a manageable level, rendering it particularly valuable for narrowing down the search space. A detailed working flow is designed if figure 1.

METHODOLOGY

Apriori Algorithm

Apriori algorithm represents one of the traditional methods utilized for the identification of Association Rules within a database or dataset. The discovery of the rules is predominantly grounded on the dealings and items present in the data source. Within this discourse, the term “item” denotes a cluster of interconnected data that embodies a particular concept, within which certain relations are anticipated to be identified. Notably, an item may consist of a single element containing a singular piece of data. A grouping of items arranged contiguously to form a functional unit alongside a record is termed a transaction. For instance, within a retail setting, a customer's purchase collection from the physical shop represents a transaction, with the items acquired in this buying compilation being categorized as its constituent elements. Every items encompasses one or more data components, which could encompass an item number, item identity or name, and item price for the goods available within the store.

The operational framework of this algorithm unfolds through the following dual phases

- The identification of conventional item sets.
- The formulation of Association Rules predicated on the identified sets; Within this algorithm, two fundamental suppositions are taken into account:
 - Very subset of an iterative item set is deemed iterative. For instance, if set {a, b, c} is considered iterative, then the set {a, b} is also categorized as iterative;
 - Conversely, every super set of a non-iterative item set is classified as non-iterative. For instance, if set {a, b} is presumed non-iterative, then set {a, b, c} is also classified as non-iterative.

The Apriori algorithm is responsible for generating a sequence of extensive item sets with a length of $K + 1$ derived from the chosen item sets with a length of K at each iteration, persisting until an item set with the maximal length is attained, provided that its support surpasses the stipulated threshold.





Support

Support can be defined as the likelihood of the coexistence of both the antecedent and consequent within a transaction. Within the context of this discourse, a transaction is synonymous with a prescription. Occasionally, the term "tuple" is employed in lieu of transaction. Essentially, the concept of "support" in a rule denotes the proportion of transactions that contain both sets V and W in relation to the total transactions present in set D.

$$\text{Support}(V \Rightarrow W) = \frac{(\text{Number of transactions containing both V and W})}{(\text{Total number of transactions})} \dots\dots\dots (1)$$

Confidence

Confidence indicates truth or accuracy of rule (2),

$$\text{Confidence}(V \Rightarrow W) = \frac{(\text{Number of transactions containing both V and W})}{\text{Number of transactions Containing V}} \dots\dots\dots (2)$$

Data Analysis and Findings

The input data utilized in this study underwent a transformation process into a textual format, subsequently serving as the primary input in Clementine. Retrieval of the data stored in the file was executed, followed by its transmission to a stream. Following the execution of our proposed Apriori algorithm, a total of ten rules were derived, presenting themselves as antecedent and subsequent entities. The illustration of the relationship between pharmaceutical substances is visually depicted in Figure 1. Within this visual representation, stronger connections are denoted by more prominent lines, while less important are represented by dashed lines. Table 1 illustrates the Association Rules acquired, followed by a comprehensive study of these rules.

Rules 1 and 2 demonstrate the relationship between Vitamin D3 and Calcium-D tablet. The analysis reveals that both Vitamin D and Calcium exhibit a high level of confidence and are positioned at the top of the table. These essential nutrients are identified as antecedent and subsequent elements in the rules. Calcium contributes significantly to bone and teeth strength, blood clotting, neural functions, and muscle activity. Similarly, Vitamin D plays a crucial role in enhancing bone density, regulating calcium levels in the body, and aiding in calcium absorption through the intestines. Consequently, these medications are commonly prescribed together due to the synergistic effect of Vitamin D on calcium absorption and regulation in the body.

Rules 3 and 10 dictate the following: (3) In the event that Omeprazole is administered, then Metronidazole should also be prescribed. (10) Conversely, if Metronidazole is administered, then Omeprazole should be prescribed as well. Metronidazole and Omeprazole are pharmaceutical agents commonly utilized in the management of gastrointestinal disorders. Metronidazole functions as an antibacterial agent, while Omeprazole exerts an antiulcerogenic effect. These medications are frequently co-prescribed for the treatment of digestive ulcers. Specifically, in cases where Metronidazole is indicated, there is a 28.6% likelihood that Omeprazole will be included in the treatment regimen.

Rule 4 in the event that Vitamin D3 is present, then Piroxicam G shall also be administered. Piroxicam gel is identified as an anti-inflammatory pharmaceutical agent that demonstrates significant efficacy in the mitigation of pain, muscular rigidity, and inflammation. Vitamin D plays a crucial role in enhancing bone strength, fortifying nerves, treating muscle contractions, cramps, and weaknesses. This particular rule stipulates that should a patient be prescribed with Vitamin D, Piroxicam gel shall also be recommended, with a confidence coefficient of 25%.

Rule 5 upon administration of Betamethasone, then theophylline G shall be concurrently prescribed. Then theophylline G is utilized for addressing bronchial spasms and is typically combined with Betamethasone, an antihistamine medication employed in the management of seasonal allergies, asthma, and bronchitis.

Rule 6 in cases where Amoxicillin is indicated, Metronidazole shall be prescribed accordingly. Amoxicillin is classified as an antibiotic within the penicillin group, utilized for the treatment of various contagions, especially those



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affecting the ear or lung. Metronidazole, also a sterile agent, is suggested as cure for the treatment of infections, thus making it a suitable companion to Amoxicillin.

Rule 7 should Aspirin (ASA) be administered, then Nitroglycerin shall also be included in the prescription. Aspirin (ASA) is commonly used for pain relief, reducing fever, and preventing blood clot formation. Nitroglycerine is a vasodilator medication belonging to the class of antianginal drugs. The combined prescription of these two medications leads to a reduction in high blood pressure and is employed in the management of heart diseases.

Rule 8 whenever Omeprazole is prescribed, Lactulose shall be included in the treatment regimen. Lactulose, categorized as a laxative, is often co-administered with Omeprazole due to its anti-ulcer properties that aid in the management of digestive disorders.

Rule 9 if the prescription includes Metronidazole, Clotrimazole shall also be recommended. Clotrimazole is recognized as an antifungal medication utilized in the treatment of yeast and fungal infections. This medicine is commonly suggested alongside metronidazole, known for its antibacterial properties in treating digestive ailments.

CONCLUSIONS

The primary aim of this study is to derive Association Rules among medications based on the patterns observed in prescriptions from a pharmaceutical establishment. The sequence of drugs in a prescription is not random but rather influenced by the patient's medical condition and symptoms, which allows for the identification of associations between co-prescribed drugs. A database containing prescription details and corresponding medications is compiled from transaction records of the pharmacy, followed by the development of a dedicated software program. Subsequently, the data is reformatted to align with the requirements of the python program for further analysis using the Apriori algorithm to uncover Association Rules. Notably, the analysis reveals a strong association between Vitamin D and Calcium, frequently co-prescribed in various instances. Additionally, Omeprazole and Metronidazole emerge as the second most commonly associated pair of drugs. The study delves into other identified Association Rules which are elaborated upon in the research manuscript. Proposals for future research include exploring alternative algorithms to extract Association Rules from the dataset. Furthermore, investigating additional dimensions of association among prescribed drugs is recommended for further inquiry. A key challenge highlighted in this study pertains to the arduous task of data collection, particularly due to the manual preservation of prescriptions by the involved pharmacy. The transition to digital prescription records is essential to facilitate data collection, suggesting the inclusion of pharmacies that utilize electronic prescription systems. Moreover, conducting comparative analyses among multiple pharmacies, especially those from diverse geographic locations, is advised to enhance the robustness of the findings. This approach is crucial as a single pharmacy's prescriptions may not yield a comprehensive understanding of drug associations.

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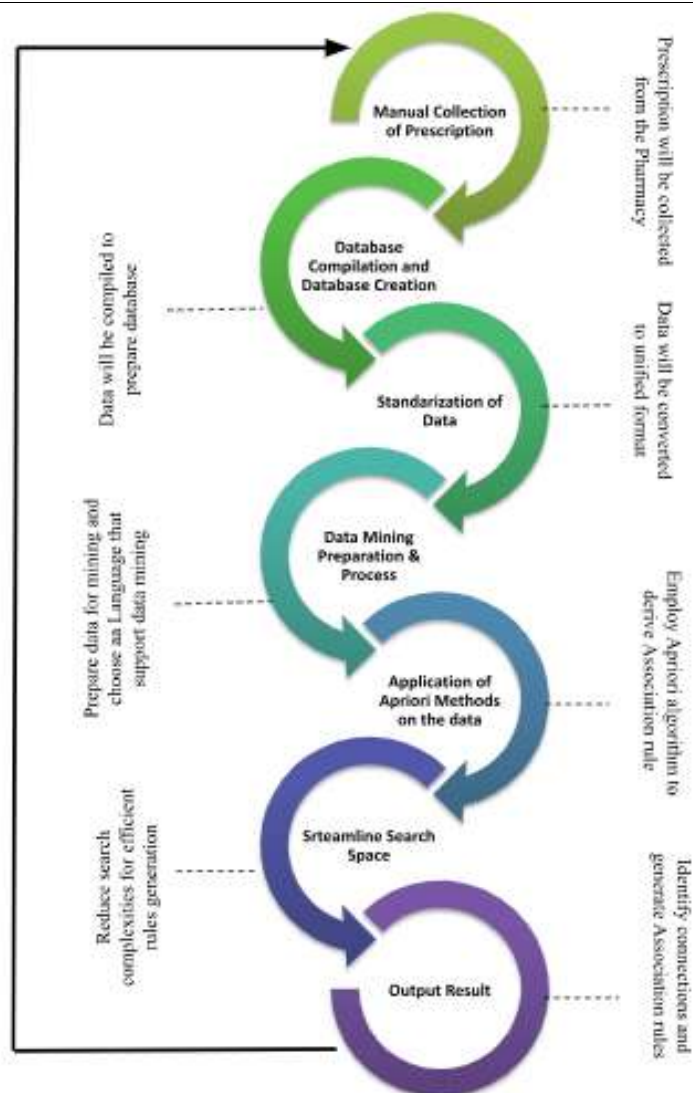
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Table 1. Results of Apriori algorithm.

SlNo.	Support	Confidence	Antecedent	Consequent
1	4.0	31.4	VitaminD3 (Colecalciferol)	Calcium-Dtablet
2	4.3	30.4	Calcium-Dtablet	VitaminD3 (Colecalciferol)
3	4.7	28.8	Omeprazole20mg cap	Metronidazole 250 mg tablet
4	4.0	25.0	VitaminD3 (Colecalciferol)	Piroxicam 0.5% gel
5	4.0	25.0	Betamethasone4mg/1ml amp	Theophylline120 g/ml syrup
6	4.0	25.0	Amoxicillin125mg/5ml 100 ml	Metronidazole 250 mg tablet
7	5.7	23.0	ASA100mgchewable tablet	Nitroglycerin sustained 2.6 mg tablet
8	4.7	21.0	Omeprazole20mgCap	Lactulose10 g/15mlsyrup
9	6.7	20.0	Metronidazole250mg tablet	Clotrimazole 100mg tablet
10	6.7	20.0	Metronidazole250mg tablet	Omeprazole20 mg cap

Source: Researcher's computations



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Source: Researcher's computations

Figure 1: Flow diagram of the Process





RESEARCH ARTICLE

Participation of Scheduled Caste Youth in Achieving SDG 4 and SDG 8: A Mixed – Method Analysis from North Uttar Pradesh

Amritansh Mishra^{1*}, Viksit Tripathi¹ and Subho Chattopadhyay²

¹Assistant Professor, Department of Management, Invertis University, Bareilly, Lucknow, Uttar Pradesh, India.

²Associate Professor, Department of Management, Invertis University, Bareilly, Lucknow, Uttar Pradesh, India.

³Professor, Department of Management, Pal College of Technology and Management, Haldwani, Udailapur, (Affiliated to Kumaun University, Nainital), Uttarakhand, India.

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*Address for Correspondence

Amritansh Mishra¹

Assistant Professor,

Department of Management,

Invertis University, Bareilly,

Lucknow, Uttar Pradesh, India.

E.Mail: amritansh.project@gmail.com



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ABSTRACT

The United Nations' Sustainable Development Goals (SDGs) were established in 2015 to address pressing global challenges such as poverty, education, gender equality, and climate change. India, with the world's youngest population, plays a critical role in achieving these goals by 2030. The government, through NITI Aayog, has implemented various policies and initiatives to empower youth, recognizing their potential as key stakeholders in sustainable development. However, challenges such as unemployment, illiteracy, and social discrimination hinder their active participation. The youth unemployment rate in India remains a pressing concern, particularly in rural areas. Despite 37.4 million young individuals pursuing higher education, the lack of practical skills and limited employment opportunities exacerbate the issue. Addressing these challenges requires a comprehensive approach that includes policy reforms, skill development, and equitable access to education and job opportunities. Strengthening youth participation in SDGs is crucial for India's socio-economic transformation and sustainable development.

Keywords: Sustainable Development Goals, youth empowerment, unemployment, education, skill development, India.



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INTRODUCTION

The United Nations' Sustainable Development Goals (SDGs), established in 2015, address critical issues such as poverty, education, gender equality, and climate change. The UN established 17 goals and 164 indicators to tackle existing global concerns and challenges, which will be accomplished by 2030. India is dedicated to these worldwide objectives to enhance its populace's social and economic welfare. The Sustainable Development Goals (SDGs) are a policy framework in India, executed through national policies, initiatives, and projects by the NITI Aayog. The nation can attain its objectives by collaborating and coordinating with all stakeholders. Young people must achieve the Sustainable Development Goals (SDGs) as critical stakeholders. According to the UN, youth are classified as aged 15 to 24. In India, youth are classified as individuals aged 15 to 29 years. According to the biological concept of youth, a person's social, physical, intellectual, and psychological capabilities continue to grow to their full potential from birth to maturity. Today's young people will be the pioneers, innovators, creators, and those who will think about the future. Youth are a powerful force for sustainable development and play a crucial role in economic advancement, social transformation, and technological innovation. However, due to insufficient funding, young people are often unable to reach their full potential in various domains, including but not limited to employment, education, athletics, and nutrition. With 371.4 million young people in India, the country has the second-most populous population in the world and the youngest population overall as of the year 2021. India has the opportunity to make the most of its young population, even as its economy is rapidly growing. It is crucial to make educational and employment opportunities accessible to all young people without discrimination, as these opportunities are necessary for attaining vital life essentials. All four goals, including Goal 4 and Goal 8, are centred on the same objective: ensuring everyone has an equal opportunity to find employment and receive an outstanding education. In terms of development, the children of a nation are the most valuable asset that it possesses. In terms of population, they constitute a sizeable fraction of the total. For this reason, young people who aspire to attend college and secure gainful work must participate actively in the Sustainable Development Goals (SDGs), realizing their significant role in achieving these goals. India possesses the youngest population among global nations, comprising 34.8%. Consequently, the government has implemented several laws and activities for youngsters who face discrimination and adversity.

The development of young individuals is impeded when they lack access to specific resources and opportunities. Moreover, young individuals hesitate to participate in government initiatives and programs due to insufficient understanding of their existence. Young people in India face significant challenges in meeting their fundamental needs and developmental requirements due to illiteracy and unemployment, the two primary impediments they encounter. There is a consensus that education is a significant determinant of individual and societal advancement. Article 21 A of the Constitution of India enshrines this article as a basic right. Caste, gender, and social status are but a few instances of the numerous forms of discrimination present within the societal framework. This imbalance has resulted in unequal access to education, healthcare, and work opportunities, all essential for human growth. The urgency of addressing these issues cannot be overstated, as the future of our nation depends on the development and empowerment of our youth. Moreover, the younger generation encounters significant challenges in securing employment in the current Indian labour market due to the complexity of the societal transformations they are undergoing. The youth unemployment rate in urban India was 25.5% during the April-June quarter of 2021, as reported by the quarterly labour force survey. The number indicates about 3% rise relative to the initial three months of 2021. The 2011 Census showed that rural regions constitute over two-thirds of India's total population, around 68.8%. In 2022, the rural unemployment rate increased to 8.3% from 6.62% in the preceding year. The unemployment rate among young individuals actively participating in the labour force is elevated in rural areas. In 2019, the labour force participation rate (LFPR) indicated that 38.1% of young Indians in rural regions were employed, in contrast to 38.7% in urban areas. Out of 371.4 million young individuals, 37.4 million are enrolled in higher education programs in Indian educational institutions. This is a significant amount. The unemployment rate among India's educated youth is 13%, which is concerning. However, it also underscores the potential of education to transform lives and open up opportunities. A significant segment of India's educated young is unemployed, attributable to multiple factors. Significant factors include disparities in resource availability, biases and cultural limitations concerning



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career trajectories, heightened competition from a large population, and insufficient skill development. Yet, with the right interventions and support, education and employment can be powerful tools for social and economic transformation, inspiring and motivating our youth to reach their full potential. Obtaining degrees without the integration of practical skills is insufficient for youth employment. Therefore, the federal government and the individual states need to prioritise the creation of educational and employment possibilities for youngsters. The complexity of issues and the necessity for related administrative decisions are two of the numerous consequences of a large population. The enduring economic and social disparities in India's delivery of fundamental services constitute a significant issue. These include, on a state-by-state basis, access to education, basic healthcare, essential utilities (such as clean water and sanitation), credit and financial services, and justice through public law enforcement organizations. Individuals from marginalized origins have heightened obstacles in educational and professional environments owing to the gendered, caste-based, and socioeconomic stratification that pervades Indian culture. This transpires as those in positions of authority acquire resources to the detriment of others who genuinely require them.

Social isolation in India: neglect of education and employment

In the Indian context, 'those with authority' denotes persons from the higher caste. Caste is a system of social stratification originating from Hinduism. The term 'scheduled caste' designates a group historically perceived as 'untouchables,' positioned at the lowest echelon of the Hindu social order. They are isolated from society and barred from participating in conventional social, economic, political, and cultural activities. The disadvantaged environment and institutional constraints significantly hinder social relationships. As a result, Scheduled Caste youth in India face multiple forms of discrimination that obstruct their capacity to fulfil basic demands since oppressive actions have violated their fundamental rights and necessities. The primary action taken by the Indian government to combat caste discrimination is the establishment of political reforms based on constitutional principles. As a result, programs and policies represent the 'rights' granted to the Supreme Court. Scheduled Castes people in India endure persistent social exclusion due to socioeconomic constraints that place them at the bottom of the social hierarchy. Due to their historical marginalization, SC youth who attain higher education nonetheless find themselves unemployed or working in informal or temporary jobs. Under Article 45 of the Indian Constitution, all children under fourteen must attend public school at no cost. With a particular emphasis on the interests of the Scheduled Classes, Article 46 requires promoting education for the economic and educational well-being of the Scheduled Castes. However, it might be challenging for young adults to get the scholarships and tuition waivers they qualify for. Because of this, they are less likely to enroll in college. People in India are socially and economically marginalized by the deeply established and widely accepted caste system. People from lower castes, especially Scheduled Castes, are not allowed to use public resources or assets according to this law. It is concerning that, despite education being a fundamental entitlement of all Indian residents, the Scheduled Caste youth have an alarmingly high illiteracy rate. Yet, social norms and practices continue to uphold this form of bias. Thus, the present system's actions immediately impact the SC community. Youth from marginalized communities, particularly those belonging to Scheduled Castes, face unique challenges when it comes to accessing resources. Educational scholarships, financial help, entrepreneurship skill development, employment reservations, and specialized courts for deciding cases of genocide and violence are all part of the government of India's efforts to broaden participation in economic prospects. Despite implementing affirmative action, such as scholarships, to enhance the educational standing of Scheduled Castes (SCs), Narwana *et al.* argue that inadequate administration and governmental procedures are to blame for the limited accessibility of these programs. The disconnect between the public and the efforts must be addressed to ensure that the policies and programs are effectively implemented. In 2009–10, almost 12% of India's young were illiterate, according to a five-year study on employment and unemployment conducted by the National Sample poll. India is home to 123 million illiterate youth, which is a disturbing one-third of the global total. This leads many to believe that young Indians suffer from severely low levels of literacy, occupational competence, and educational accomplishment. Of India's overall population, 16.6% are members of Scheduled Castes, while 8.6% are Scheduled Tribes. Action needs to be taken to address the persistent young unemployment challenge. Nearly all young workers in developing nations are estimated to be involved in the informal sector. The unemployment rate for SC teens (15–29 years old) fell from 20.6% in 2018 to 17.3% in 2019, which is still a significant rate. India has taken many steps towards achieving the Sustainable Development Goals (SDGs) via its programs, policies, and projects. Their active participation influences



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youth engagement with the SDGs in various programs and projects. Consequently, the study highlights the importance of education and work as pivotal elements in young people's formative years, fostering their intellectual and independent development. This is why the writers set out to conduct the research: to find out whether the policies and initiatives impact SC youngsters. Governmental activities and policies that advance Sustainable Development Goals 4 and 8, respectively, are less likely to involve youngsters from Scheduled Castes, who have limited involvement in education and employment. Youth participation in social development is vital, as they represent an integral segment of society. Various social, economic, political, and cultural obstacles hinder young Indians from participating in development efforts. In SC, young individuals are under-represented in government initiatives designed to support them owing to insufficient resources and limited opportunities for meaningful participation. Utilizing institutional mechanisms and inclusive methods, we can tackle the challenge of youth involvement in SC stemming from a deficiency in comprehension. The institutionalist perspective contends that national governments are legitimate bodies empowered to formulate and implement policies and programs for their citizens. The institutional architecture paradoxically lacks the foundation for properly executing plans and schemes, hindering their influence on the intended audience. The government must employ decentralized governance to address challenges impacting marginalized populations, notably the youth in SC. Figure 1 illustrates the conceptual framework for enhancing youth engagement in achieving the Sustainable Development Goals (SDGs). As a result, encouraging participation among SC youngsters requires the unambiguous role of state institutions. Youth from Scheduled Castes are influenced by several processes that impact their knowledge and participation in government programs. According to Emile Durkheim, society is a complex web of interrelated and mutually supportive parts. Cultural norms, he argued, are dictated by religious ideas, practices, and values. The socially accepted viewpoint of caste dictates that people advance in life based on their caste rather than their talents. This idea is deeply ingrained in the community's cultural and religious consciousness. People are marginalized and have limited access to resources because of the caste system, which is the dominant authority. Federal and state governments are taking measures to make it illegal to discriminate against people in this way. Scheduled Caste youth are less likely to engage in initiatives meant for them due to a lack of understanding of the schemes.

Statement of the Problem

Since youth are seen as crucial SDG change agents, Agenda 2030 emphasizes enhancing relationships between youth and other stakeholders. Fourth SDG goal (Quality Education) and eighth SDG goal (Decent Work and Economic Growth) among the seventeen Sustainable Development Goals are the most important for a country's societal and economic advancement. The 2011 Census revealed that 20.85% of people in Uttar Pradesh belong to the Scheduled Caste category. The SC participation rate in Uttar Pradesh is lower than the national average in some areas, even though the state and central governments have implemented numerous initiatives and programs to increase SC involvement. Because of the enormous obstacles posed by poverty and a lack of knowledge, this is typically the result. Similar problems exist across the country for SC youngsters, and Uttar Pradesh is no exception. To achieve the Sustainable Development Goals (SDGs), this study aims to identify the barriers that prevent youth from SC caste from participating in state- and center-sponsored programs and activities. The study used a mixed-methods strategy, combining quantitative and qualitative techniques. By employing this strategy, we can get comprehensive data regarding the socioeconomic status of SC youth, their familiarity with government initiatives, and their level of engagement in pursuing SDGs 4 and 8. The target population comprises SC youth (aged 15–29) from North Uttar Pradesh across two commissionaires, Meerut and Bareilly, in different districts. A stratified random sampling technique ensures representation from different geographical areas, and socio-economic backgrounds. The study will involve 128 respondents across the ten districts, as provided in the existing data. In-depth interviews were conducted with chosen participants to collect qualitative data regarding the possibilities and obstacles young people in SC face to get into college and find a job. Data was collected from the Meerut and Bareilly Commissionaires. Bareilly division consists of Bareilly, Badaun, Pilibhit and Shahjahanpur, and Meerut Commissionerate comprises Meerut, Bagpat, Bulandshahr, Ghaziabad, Gautambudh Nagar, and Hapur. This sample size is adequate for conducting statistical tests such as the Mann–Whitney U and Kruskal–Wallis H tests.





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MATERIALS AND METHODS

This study employed a descriptive research technique to delineate the current status of youth engagement in social change concerning Sustainable Development Goals 4 and 8. Information was collected from young individuals of Scheduled Castes in 10 districts of Uttar Pradesh: Bareilly, Badaun, Pilibhit and Shahjahanpur, Meerut, Bagpat, Bulandshahr, Ghaziabad, Gautambudh Nagar, and Hapur, utilizing an interview schedule. 128 people were chosen for the study using a multi-stage sampling method. Informed consent was successfully acquired from each subject. The ethical review boards of each institution were approved.

RESULTS AND DISCUSSION

Socio-economic profile of the respondents

Table 1 demonstrates that male respondents outnumber female respondents, suggesting lower participation of female youth in Youth club activities due to gender imbalance within family and community contexts. The survey indicates that the majority of respondents originate from rural regions, highlighting that Scheduled Caste communities reside separately and are marginalized. In contrast, all caste groups interact in urban and semi-urban locales. The largest income source for respondents is monthly salary, with 73 individuals (57.03%) reporting this as their primary income. Daily wage and weekly wage earners are evenly distributed, each group comprising 20 individuals (15.63%). A small number of respondents, 15 (11.72%), reported no applicable income source, indicating they may be unemployed, students, or dependent on others in the selected area.

Awareness participation of SC youth in government schemes and programmes

Goal 4 (Quality Education) and Goal 8 (Decent Work and Economic Growth) are two crucial Sustainable Development Goals (SDGs), and the study shows that the Mann-Whitney U Test results provide light on the degree to which persons from the Meerut and Bareilly Commissionerate are familiar with them. *To determine if there are significant differences in the respondents' levels of awareness between the two locations, this non-parametric test yielded the following interpretations of its results:* With a p-value of 0.196, which is higher than the significance threshold of 0.05, there is no significant difference in the levels of awareness of SDG 4: Quality Education between the Meerut and Bareilly Commissionerate respondents. Even though Meerut's mean rank is higher than Bareilly's (50.21 vs. 43.37), the gap (6.84) is too small to be considered statistically significant. It appears that there is a similar level of knowledge in both regions regarding the education-related objectives of SDG 4. *According to the literature, educational programs and awareness campaigns typically have consistent regional outreach when policies are directed at the national or state level (Mukherjee and Chakraborty, 2021).* Reasons for the high level of awareness could be related to the fact that both Commissionerate have education policies in place, mainly through national programs like RTE (Right to Education) and Sarva Shiksha Abhiyan, which aim to provide quality education to all individuals regardless of their socioeconomic status (Khan and Sharma, 2022). Respondents' familiarity with SDG 8—Decent Work and Economic Growth—varies considerably between Meerut and Bareilly, according to the results. With a p-value of 0.028 (less than 0.05), it is clear that Meerut participants have a significantly higher awareness of Goal 8 than Bareilly participants. The Meerut population seems to better grasp the employment and economic growth activities under SDG 8 than the Bareilly population, with a mean rank of 53.63 compared to 41.83. Perhaps the higher awareness of SDG 8 among Meerut inhabitants results from their district's more substantial industrial base and better economic possibilities, encouraging citizens to invest in projects that promote decent employment and economic prosperity. Singh, A. and Banerjee, S. found in 2020 that places like Meerut and Gautam Buddha Nagar, which have a lot of factories and other industrial facilities, are more likely to be aware of and involved in initiatives to boost employment and the economy. Economic centres usually have more excellent job prospects and better interaction with politicians. However, Bareilly's rural and agricultural economy may explain why its residents are not as well-versed in SDG 8. This sector tends to focus on agricultural activities rather than industrial employment strategy. As a result of factors such as limited access to information dissemination channels, a lack of exposure to non-agricultural job opportunities, and economic policies centred on cities, rural areas are less likely to be aware of and participate in



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programs aimed at fostering economic growth (Prasad and Kumar, 2021). A significant regional disparity in understanding Goal 8 reflects a broader trend of economic inequality and the uneven impact of growth-related awareness programs. *In places like Meerut and Gautam Buddha Nagar, where the Scheduled Caste (SC) population is more concentrated, initiatives to increase employment and income are prioritised. It is important to bring people's attention to these areas' government programs and economic prospects, especially since research shows that urbanized regions often have better infrastructure (Raman and Gupta, 2019).* Because of this, people are better able to comprehend and participate in SDG 8 initiatives. There may be a lack of awareness about initiatives to boost industrial or urban job growth in agriculturally based districts like Bareilly. Studies have linked socioeconomic factors, including income, industrialization, and urbanization, to SDG knowledge and involvement levels, confirming the significant gap in Goal 8 understanding. People in Meerut are very concerned about sustainable growth, fair salaries, and job security because of the significant concentration of companies and cities there (Kumar and Mishra, 2022). Being more exposed to government programs that aim to promote the economy has helped the district better understand them. On the other hand, Bareilly has lower levels of knowledge; this might be because its inhabitants are less likely to be involved in programs that boost city economies or because the city is situated in a more rural area. The difference in program reach and impact between urban and rural communities has been highlighted in recent policy studies. *Mehta and Roy (2021) highlight the need to develop regionally specific awareness initiatives to solve this problem.* In particular, the Mann-Whitney U Test results for SDG 4 (Quality Education) and SDG 8 (Decent Work and Economic Growth) illuminate regional variations in SDG understanding. While both Meerut and Bareilly appear to comprehend the need of quality education, Meerut is far more cognizant of programs aimed at fostering economic progress. Some possible factors contributing to this inequality include the presence of industries, economic infrastructure, and the rate of urbanization on a regional level. Different regions' socioeconomic realities should be considered when designing future awareness efforts to facilitate equitable participation in SDG-related projects and close these disparities. Mann-Whitney U Test for awareness level of schemes and programs of the respondents concerning SDGs between Bareilly and Meerut Commissionerate (Table 2).

Sustainable development goal number 4—quality education

27.10 per cent of all higher education students in India are between 18 and 23 years old. The proportion of male students has reached 26.90%, with Scheduled Caste males constituting 22.8%. Only 24.1% of women from Scheduled Castes are enrolled, whereas 27.3% of girls attend school; to compare the levels of participation in various initiatives and programs across several districts in the Bareilly and Meerut Commissionerate, a non-parametric statistical test known as the Kruskal-Wallis was utilized. The outcomes of this examination are detailed in the table that follows. This test aims to determine whether or not there is a major difference in involvement between the districts that make up each Commissionerate. The Mean Ranks represent the average number of respondents in each district within the Bareilly Commissionerate. The data are also utilized to determine the overall mean. Out of all the districts that make up the Bareilly Commissionerate, the district with the highest mean rank is the Bareilly district, followed by the district with the highest participation by the Shahjahanpur district. The p-value (0.000), lower than the significance level of 0.05, demonstrates a considerable variation in response rates to schemes and programs among the four districts comprising the Bareilly Commissionerate. Bareilly, with a mean participation rate of 78.22 per cent, is the district that has the highest mean involvement in schemes and programs, after Badaun, Pilibhit, and Shahjahanpur. Compared to other Commissionerate districts, the Bareilly district appears to put greater effort into participating in these activities. Likewise, the Mean Ranks provide information regarding the number of individuals participating in each Meerut Commissionerate district. Bagpat is the most active district in the Meerut Commissionerate, whereas Hapur ranks the lowest in involvement. Its popularity distinguishes Bagpat. The Kruskal-Wallis H statistic and the significance level are not provided in the table for Meerut Commissionerate; nonetheless, it is important to note that the group mean rank is 39.86, which is lower than the group mean for Bareilly. This is something that should be taken into consideration. With an average rank of 56.13, Bagpat, Bulandshahr, Ghaziabad, Gautambudh Nagar, and districts have the low involvement rates. Hapur, on the other hand, has the lowest level of engagement among the cities, with a mean rank of 10.47. According to the p-value of 0.000, which is statistically significant, there is a clear gap in the level of involvement amongst the several districts that make up the Bareilly Commissionerate. Even if we do not see precise test findings (p-value) for Meerut Commissionerate, the overall number of persons who participate



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in schemes and programs is lower in Meerut Commissionerate (group mean rank: 39.86) than it is in Bareilly Commissionerate (group mean rank: 61.60). There is a huge disparity between the levels of engagement displayed by different districts within each Commissionerate. For example, some districts, like Bareilly and Bagpat, have significantly higher levels of engagement than others, like Shahjahanpur and Hapur. It has been determined by the Kruskal-Wallis test that the district of Bareilly has the greatest participation percentage among the districts that make up the Bareilly Commissionerate. Bagpat has the highest degree of involvement, whereas Hapur has the lowest, according to the Meerut Commissionerate, even though the exact significance values are not provided. Considering the group mean ranks, the Bareilly Commissionerate appears to have a greater number of scheme and program participants than the Meerut Commissionerate. Kruskal-Wallis test for the participation of schemes and programs by the respondents between Meerut and Bareilly Commissionerate (Table 3). The Uttar Pradesh government assists Scheduled Caste children in academic improvement by providing free computers, post-secondary scholarships, educational incentives, and extracurricular activities. The 2030 Report on the Sustainable Development Goals states that the objective of the fourth SDG is to "ensure inclusive and equitable quality education and promote opportunities for lifelong learning for all populations." *Goal 4.4 aims to ensure that by 2030, countries significantly enhance the number of young individuals and adults with the technical and vocational skills necessary for employment, quality jobs, and opportunities to establish their enterprises. Similarly, governments aim to ensure that by 2030, all children and adolescents, together with a substantial proportion of individuals of both genders, possess literacy and numeracy skills (Target 4.6).* This study used the non-parametric Kruskal-Wallis test to determine if there are statistically significant differences in participation rates between districts in the Bareilly and Meerut Commissionerate. Based on the results of the tests and what is already known from the literature, we can infer that based on the p-value of 0.000, which is less than 0.05, there is a statistically significant variation in involvement among the districts of the Bareilly Commissionerate. It would appear that the level of participation in initiatives and programs by the different districts is extremely variable. With an average participation percentage of 78.22%, Bareilly has the highest mean rank among the districts. That Bareilly is involved in so many different government projects and initiatives is clear from this. Literature on regional disparities and the implementation of public policies suggests that districts with stronger administrative infrastructure or in more urbanized areas are more likely to participate in public programs (Kapur *et al.*, 2021). Bareilly's greater engagement may be due to better outreach, administrative efficiency, or socioeconomic elements. Shahjahanpur is the most involved, despite Bareilly having the highest mean rating. Even if there may be more participants in Bareilly, it's plausible that folks in Shahjahanpur put more effort into the programs. Research shows that districts with lower socioeconomic indices have peaks of high involvement when programs are tailored to meet specific local needs (Verma and Singh, 2019). Bagpat has the highest level of engagement within the Meerut Commissionerate, while Hapur has the lowest. As in the Bareilly Commissionerate, differences in participation rates between Meerut districts indicate that local factors influence program acceptance in different ways. Districts like Bagpat may benefit from stronger administrative efforts or a better matching of programs with local requirements, as shown by the observed targeted policy efficacy in areas with higher governance (Mitra, 2020). Without specific test data and significance levels for Meerut, the lower group mean rank (39.86) compared to Bareilly's 61.60 indicates a lack of interest in the Commissionerate. That fits with what we already know from prior research: people in more urbanized and industrialized districts have a harder time becoming involved with government programs, perhaps because they do not need them as much as those in more rural areas (Banerjee *et al.*, 2022). According to the data, Bareilly Commissionerate is more active in schemes and programs than Meerut Commissionerate, as indicated by their higher group mean rank. Socioeconomic factors may explain this inequality; for example, areas in Bareilly may rely more on government welfare and livelihood programs. Studies have shown that districts with a higher percentage of the rural population are more inclined to participate in welfare schemes than urban districts, which generally struggle to mobilize their inhabitants for government initiatives (Sarkar and Gupta, 2021). Among the districts within each Commissionerate, the Kruskal-Wallis test shows a significant difference in involvement; the districts with the highest participation rates are Bareilly and Bagpat. More proof that administrative capability, the quality of local governance, and program modification to match local requirements all contribute to participation rates. Consistent with other research demonstrating that regional disparities affect the effect and success of government programs, the varying mean ranks demonstrate that districts are not all involved to the same degree (Roy and Sharma, 2018). Possible explanations for the lower engagement in Shahjahanpur and Hapur compared to



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Bareilly and Bagpat include insufficient administrative support, lower educational attainment, and inadequate infrastructure. Using the Kruskal-Wallis test, we can see that the districts in the two Commissionerate have significantly different levels of involvement. Compared to Bareilly and Bagpat, Shahjahanpur and Hapur are not as active. Something else worth noting is that the entire participation rate in the Meerut Commissionerate is lower than in Bareilly. When factors like administrative capacity, local governance, and program alignment with local needs are considered, the likelihood of effective participation in public programs increases. As a result, we need further studies concentrating on areas with low engagement rates to determine what factors contribute to districts like Bareilly and Bagpat, which have high involvement rates. Educational Qualification of the Respondents (Table 4). The figure provided under "Education Status of Respondents" depicts the educational qualifications of the surveyed individuals. It is depicted as a horizontal bar chart comprising four categories: The primary cohort, comprising 67 individuals, has engaged in higher education. This indicates that a significant percentage of the studied population possesses access to and achieved high levels of education. 39 respondents belong to this category, signifying they have completed secondary education or possess a diploma. This constitutes the second-largest cohort, signifying a comparatively elevated educational achievement. Eighteen individuals have attained high school education. This signifies a reduced proportion of the assessed population that did not seek education beyond secondary school. Four respondents choose not to reveal their educational qualifications. This limited data indicates that most respondents were candid about their educational background. The data indicates that most respondents achieved higher education or at least a secondary level, signifying a well-educated sample population. Enrollment ratio of SC population from last 5 years (Figure 4). Over five years, from 2015-2016 to 2019-2020, the diagram shows responder data broken down by gender (Male and Female). The information is shown as a bar chart, with blue bars showing the number of men, red bars showing the number of women, and green bars showing the total number of people each year. The number of men who responded in 2015-2016 was 2,743,277,354, while the number of women who responded was only 551,677. That year, there were 551,677 responses from both men and women. Between 2016 and 2017, the number of men who responded rose to 3,009,302,856, while the number of women who responded rose to 603,786. This meant that more people were participating, and 603,786 people answered. In 2017-2018, male and female respondents increased to 3,205,878 men and 333,043 females. This year's total was much higher than usual; it reached 653,800, the most recorded responses. From 2018 to 2019, the trend changed slightly, with fewer men responding (3,134,653) and more women responding (3,21,401). Even though there was a small drop in both genders, the general total stayed high at 634,866, showing that people were still involved. Last, a small drop in responses was seen in 2019-2020. The total number of people who answered was 3,298,484. There were 2,982,878 male respondents and 315,606 female respondents. In all years, more male respondents than female respondents, which shows a big difference between the sexes in involvement. The total number of responses mostly went up until 2017-2018, when it reached its highest point. After that, it went down slightly over the next two years. This figure shows that participation steadily rose at first, especially from 2015 to 2018, but then it started to level off and slowly decreased after 2018. The numbers show that engagement has been pretty steady, though it has decreased for both men and women in recent years. The graph shows important information about how involvement rates changed by gender over five years. Even though both male and female participation went up early on, it is clear that females have been more active than males throughout all years. Total engagement numbers show an initial rise that peaked in 2017-2018, followed by a slight drop near the end of the observation period. This knowledge could help people develop new ways to get men and women to participate more equally in the future. Kruskal-Wallis test for awareness of schemes and programs among the respondents in the Meerut and Bareilly Commissionerate concerning sustainable goal no.4 (Table 5). A better understanding of the SDG 4: Quality Education table and the performance of the districts in the Bareilly and Meerut Commissionerate can be gained from recent research by taking into account a variety of factors, such as the accessibility of schools, the quality of infrastructure, the availability of teachers, and other socioeconomic factors. All the evidence from recent research points to this: The high mean rank in the Bareilly area shows how seriously they take providing a good education. This can be because of new laws, better infrastructure, or efforts to raise awareness of the problems. New studies reveal that test scores are higher in schools where pupils and teachers are more often present (UNICEF, 2021). Government funding and ongoing improvements to educational infrastructure may explain Bareilly's improved standing. Following closely behind them are Pilibhit and Badaun, whose achievements are below par. According to the Annual Status of Education Report (ASER) 2022, these districts



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and others in rural and semi-urban Uttar Pradesh have made great strides toward bettering elementary and secondary education. They have done this through enhanced focus on teacher training programs and digital education initiatives. According to research on rural education in India, Shahjahanpur may have problems with insufficient facilities, a lack of competent instructors, or a small number of students enrolling (Ministry of Education, 2021). It also has the lowest mean rank. While many developing localities struggle with unequal distribution of educational resources, Shahjahanpur stands out in this regard (UNESCO, 2022). Among the commissionerate in Meerut, Bagpat has the highest mean rank. This is partly explained by its closeness to urban regions, which often have better infrastructure and more educational resources (Kumar and Verma, 2023). Studies show that communities near cities have better educational outcomes (World Bank, 2021). This is likely because governments and corporations allocate more resources to these areas. Ghaziabad and Bulandshahr also do very well, which may be related to the fact that they are both urban and industrial centres. A NITI Aayog forecast for 2022 predicts that districts with higher economic activity tend to devote more funding to education. That may shed light on the relative importance of different regions. Hapur has inadequate instructional resources, as shown by its low mean rank. This is in line with research that has shown rural areas can have slower economic growth and less government support, both of which contribute to a lack of educational opportunities for their residents (UNESCO, 2022). Several factors, such as gender disparities, poverty, and low literacy rates, impede rural India's educational progress (Pandey, 2022). The findings of the Chi-square test show that the differences between districts are not random but rather statistically significant ($p=0.002$). Therefore, policy changes should be more targeted and tailored to certain regions. World Economic Forum research from 2023 suggests that investing in infrastructure, teacher training, community involvement, and focusing on underperforming areas will help fix educational inequality. These results align with previous research on Sustainable Development Goal 4 (Quality Education), which states that all people should have the chance to get a good education and continue learning throughout their lives (UN, 2022). Recent UNESCO publications (2022) stress the need for a tailored strategy to achieve SDG 4, especially in rural regions with pronounced educational inequality. The table demonstrates that there are substantial differences among the districts. This suggests that certain regions are falling behind and need more help and that others are on track to meet SDG 4. It is crucial to tailor policy decisions to suit every situation since the performance of each area varies significantly. New research suggests that to improve enrollment rates, school facilities, and teacher availability, the government should prioritize areas like Hapur and Shahjahanpur (NITI Aayog, 2022). Conversely, other regions can learn from Bareilly and Bagpat's successes by implementing best practices in education. The Chi-square and Kruskal-Wallis tests show that students' results vary across domains. This highlights the significance of allocating resources strategically and keeping a close eye on developments to guarantee that SDG 4 objectives are met in all areas by 2030.

Sustainable development goal number 8—Decent work (Employment)

Goal 8 mandates that countries promote inclusive and sustainable economic growth, create employment opportunities, and ensure equitable working conditions for all citizens. Target 8 seeks to provide inclusive and productive employment and dignified work for all individuals, including women, men, youth, and persons with disabilities, while ensuring equitable compensation for labour of equal value by 2030 (target 8.5). The supplementary goal for youth is to markedly reduce the proportion of young individuals disengaged from employment, education, or training by 2020. Moreover, by 2020, countries must develop and implement a global strategy for youth employment and support the International Labour Organization's Global Jobs Pact. The reduced educational achievement of Scheduled Castes leads to a largely unskilled employment force, with most individuals engaged in informal sectors. Discrimination in the job market, observable in both formal and informal sectors, results from employment opportunities being influenced not just by educational qualifications but also by the individual's social status. The youth unemployment rate has increased throughout the years. The SC youth lack opportunities and resources, making them vulnerable and attempting to obtain essential means of survival. SC had the highest unemployment rate in India during the 1990s. Table 6 depicts the employment status of youth in correlation with their age. The predominant number of survey respondents were employed. It was shown that most of the participating SC teenagers were underemployed. The lack of opportunity and involvement prevents SC children from securing appropriate work that aligns with their educational skills. Figures 4 and 5 illustrate that the proportion of the non-SC workforce is markedly more significant in regular-pay employment and self-employment than in the



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SC population. In contrast, the SC population predominantly participates in casual labour. From January to March 2020, the youth labour force participation rate (ages 15–29) was 39.5%, which decreased by approximately one percentage point to 38.4% during the corresponding period of 2021. The unemployment rate increased to 22.9% during January–March 2021, up from 21.2% in January–March 2020. In Tamil Nadu, the youth labour force participation rate (ages 15–29) was 44.5% from January to March 2020 but decreased by 0.2% over the same period in 2021. The unemployment rate increased from 19.9% in January–March 2020 to 23.9% in January–March 2021. Figures 4 and 5 depict the employment status of women and men from Scheduled Castes compared to their Non-Scheduled Caste counterparts. Both photographs demonstrate that, in comparison to other caste groups, Scheduled Caste males and females mainly participate in informal labour, characterized by volatility and the absence of employment guarantees.

Hypothesis

H₀: there is no difference between SC participations in SDG 4 in Bareilly and Meerut.

H₁: there is difference between SC participations in SDG 4 in Bareilly and Meerut.

H₀: there is no difference between SC participations in SDG 8 in Bareilly and Meerut.

H₁: there is difference between SC participations in SDG 8 in Bareilly and Meerut.

RESULTS AND DISCUSSION

Notably, a significant percentage of SC youth (24.40% and 10.00%) did not finish their upper secondary schooling after graduating. AISHE secondary data shows that the number of SC teens enrolling in college will decrease from 2018 to 2020, which aligns with this finding. SC kids cannot get work that fits their educational skills because they lack opportunities or activities. The poll shows that even though 42.2% of young people in SC had jobs, they were still underemployed. Also, 4.4% of young people in SC were found to be jobless. Because of this, a lot of young people from Scheduled Castes in Tamil Nadu are either underemployed or not working at all. The study results and secondary data from the Periodic Labour Force Survey show that the jobless rate went up from 19.9% to 23.9%. So, the SC kids cannot get jobs that match their educational background because they do not have enough opportunities or ways to get involved. Many more people are working for a controlled wage or on their own than people working for a casual wage or on their own in SC. They are likely to be poor because they work in the informal economy and have temporary jobs. So, to ensure they get the benefits under the law, they should be encouraged to work in the official field. The Kruskal-Wallis test showed a significant difference ($p < 0.000$) between respondents' level of schooling and their knowledge of schemes and programs in the chosen districts. So, schooling is very important for getting more SC youth involved in the SDGs. The Kruskal-Wallis test showed a big difference in how much Scheduled Caste youth in all seven districts knew about programs and efforts that helped reach Goal No. 4 (Quality Education) and Goal No. 8 (Decent Work). So, the Government of Tamil Nadu needs to ensure that these goals are met for SC youth by enforcing the law, ensuring policies are tailored to their needs, and running aid programs. The Mann-Whitney U test shows a significant difference at the 0.005 level ($P < 0.05$) between the involvement of Scheduled Caste youth in projects and programs in Aspirational Districts and other districts. This shows good governance in the places where people want to be involved in the projects of both the state and central governments. Classes must be available, known about, and easy to get to. The kids from Scheduled Caste do not fully understand the current goals and rules, and there is not enough help from administrators and organizations. The main reason for the shortfall is insufficient resources to teach and inform SC's kids about policies and programs. Getting young people from Scheduled Castes involved in schooling and jobs. So, the study's conceptual framework is an all-encompassing plan emphasizing how national and state youth policies are carried out by governmental and non-governmental organizations working together. It also includes micro, mezzo, and macro-level analyses of social work methodologies that aim to increase the involvement of Scheduled Caste youth in educational and job-related programs that align with Sustainable Development Goals 4 and 8. The availability of jobs and higher rates of educational participation in jobs mainly help SC kids meet their basic needs and give them the power to overcome being left out. The main goal of education should be to make more people aware of how Scheduled Caste kids are



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mistreated and to give them the tools they need to fight against the unfair social order they live in. In this way, achieving sustainable development goals is fundamental to supporting fairness and equality.

CONCLUSION

According to the numbers, different regions have different conceptions of the SDGs. Compared to Bareilly, Meerut is more cognizant of Goal 8 (Decent Work and Economic Growth). The findings emphasize the need for targeted policy actions, even though both regions have a similar understanding of Goal 4 (Quality Education). To reduce these disparities, officials should use region-specific strategies to raise awareness of and engage in economic growth projects, especially in rural areas like Bareilly. More possibilities should be made available to rural populations to help rural areas catch up to urban areas economically and in terms of employment. Maintaining and improving educational outreach programs is critical to ensure continuous further engagement with SDG 4. In order to achieve inclusive and equitable development by the SDGs, it is crucial to apply targeted interventions that consider the unique socio-economic conditions of each region. Policy implications like these highlight this.

Policy Implications

Based on the findings from the analysis of awareness levels regarding Sustainable Development Goals (SDGs), particularly Goal 4 (Quality Education) and Goal 8 (Decent Work and Economic Growth), the following policy implications can be suggested:

Targeted Awareness Campaigns for Economic Growth Initiatives

Given the significant disparity in awareness of Goal 8 between Meerut and Bareilly, policymakers should implement region-specific awareness campaigns in more rural districts like Bareilly. These campaigns should focus on educating residents about employment opportunities, skill development programs, and economic growth initiatives. Community-based outreach and local institutions can help ensure that the information reaches the intended populations.

Enhancing Access to Employment and Economic Growth Programs in Rural Areas

The lower awareness of Goal 8 in Bareilly highlights the need for better access to economic programs in rural regions. Policies should focus on improving infrastructure, creating more rural employment schemes, and facilitating access to government initiatives that promote decent work and sustainable economic growth. Establishing employment information centres or digital kiosks in rural areas could help bridge this gap.

Strengthening Educational Outreach

Although no significant difference in awareness of Goal 4 (Quality Education) was found, policymakers should continue strengthening educational outreach to maintain and improve current levels of awareness. Particular attention should be paid to enhancing teacher training, improving school infrastructure, and ensuring that marginalized groups have equal access to quality education in urban and rural areas.

Urban-Rural Parity in Program Implementation: The urban areas of Meerut exhibit higher awareness due to their economic and industrial activity. To reduce regional disparities, policies should aim to create rural equivalents of urban-based economic initiatives, ensuring that government programs related to decent work and economic growth are adapted to rural contexts. This could involve promoting agriculture-related industries, micro-enterprises, and skill development programs that cater specifically to the economic realities of rural districts like Bareilly.

Monitoring and Evaluation of SDG Progress

Regular monitoring and evaluation mechanisms should be established to assess regional progress on the SDGs, especially in underperforming areas. Policymakers should gather data on program engagement, barriers to participation, and areas where awareness is lacking to tailor future interventions more effectively.





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Amritansh Mishra *et al.*,**Table 1: Socio-economic Profile**

Sl. No.	Sex	Frequency	Percentage
1	Male	101	78.90625
2	Female	27	21.09375
	Total	128	100
Sl. No.	Community	Frequency	Percentage
1	Rural	88	68.75
2	Semi-urban	30	23.4375
3	City	10	7.8125
	Total	128	100
Sl. No.	Income Source	Frequency	Percentage
1	Monthly salary	73	57.03125
2	Daily wage	20	15.625
3	Weekly wage	20	15.625
4	Not applicable	15	11.71875
	Total	128	100

Source: Field Survey

Table 2: Mann–Whitney U Test for awareness level of schemes and programs of the respondents concerning SDGs between Bareilly and Meerut Commissionerate

SDG Goals	Commissionerate	N	Mean rank	Sum of ranks	Mann–Whitney U	P-Value	Result
Goal 4	Meerut	40	50.21	1406	736	0.196	Not significant
	Bareilly	88	43.37	2689			
Goal 8	Meerut	40	53.63	1501.5	640.5	0.028	Significant
	Bareilly	88	41.83	2593.5			

p-value = 0.000 ($p < 0.05$)p-value < α – The differences between the mean ranks are statistically significant concerning Goal 8**Table 3: Kruskal–Wallis test for the participation of schemes and programs by the respondents between Meerut and Bareilly Commissionerate**

and Bareilly Commissionerate							
Bareilly	Districts	Mean rank	Rank order	Kruskal-Wallis H	df	Significant	Result
	Bareilly	78.22	1	51.59	8	0.000	Significant
	Badaun	68.38	2				
	Pilibhit	66.04	3				
	Shahjahanpur	50.39	4				
	Group Mean	61.60					
Meerut							
	Bagpat	56.13	1				
	Bulandshahr	50.91	2				
	Ghaziabad	49.42	3				
	Gautambudh Nagar	32.4	4				
	Hapur	10.47	5				
	Group Mean	39.86					

Source: Author's Calculation



Amritansh Mishra *et al.*,**Table 4 Educational Qualification of the Respondents**

S. No	Education	Frequency	Percentage %
1	Higher education	67	52.34
2	Secondary level and diploma	39	30.46
3	High school level	18	14.06
4	Not willing to answer	4	3.12
	Total	128	100

Source: Field Survey

Table 5: Kruskal–Wallis test for awareness of schemes and programs among the respondents in the Meerut and Bareilly Commissionerate concerning sustainable goal no.4

SDGs-4 Quality Education	Districts	Mean rank	Rank order	Chi- square	df	Significant	Result
	Bareilly	48.22	1	21.863	8	0.002	Asymp. Significant
	Badaun	42.38	2				
	Pilibhit	36.04	3				
	Shahjahanpur	31.39	4				
	Group Mean	36.6					
	Bagpat	46.13	1				
	Bulandshahr	40.93	2				
	Ghaziabad	39.3	3				
	Gautambudh Nagar	32.4	4				
	Hapur	8.39	5				
	Group Mean	33.43					

Source: Field Survey

p-value = 0.002 ($p < 0.05$)p-value $< \alpha$ – The differences between the mean ranks are statistically significant**Table 6: Age and Occupation – cross-tabulation**

Age	Occupation				
	Employed	Unemployed	Self-employed	Student	Total
15–20	8	13	2	22	45
20–25	22	12	11	12	57
25–29	8	10	6	2	26
Total	38	35	19	36	128

Source: Field Survey





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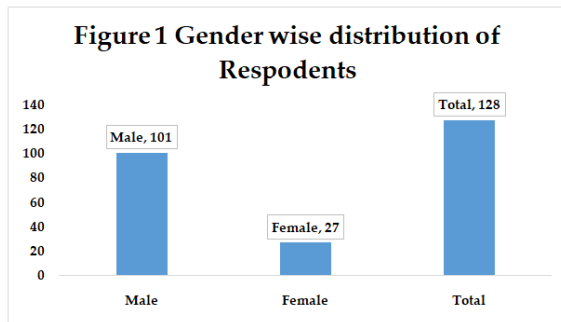


Figure 1: Gender wise distribution of Respdents

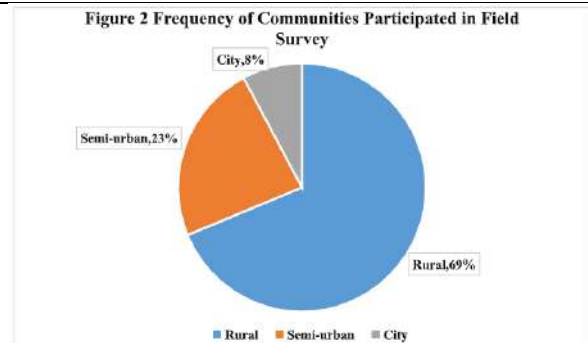


Figure 2: Frequency of Communities Participated in Field Survey

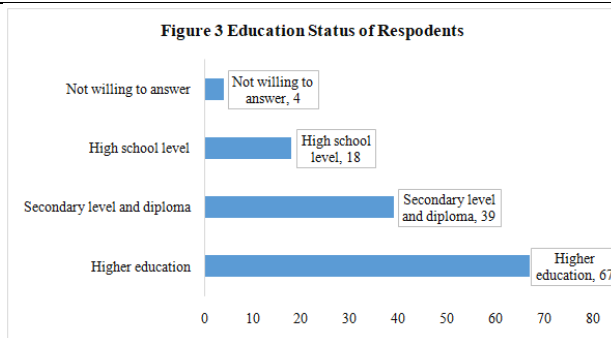


Figure 3: Education Status of Respdents

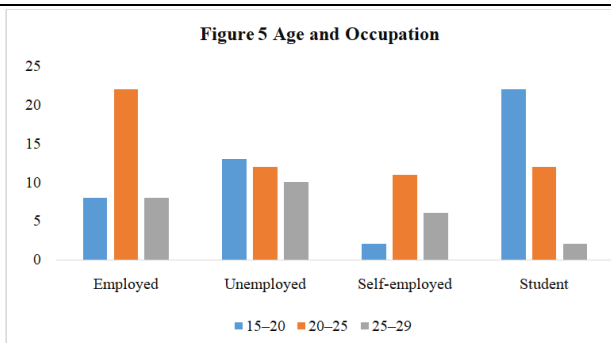
Figure 4: Enrollment ratio of SC population from last 5 years
Source: All India survey for higher education (AISHE), 2022

Figure 5: Age and Occupation

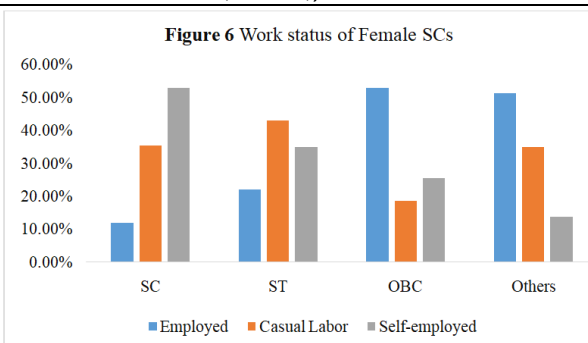


Figure 6: Work status of Female SCs





RESEARCH ARTICLE

Effect of Swiss Ball Exercise and Lumbar Stabilization Exercise in Individual with Core Weakness and Functional Ability in Female Physiotherapist with Mechanical Low Back Pain: A Pilot Study

Gajjar Bindi^{1*}, Vrunda Gujar² and Gaurav J. Patel³

¹MPT (Enrollment No.: 2307192080003), Department of Physiotherapy, Ahmedabad Physiotherapy College, Ghuma, Parul University, Vadodara, Gujarat, India.

²Associate Professor, Department of Physiotherapy, Ahmedabad Physiotherapy College, Ghuma, Parul University, Vadodara, Gujarat, India.

³Principal, Department of Physiotherapy, Ahmedabad Physiotherapy College, Ghuma, Parul University, Vadodara, Gujarat, India.

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*Address for Correspondence

Gajjar Bindi

MPT (Enrollment No.: 2307192080003),

Department of Physiotherapy,

Ahmedabad Physiotherapy College,

Ghuma, Parul University, Vadodara,

Gujarat, India.

E.Mail: gajjarbindi.02@gmail.com



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ABSTRACT

Around 20% of people in all countries and ethnic groups experience back pain at some point each year, and up to 50% of them do so at least once. Back pain is common and likely affects practically everyone. In order to address muscular back pain, core muscle stabilization exercise is advised. Swiss balls have been shown to be beneficial for patients with muscular back discomfort in addition to helping with upper body development. To assess a female physiotherapist's functional abilities and core weakness in relation to lumbar stabilization exercises and Swiss ball exercises for muscular back pain. Ten college-educated physiotherapists were enlisted for the study. All participants were informed about the activity and study protocol before providing written consent. Participants who met the requirements for inclusion or exclusion have been vetted and included to the research. The results for pain and muscle strength were obtained using the NPRS and manual muscle testing. Additionally, after 15 days of exercise, post-data was recorded. While both exercises were successful in reducing pain, the Swiss ball exercise significantly increased core muscle strength ($p=0.004^*$) compared to the lumbar stabilization exercise. For muscular low back pain, Swiss ball strengthening is superior to dynamic lumbar stabilization.

Keywords: Swiss ball, lumbar, dynamic, back pain





INTRODUCTION

Most people have back pain at some point in their lives, which is a very common issue. Although there is significant variation among epidemiological studies of low back pain, which makes it difficult to compare and aggregate data, estimates of the 1-year incidence of a first-ever episode of low back pain range from 6.3% to 15.4%, while estimates of the 1-year incidence of any episode of low back pain range from 1.5% to 36%. The range of episode remission at one year in research conducted in clinics or medical facilities is 54% to 90%[1]. The majority of primary healthcare settings handle low back pain, which is a significant health issue in all developed nations. With or without leg pain, it is typically described as pain, stiffness, or muscle tension that is localized above the inferior gluteal folds and below the costal border. General practitioners, medical specialists, and other healthcare providers have long varied considerably in how they diagnose and treat individuals with low back pain, both within and between nations[2]. Back pain that naturally arises from the intervertebral disks, soft tissues around the spine, or both is referred to as mechanical low back pain. These include lumbar spondylosis, spondylolisthesis, spondylolysis, lumbosacral muscular strain, vertebral compression fractures, and acute or chronic traumatic injury. Chronic mechanical low back pain often arises from work-related injuries and is often caused by overuse and repetitive damage. Most people with low back pain that restricts their activities experience recurrent episodes. Up to 23% of people worldwide suffer from chronic low back pain, and between 24% and 80% of patients experience a recurrence within a year [3]. Mechanical low back pain is commonly diagnosed by physical examination, physical testing, palpation, and imaging tests such as MRIs, CT scans, and x-rays. Surgery, physical therapy, and medication are the three most common ways to address mechanical low back pain. Physical therapy management may include manual treatment, exercise therapy, modalities, patient education, and a comprehensive home care plan, depending on the patient's condition. Even while manual physical therapy and core stability exercises are obviously beneficial when used independently to treat mechanical low back pain, there isn't a single study in the literature on their combined effects[4]. Core strength training targets the deep trunk muscles. Even though there are numerous core strength training methods available, CLBP sufferers struggle with autonomous training[5]. According to one definition, the diaphragm is the uppermost layer of the muscular box known as the "core," which is composed of the abdominal muscles in the front, the paraspinals and gluteals in the back, and the pelvic floor and hip girdle musculature at the bottom. Bergmark divided the trunk muscles into a local and a global system to preserve the stability of the lumbar spine. The global system consists of muscles with origins on the pelvis and insertions on the thoracic cage, while the local system consists of muscles that have origins or insertions (or both) at the lumbar vertebrae. The morphological, physiological, and biomechanical properties of muscles can be categorized as either mobilizers or stabilizers. Since the two muscle groups have different anatomical and functional characteristics, the stabilizers are better adapted for postural holding with a "anti-gravity" function. Often referred to as "task muscles," the mobilizers are more adapted for rapid ballistic movements. With respect to the abdominal muscles, the rectus abdominis and lateral fibers of the external oblique may be considered the prime movers (mobilizers) of trunk flexion, the erector spinae as the trunk extensor, and the internal oblique, multifidus, and transversus abdominis as the primary stabilizers of trunk movement in general. Stabilizers can be further divided into primary and secondary categories. The primary stabilizers are the muscles that cannot generate significant joint movements, such as the lumbar multifidus (LM) and transversus abdominis (TrA). These muscles are only used to support the lumbar spine. In addition to their considerable ability to stabilize, secondary stabilizers such as the quadratus lumborum, external oblique medial fibers, and internal oblique can also move the joints of the spine. Adding to this description, mobilizers may be called "tertiary stabilizers" since they primarily move the joint but can stabilize in an emergency, like a muscle spasm or pain[6]. There are lumbar stabilization exercises that aim to improve the neuromuscular control, strength, and endurance of the muscles necessary to maintain the trunk's and spine's dynamic stability. The lumbar multifidus and transversus abdominis were specifically addressed by several muscle groups, in addition to other paraspinal, abdominal, diaphragmatic, and pelvic muscles[7]. A common technique for building core muscles for a number of years has been Swiss ball training. Numerous research have examined how core muscles are recruited during different Swiss ball abdominal workouts and more traditional abdominal exercises like the bent-knee sit-up and crunch (abdominal curl-up). When analyzing the use of Swiss ball exercises, most studies assessed the abdominal



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muscles' activity during the bench press, push-up, and crunch movements. The recruitment patterns of one or two muscles were typically the only ones they examined. For training and rehabilitation, a few more Swiss ball movements are used to enhance core stability and growth. For example, prone hip extension on the gluteus maximus and hamstrings is a popular exercise for core. However, there is currently no research on how much core muscle activation occurs during prone hip extension on a Swiss ball. More complex Swiss ball workouts that athletes perform include the roll-out, pike, knee-out, and skier, though it's uncertain how effective these are at recruiting core muscles. A few of these exercises have been chosen due to their usefulness or sport-specificity. The relative effectiveness of a sequence of Swiss ball exercises against more traditional abdominal-strengthening exercises like the crunch and bent knee sit-up in terms of core muscle engagement is still unclear[8]. Many researches have been conducted on mechanical low back pain, and various writers have suggested that certain exercise regimens can help with this condition. Lumbar stabilization has proven a useful therapy plan for various types of back pain, and core exercises have been successful in reducing low back pain. Finding an improved technique to treat mechanical low back pain in physiotherapists is the goal of this study.

MATERIALS AND METHODOLOGY

This study compares Ahmedabad Physiotherapy College and Parul University. After signing an informed consent form, ten physiotherapists were enlisted. The nature of the study, its methodology, and the tests that would be conducted were all explained to the participants. The nature of the study, its methodology, and the tests that would be conducted were all explained to the participants. Participants between the ages of 18 and 25 who have no neurological deficiencies or a history of spinal surgery are included; those with neurological involvement, a dermatological problem, or a fracture are not[9]. Every participant's demographic information was gathered. NPRS was used to measure pain, while manual muscle testing was used to measure core strength.

PROCEDURE

The Numerical Pain Rating Scale (NPRS) is a one-dimensional tool used to quantify the severity of pain. "0" denotes no pain, while "10" denotes severe pain on the 11-point numerical scale. In the segmented numerical version of the Visual Analogue Scale (VAS), known as the NPRS, respondents choose a whole number (0–10) that most accurately represents the level of pain they are experiencing. The patient's overall level of pain was represented by the average of the three scores. The NPRS's ICC value is 0.92[10]. Manual Muscle Testing: Professionals in the fields of medicine, osteopathic medicine, chiropractic care, physical therapy, rehabilitation, and athletic training employ manual muscle testing (MMT) for a number of reasons. Different testing methods are not always interchangeable and are relevant in different situations. The most widely accepted opinion is that MMT is an effort to determine the most force that a muscle can produce[11]. Individual muscular strength grades had reliability scores ranging from .80 to .99, with the highest scores occurring in the gravity-eliminated range[12]. Group A: Swiss Ball Exercise [13](Table:1). Group B : Lumbar Stabilization Exercise[14] (Table:2). Both exercises should be done 5 days/week for 15 days

RESULT

The statistical software SPSS 26.0 was used to evaluate the data, and a significance level of $p < 0.05$ was established. The mean and standard deviation of each group were evaluated using descriptive statistics. The Shapiro-Wilkinson test was used to determine whether the data was normal. Given that the data was not normally distributed, the MANN WHITNEY U TEST was used for inferential statistics to determine group differences, and the Wilcoxon Sign Rank Test was used for within-group analysis. Table 3- Comparison of Age. Figure1: mean $\pm$ SD age. Table 4- Comparison of MMT. In reference to MMT, The Mann Whitney U test between-group analysis of "PRE & POST values" revealed a statistical difference with respect to "POST" values alone ($P < 0.05$). The statistical significance of the "mean difference" ($p < 0.05$) between groups was also reported by the Mann Whitney U test. Only the GROUP A-SWISS BALL EXERCISE showed a significant difference in the Wilcoxon Sign rank test used for group analysis. The

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GROUP A-SWISS BALL EXERCISE showed a better mean difference (PRE-POST) than the GROUP B-LUMBAR STABILIZATION EXERCISE. Mean $\pm$ SD of Manual Muscle Testing (Figure 2). Table 5- Comparison of NPRS. In reference to NPRS, The Mann Whitney U test between-group analysis of "PRE & POST values" revealed a statistical difference with respect to "POST" values alone ($P < 0.05$). The "mean difference" ($p > 0.05$) between the groups was not statistically significant according to the Mann Whitney U test. Only the GROUP A-SWISS BALL EXERCISE showed a significant difference in the Wilcoxon Sign rank test used for group analysis. The GROUP A-SWISS BALL EXERCISE showed a better mean difference (PRE-POST) than the GROUP B-LUMBAR STABILIZATION EXERCISE. Mean $\pm$ SD of NPRS (Figure 3).

DISCUSSION

Swiss ball exercises have been shown to improve muscle strength and discomfort at the same time. The impact of a 10-week core stabilization program on pain presentation pattern, disability, and trunk muscle activation in individuals with clinical lumbar spine instability was assessed by Areeudomwong et al. in a pilot randomized controlled trial. The participants in the control group received hydrocolator therapy and trunk muscular stretching. The outcomes of this study are consistent with theirs, which showed reductions in pain and impairment in both therapy groups. However, the enhancement of the transverse abdominis activation ratio and There was an internal oblique in relation to the rectus abdominus muscle in the participants who received core stability exercises[15]. According to a study by Hye Jin Moon, the internal oblique, multifidus, and transverse abdominal muscles, among other abdominal muscles, aid in raising intra-abdominal pressure, which supports spinal and pelvic stability [18,20,21]. Some lumbar dynamic activities were part of our lumbar stability exercise group, which would have helped this patient group's lumbar extensors at the large lumbar flexion angle. But the group that did the stabilization exercises showed better lumbar extensor strength at low lumbar flexion angles and functional gains, which may indicate that the stabilization exercises were the cause of these benefits. The length-tension relationships show that the lumbar extensors are shortest at the[14] In a similar vein, a study that included core strengthening workouts with Swiss ball activities for four weeks revealed a statistically significant change in the 60 degree curl-up test. During the workouts, the low back is given more stability by the mini stability ball, which also increases muscular work and utilization. Additionally, because of the micro stability ball's small diameter, it provides a broader range of motion. In group A, this test revealed statistically significant differences between 0 and 2, 2 and 4, and 0 and 4 weeks using the modified Sorensen's test. Between groups A and B, however, there was no statistically significant difference. Swiss ball activities and micro stability ball exercises had the same impact on core endurance, per the statistical data. According to a study, an 8-week Swiss ball core strength training program can help with both LBP and core endurance[16]. The Swiss ball significantly improved core muscular strength and reduced discomfort in physiotherapists with mechanical low backs, according to our study.

CONCLUSION

The Swiss ball exercise in group A has been shown to be more effective than the lumbar stabilization exercise in group B in reducing pain and improving core strength.

LIMITATIONS

- Different outcomes for core strength could be used.
- A scale for disability could be used.

FUTURE RECOMMENDATIONS

This exercise could be tried in different professionals.





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Table 1: Group A: Swiss Ball Exercise [13]

Exercise	Repetitions	Sets
Swiss ball push-up	10 with 10 seconds hold	1
Swiss ball bridging	10 with 10 seconds hold	1
Swiss ball abdominal curl-up	10 with 10 seconds hold	1
Swiss ball Prone ball hold with knee drive.	10 with 10 seconds hold	1
Swiss ball wall squat	10 with 10 seconds hold	1
Swiss ball plank	10 with 10 seconds hold	1





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Table 2: Group B: Lumbar Stabilization Exercise[14]

Exercise	Repetitions	Sets
Plank	10 with 10 seconds hold	1
Birddog	10 with 10 seconds hold	1
Cat-camel	10 with 10 seconds hold	1
Knee raise	10 with 10 seconds hold	1
Unilateral leg raise	10 with 10 seconds hold	1
Side plank	10 with 10 seconds hold	1

Table 3: Comparison of Age

		Group A- Swiss Ball Exercise	Group B-Lumbar Stabilization Exercise
Age	Mean	24	23.2
	Sd	0.63	0.74
T value		0.27	
P value (independent t test)		0.79	

*P<0.05 is statistically significant (Shapiro Wilkinson test, p>0.05)

Table 4: Comparison of Mmt

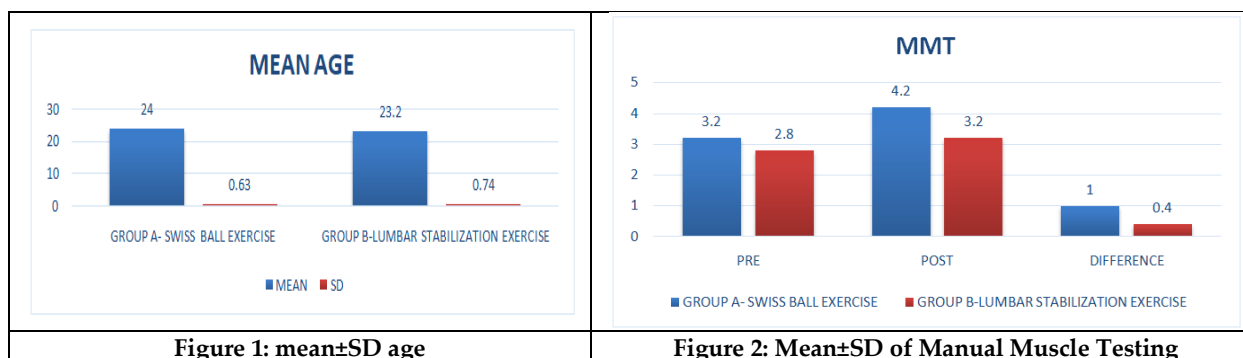
		Group A- Swiss Ball Exercise	Group B-Lumbar Stabilization Exercise	Z value	P value
MMT	Pre	3.2+0.4	2.8+0.4	1.59	0.15
	Post	4.2+0.4	3.2+0.4	3.95	0.004*
Difference		1+0.4	0.4+0.4	2.37	0.04*
Z value		3.95	1.59		
P value		0.004*	0.15		

*P<0.05 is statistically significant (Shapiro Wilkinson test, p>0.05)

Table 5: Comparison of Nprs

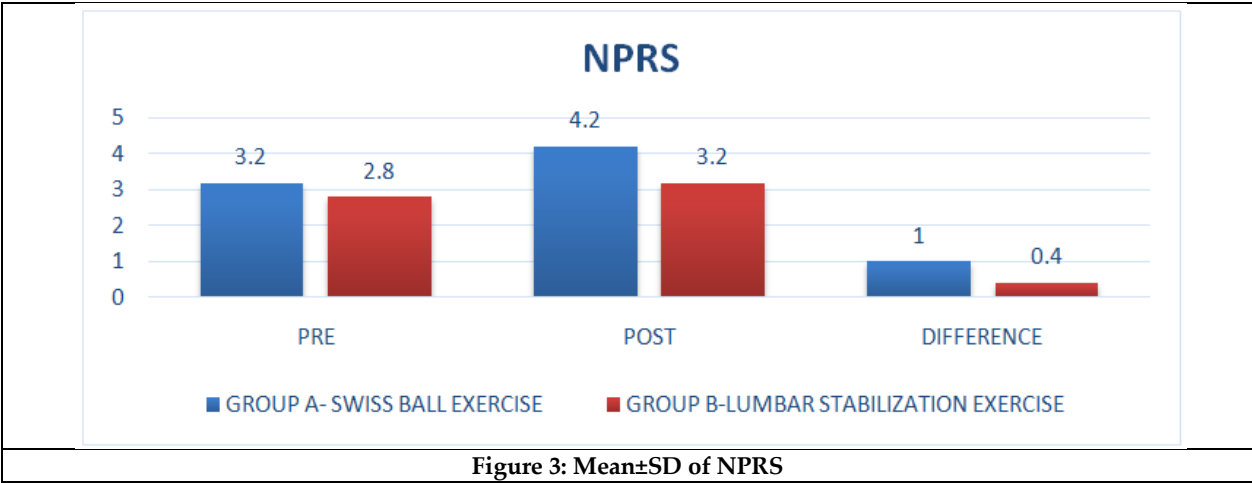
		Group A- Swiss Ball Exercise	Group B-Lumbar Stabilization Exercise	Z value	P value
NPRS	Pre	79.4+2.33	77.6+4.71	0.76	0.46
	Post	84+3.03	78.6+4.58	2.19	0.04*
Difference		5.6+2.86	1+4.6	1.91	0.09
Z value		2.69	0.34		
P value		0.02*	0.74		

*P<0.05 is statistically significant (Shapiro Wilkinson test, p>0.05)





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CASE STUDY ARTICLE

Case Study on Aartavakshaya (Oligomenorrhea and Hypomenorrhea) – Ayurvedic and Clinical Insights

Princy Patel^{1*} and Rita Makim²

¹Final Year P.G. Scholar, Department of Prasuti Tantra Evum Stree Roga, Parul Institute of Ayurved, Parul University, Limda, Waghodia, Vadodara, Gujarat, India.

²Professor, Department of Prasuti Tantra Evum Stree Roga, Parul Institute of Ayurved, Parul University, Limda, Waghodia, Vadodara, Gujarat, India.

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*Address for Correspondence

Princy Patel

Final Year P.G. Scholar,

Department of Prasuti Tantra Evum Stree Roga,

Parul Institute of Ayurved, Parul University,

Limda, Waghodia, Vadodara, Gujarat, India.

E.Mail: patelprincy722@gmail.com



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ABSTRACT

Oligomenorrhea, often referred to as *Aartavkshaya* in Ayurveda, is a menstrual disorder characterized by infrequent or scanty menstrual bleeding. This case study delves into the clinical presentation, diagnostic evaluation and management of a patient diagnosed with oligomenorrhea. The patient's medical history, physical examination findings and investigations are thoroughly described. The Ayurvedic perspective on *Aartavkshaya* is explored, highlighting its underlying pathophysiology and therapeutic approaches. Ayurvedic principles in the management of this condition is discussed, emphasizing the importance of a holistic approach. Treatment focuses on addressing the root cause and may include lifestyle modifications, hormonal therapies, and stress management techniques. Early intervention is crucial for restoring menstrual regularity and improving overall health. Awareness of oligomenorrhea is essential for effective management and to mitigate potential long-term health consequences. This case study aims to contribute to a better understanding of oligomenorrhea and its management, both from conventional and Ayurvedic perspectives.

Keywords: *Ayurveda, Artava Kshaya, Artavadushti, Hypomenorrhea, Ksina Artavadushti, Oligomenorrhoea, Shaman Chikitsa.*





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INTRODUCTION

Aartavakshaya, often equated with oligomenorrhea in modern medicine, refers to a condition characterized by infrequent menstrual cycles with intervals exceeding 35 days. It is a common menstrual irregularity affecting women of reproductive age and can significantly impact their overall health and quality of life. Oligomenorrhea is frequently associated with various etiological factors, including hormonal imbalances, polycystic ovarian syndrome (PCOS), thyroid disorders, stress, and obesity. It is often considered an early indicator of underlying endocrine dysfunctions, such as anovulation or hyperandrogenism. In Ayurveda, *Aartavakshaya* is described as a state of diminished or irregular menstrual flow resulting from an imbalance in *Vata* and *Pitta* doshas, impaired *Agni* (digestive fire), and accumulation of *Ama*(toxin). Such imbalances disrupt the reproductive tissues (*Artava-Dhatu*) and channels (*ArtavavahaSrotas*), leading to menstrual irregularities. The majority of menstruation diseases have been discussed in *Ayurvedic* classics under the term *Artavadushti*. One of the varieties of *Ashta-Artavadushti* is *Ksina* (scanty) *Artavadushti*. *Pitta* and *Vayu* together cause *KsinaArtavadushti*. Classical texts highlight the significance of addressing lifestyle factors, dietary habits, and mental stress in managing *Aartavakshaya*[1].

Case Report

An unmarried girl aged 22yrs visited the Outpatient department of Prasuti Tantra EvumStreeRoga, Parul Ayurveda Hospital, Vadodara on 29/09/2023, with complaints of irregular scanty menses since 6 months associated with mood swings and lethargy.

Past History: No relevant History.

Family History: No history of similar problem any of the family members.

Menstrual History

LMP	05/08/2023
Previous LMP	10/06/2023
Regularity	Irregular
Interval	50-60 days
Duration	2-3 days
No. of pads/day	1-2 Pads (Not fully soaked)
Pain	Present
Consistency	No Clots
Colour	Dark Red
Odour	No foul smell
Discharge	Present

Obstetric History: Nulligravida (unmarried)

Personal History (Table:2)

Diet	Veg.
Appetite	Good
Bowel	Satisfactory (once in a day)
Micturition	5-6 times/day
Sleep	Sound
Addiction	None

General Examination

Built - Average

Blood Pressure – 120/70 mmHg

Pulse –92/min





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Temperature – 98.3°F

Hight – 162 cm

Weight – 50 kg

BMI – 19.1 kg/m²

Pallor - Absent

Icterus - Absent

Oedema - Absent

Cyanosis - Absent

Clubbing - Absent

Lymphadenopathies– Absent

Systemic Examination

RS –Air entry bilateral equal, no added sounds

CVS – S₁S₂ normal

CNS – Conscious and well oriented

Asthavidha pariksha	Dashvidha pariksha
1. Nadi – Vataj 2. Mala – Samyak 3. Mutra – Samyak 4. Jihwa – Niram 5. Shabda – Spashta 6. Sparsha – Anushnasheeta 7. Drik – Prakrut 8. Aakriti - Madhyam	1. Prakriti – Pitta-Kaphaj 2. Vikruti – Vata 3. Sara – Madhyam 4. Samhanana – Madhyam 5. Satva – Pravar 6. Satmya – Pravar 7. Aahar Shakti Abhyavarana Shakti – Madhyam Jaran Shakti – Madhyam 8. Vyayam Shakti – Pravar 9. Pramana – Madhyam 10. Vaya - Madhyam

Local Examination

Per abdomen

Inspection- No discolouration was observed.

Palpation- Soft, No tenderness, No organomegaly

Auscultation – bowel sounds present 1 in every 3-4 minutes

Peristaltic sounds were heard well.

Investigations

USG Abdomen Pelvis: Uterus-75×34×40 mm, normal size, ET-5mm,

Rt. ovary- 35×20×18 mm, Lt. ovary- 34×19×17 mm, normal echotexture, no dominant follicle or cyst, No evidence of polycystic ovarian morphology.

No focal lesions, no significant abnormality noted.

Sampraptighatak

Dosha – Vata, Pitta

Dushya – Rasa, Rakta, Shukra

Srotas –Rasavaha, Raktavaha, Aartavavaha

Udbhavasthana –Pakvashaya

Vyaktisthana –Garbhashaya



**Chikitsa/ Treatment Adopted****Oral Medications:**

Timeline of medications (Table 1).

Follow up Medications (Table 2).

Follow up Medications (Table 3).

Follow up Medications (Table 4).

Follow up Medications (Table 5).

Follow up Medications (Table 6).

Follow Pathyapathya

Pathya	Apathya
- Godhum, Shali, Mudga, Masha, Kulattha, Amalaki, Shigru. - Yoga, Pranayam and Suryanamaskara.	- Spicy, Oily, Overeating, Fried food, Bakery items, Fermented items, Carbonated drinks, Dairy products. - Mental stress, worries, over anxiety.

RESULTS AND DISCUSSION

The clinical management of *ArtavaKshaya* was assessed in a female patient presenting with symptoms of irregular cycles, reduced menstrual flow, and associated discomfort. The treatment protocol included dietary modifications, herbal formulations, and lifestyle changes based on Ayurvedic principles. The observations were as follows

Improvement in Menstrual Flow

Before treatment: Menstrual flow lasted for 1–3 days, with dark red blood.

After treatment: Flow normalized to 3–4 days with a healthier red color.

Regularization of Cycle

Pre-treatment: Delayed cycles of 50-60 days.

Post-treatment: Cycles regularized to 28–32 days within three months.

Relief in Associated Symptoms

Abdominal pain, mood swings, and lethargy significantly reduced after two months of therapy.

Improvement in Overall Health, Improvement in digestion and reduction in constipation were noted, Increased energy levels and better sleep quality were reported.

The Ayurvedic approach to its management focuses on correcting these imbalances, rejuvenating the reproductive system, and improving systemic health. Below is a discussion of key Ayurvedic medicines used for this condition

DashamoolaKwath: *Dashamoola*, comprising the roots of ten medicinal plants, primarily pacifies *Vata dosha* and reduces inflammation. Its anti-inflammatory and analgesic properties relieve pelvic congestion and enhance uterine health, facilitating regular menstruation. It also supports *Srotas* (body channels) to ensure proper blood flow and nutrient transport to the reproductive tissues.[2]

Punarnava Kwath and Churna: *Punarnava* (*Boerhaviadiffusa*), used in both *Kwath* (decoction) and *Churna* (powder) forms, is a renowned diuretic and anti-inflammatory agent. It detoxifies the body, reduces pelvic congestion, and enhances circulation in the reproductive system. These actions help regulate hormonal balance and improve uterine function, addressing scanty menstruation.[3][4]

Rajahpravartini Vati: This formulation includes emmenagogue herbs like *Hing* (*Asafoetida*) and *Kaseesa* (Iron sulphate), which stimulate uterine contractions and regulate menstrual flow. It balances *Vata* and *KaphaDoshas*, directly addressing delayed or suppressed menstruation by promoting blood circulation in the uterus[5].



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Kanyalohadi Vati: Containing *Kumari* (Aloe vera) and *Lohabhasma* (iron), this *Vati* works on *Rakta Dhatu* and promotes uterine health. It replenishes iron deficiency, enhances blood production, and balances hormones to regulate menstruation[6].

Ashwagandha Churna: *Ashwagandha* (*Withaniasomnifera*) is an adaptogen that reduces stress and balances *Vata*. Stress is a common contributor to hormonal imbalance and menstrual irregularities. By rejuvenating the reproductive tissues and reducing oxidative stress, it supports regular menstrual cycles[7].

Shatavari Churna: *Shatavari* (*Asparagus racemosus*) is a potent uterine tonic and hormonal modulator. It nourishes *rasa dhatu* and promotes the production of oestrogen, which is crucial for maintaining a healthy menstrual cycle. It also supports reproductive health by balancing *Pitta Dosha*. [8][9]

YashtimadhuChurna: *Yashtimadhu* (*Glycyrrhiza glabra*) has anti-inflammatory and adaptogenic properties, promoting hormonal balance and reducing uterine inflammation. It also nourishes the reproductive tissues and supports the endocrine system[10].

Punarnava Mandoor: This iron-rich preparation addresses anemia, a common underlying cause of scanty menstruation. It improves haemoglobin levels, enhances blood circulation, and detoxifies the body, ensuring better oxygen and nutrient delivery to the reproductive system[11].

Chandraprabha Vati: This multi-herb formulation rejuvenates the reproductive and urinary systems, balancing *Tridoshas* and detoxifying the body. It enhances uterine function, hormonal regulation, and systemic metabolism, all contributing to healthy menstrual cycles[12].

Trikatu and Panchakola Churnas: Both formulations enhance *Agni* (digestive fire) and improve nutrient assimilation. They reduce *Ama* (toxins) in the body, which can obstruct channels and contribute to hormonal imbalances. By improving digestion and metabolism, they indirectly support reproductive health[13][14].

CONCLUSION

The case study on *Aartavakashaya* highlights the intricate interplay between hormonal imbalances, lifestyle factors, and their impact on menstrual health. Through a holistic approach combining Ayurvedic principles and dietary modifications, significant improvements were observed in the patient's menstrual cycle regularity, pain management, and overall well-being. The treatment regimen comprised

Internal Medication: *Dashamoola Kwath*, *Punarnava Kwath and Churna*, *Rajahpravartini Vati*, *Kanya Lohadi Vati*, *Ashwagandha Churna*, *Shatavari Churna*, *YashtimadhuChurna*, *RasayanChurna*, *Punarnava Mandoor*, *Chandraprabha Vati*, *TrikatuChurna*, *PanchakolaChurna*.

Lifestyle Modifications: Dietary recommendations, sleep hygiene, stress management techniques, etc.

This case study highlights the efficacy of Ayurvedic medicine in managing *Aartavakashaya*. The personalized approach, considering the individual's unique constitution (*Prakriti*) and disease manifestation (*Vikruti*), is crucial for achieving optimal results. The study not only reaffirms the relevance of Ayurveda in contemporary healthcare but also serves as a reminder of the importance of individualized treatment protocols for achieving long-term health benefits.





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Table 1: Timeline of medications

DATE	C/O;	TREATMENT
29/09/2023	Irregular Scanty Menses, Mood swings, Lethargy since 6 months. LMP – 05/08/2023	1. <i>DashamoolaKwath</i> + <i>Punarnava Kwath</i> = 40ml luke warm BD B/F 2. <i>Rajahpravartini Vati</i> 2 BD A/F with warm water 3. <i>Kanyalohadi Vati</i> 2 BD A/F with warm water For 30 days

Table 2: Follow up Medications

DATE	C/O;	TREATMENT
13/10/2023	No any complaints. LMP – 07/10/2023	1. <i>RajahpravartiniVati</i> 2 BD A/F with warm water 2. <i>Ashwagandha Churna</i> + <i>Shatavari Churna</i> + <i>YashtimadhuChurna</i> + <i>RasayanChurna</i> = each 1 grams BD A/F with warm water For 30 days

Table 3: Follow up Medications

DATE	C/O;	TREATMENT
08/12/2023	Constipationsince 1 week. LMP – 20/11/2023	1. <i>Rajahpravartinivati</i> 2 BD A/F with warm water 2. <i>Punarnava Mandoor</i> 2 BD A/F with warm water 3. <i>Ashwagandha Churna</i> + <i>Shatavari Churna</i> + <i>YashtimadhuChurna</i> + <i>RasayanChurna</i> = each 1 grams BD A/F with warm water 4. <i>TriphalaChurna</i> 2 grams HS with hot water For 15 days





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Table 4: Follow up Medications

DATE	C/O;	TREATMENT
29/12/2023	No any complaints. LMP – 25/12/2023	1. <i>Rajahpravartini</i> 2 BD A/F with warm water 2. <i>Punarnava Mandoor</i> 2 BD A/F with warm water 3. <i>Ashwagandha Churna</i> + <i>Shatavari Churna</i> + <i>YashtimadhuChurna</i> + <i>RasayanChurna</i> = each 1 grams BD A/F with warm water For 15 days

Table 5: Follow up Medications

DATE	C/O;	TREATMENT
16/02/2024	No any complaints. LMP – 23/01/2024	1. <i>Chandraprabha Vati</i> 2 BD A/F with warm water 2. <i>Kanyalohadi Vati</i> 2 BD A/F with warm water 3. <i>Shatavari Vati</i> 2 BD A/F with warm water For 15 days

Table 6: Follow up Medications

DATE	C/O;	TREATMENT
23/02/2024	No any complaints LMP – 23/02/2024	1. <i>Shatavari Vati</i> 2 BD A/F with warm water 2. <i>RasayanChurna</i> + <i>TrikatuChurna</i> + <i>PanchakolaChurna</i> + <i>Ashwagandha Churna</i> = each 1 grams BD A/F with warm water For 15 days





RESEARCH ARTICLE

Memory and Performance Synergy in Post-Quantum Digital Signature Schemes

Alvary Kefas Kwala^{1*}, Alpna Mishra² and Shri Kant³

¹Ph.D Scholar, Department of Mathematics, Sharda University, Greater Noida, Uttar Pradesh, India.

²Associate Professor, Department of Mathematics, Vivekananda Institute of Professional Studies - Technical Campus (VIPS-TC), Pitampura, New Delhi, Delhi, India.

³Professor, Department of Computer Science, Sharda University, Greater Noida, Uttar Pradesh, India.

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*Address for Correspondence

Alvary Kefas Kwala

Ph.D Scholar,

Department of Mathematics,

Sharda University, Greater Noida,

Uttar Pradesh, India.

E.Mail: 2022823335.alvary@dr.sharda.ac.in



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ABSTRACT

This paper examines the balance between memory efficiency and performance in post-quantum digital signature schemes, focusing on code-based, hash-based, and lattice-based algorithms. It evaluates key schemes such as Dilithium, Falcon, and SPHINCS+ in terms of memory usage, processing speed, and suitability for IoT, healthcare, and financial applications. The analysis highlights that Dilithium is well-suited for low-memory systems, Falcon offers fast verification, and SPHINCS+, though memory-intensive that provides strong security for high-assurance environments. The study underscores the importance of selecting algorithms based on specific application needs and calls for improved strategies to manage memory usage in quantum-resistant implementations. These insights support the development of secure and efficient digital signatures across various sectors.

Keywords: Digital Signature Scheme, Post-quantum Cryptography, Quantum-resistant Algorithm, Performance efficiency, Cryptographic Security levels

INTRODUCTION

With the rise of quantum computing, traditional cryptographic systems like RSA and ECC are increasingly at risk. In response, post-quantum cryptography (PQC) has emerged to develop algorithms secure against quantum threats[1]. This study focuses on digital signatures, a crucial cryptographic primitive used to ensure data integrity and authenticity. Post-quantum digital signature schemes face unique challenges, including large key and signature sizes



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and high computational requirements. Additionally, memory usage and operational efficiency are critical performance factors, especially for systems operating in resource-constrained environments.

Role of Digital Signature in PQC

In the realm of PQC, digital signatures play a vital role in maintaining core security properties such as data integrity, authenticity, and non-repudiation. As quantum computing threatens classical cryptographic algorithms like RSA and ECC[2], quantum-resistant digital signature schemes have been developed to safeguard sensitive information from powerful quantum attacks. These signatures ensure that data remains unaltered during transmission, verify the sender's identity to prevent impersonation, and provide non-repudiation, ensuring that senders cannot deny their actions. These capabilities make digital signatures essential to post-quantum security systems across various applications, including secure commercial transactions and confidential government communications.

Contribution of this Study

In this paper, memory and performance efficiency in quantum-resistant digital signature schemes are examined, which advances the field of PQC. The principal contribution consists of assessing the resource requirements of several PQC algorithms, with an emphasis on their suitability for situations with limited memory and computing power, such as embedded technologies, healthcare systems, and Internet of Things devices. This study compares the main PQC signature schemes, such as lattice-based, hash-based, and code-based algorithms in terms of key generation, signing, and verification, to determine the best solutions based on a trade-off between security and resource requirements. The results provide useful information on the performance of each method and the comparison results suggest appropriate decision-making for implementing quantum-resistant digital signatures in practical scenarios. Also, this study provides the base for further refinement and development of PQC algorithms for practical application on a large scale in various fields.

Background and Related Work

Overview of Digital Signature Process

The digital signature scheme [3], as shown in Figure 1, is a two-step process where it is mainly executed by two entities, namely, the signer and the verifier. First the signer creates a hash value with the data using a hash function; afterwards the signer encrypts the hash value with their private key using a signature algorithm to get the signature. The first data and the digital signature are transmitted to the verifier. If the data and the signature have been received and signed then the verifier use the public key of the signer to decrypt the digital signature. A new hash value is then generated from the above received data and checked with the decrypted hash value by the receiver unit. If there is an exact match to both hash values, then the data has been secured as well as the data integrity and originality has been proven valid.

Key Families of PQC Algorithms

Post-quantum digital signature algorithms are described and are categorized in several types of cryptographic systems originating from several 'hard' mathematical problems. Among the three most well-known families are:

Lattice-Based Signatures

Lattice-based cryptography is cited among the most promising categories of PQC. There are some new schemes proposed for implementing digital signatures such as Dilithium [4] and Falcon [5]. These algorithms are based on the hardness of the well-known Short Integer Solution (SIS) [6] and Learning with Errors (LWE) [7] problems for which no efficient solutions have been found despite attack from quantum computers. Lattice-based signatures, in general, have a satisfactory level of security-to-performance ratio. Nevertheless, their memory storage especially for the key storage and signature creation is comparatively higher due to the large size of the key and signature.

Hash-Based Signatures

Post-quantum hash-based signatures, like SPHINCS+[8], rely only on the security of cryptographic hash functions least susceptible to quantum attacks. These algorithms are also said to be stateless and come with long term security



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assurances. However, they commonly tend to need more memory to create the signature and verify it since hash trees and signatures' strings often become really large [9]. Still, at the same time, SPHINCS+ can provide interesting features in many use cases where exchanging large memory resources for higher security and reliability can be possible [10].

Code-Based Signatures

Code-based signatures like Classic McEliece schemes support error-correcting codes for quantum resistance [11]. Despite the excellent security guarantees of these schemes, they are much larger than lattice- and hash-based peers, so memory optimization is a critically important issue for practical applications.

RELATED WORK

Vidaković and Miličević[12] evaluated the performance of post-quantum digital signature algorithms—Crystals-Dilithium, Falcon, and SPHINCS+—on limited-resource IoT devices and Smart Cards. Their study found Falcon to be the fastest in verification, making it ideal for applications requiring frequent verification, such as car-to-car communication. However, SPHINCS+ exhibited high computational demands due to its reliance on hash functions, limiting its suitability for low-resource environments unless hardware acceleration is available. Crystals-Dilithium emerged as a balanced option, offering good performance with relatively low resource requirements, making it suitable for low-power devices. Building on this, Roma *et al.*, [13] assessed the energy efficiency of post-quantum digital signature schemes using the Performance API (PAPI) on an Intel Core i7-6700 CPU. Their findings showed that lattice-based schemes outperformed code-based and isogeny-based schemes in energy usage, making them preferable for battery-powered and resource-constrained systems due to their efficient energy profiles and robust security. Liu, Ramachandran, and Jurdak[14]extended the analysis to lightweight IoT devices, highlighting the computational complexity of PQC schemes as a significant barrier. They concluded that while some PQC implementations are feasible, the lack of standardized optimization techniques necessitates further collaborative research to enable efficient deployment in constrained environments. Seyhan *et al.*[15]focused on the practicality of lattice-based schemes for IoT devices with limited resources. They categorized devices based on constraints and identified real-world implementation challenges, especially related to limited memory and processing power. Similarly, Fournaris *et al.*,[16]discussed the memory challenges posed by many PQC schemes, noting that while memory requirements are often high, optimizations can allow these algorithms to be used effectively on constrained devices without overwhelming system resources.

Implementation and Experimental Setup

CLI Application and liboqs Library Integration

PQC digital signature schemes were assessed using a custom Command-Line Interface (CLI) application built with the liboqs library from Open Quantum Safe. This integration enables users to perform quantum-resistant signature operations directly via command-line inputs. The application supports essential cryptographic functions such as key generation, signing, and verification. Developed using Python's Click library, the CLI offers a user-friendly and intuitive command structure—for example, the generate-keypair command creates a secure keypair and signs a file to verify its authenticity. The tool also allows flexible testing of various PQC algorithms by adjusting configuration parameters, making it valuable for evaluating memory and performance impacts. Overall, it provides an efficient way to experiment with and implement quantum-safe digital signatures in practical applications.

Virtual Machine Environment

Digital signature schemes were implemented and tested in a virtual machine (VM) environment using VMware Workstation 16 with Ubuntu 24.04 LTS. This VM setup was chosen for its standardized and controlled environment, which ensures accurate and reproducible performance measurements. The isolated nature of the VM minimizes external variables that could influence cryptographic results, making it ideal for benchmarking memory and processing demands. Additionally, the VM can be saved and cloned, enabling consistent configuration sharing across



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different systems. This reproducibility supports reliable testing at all development stages of post-quantum algorithms. The VM configuration strikes a balance between performance and resource efficiency, allowing effective execution of cryptographic operations with optimized memory and CPU usage.

Analysis of Memory and Performance in PQC Algorithms**The Standard NIST Algorithm Specifications**

In the specifications of each digital scheme [17] along with security strengths in terms of NIST Security Levels [18] as shown in Table 1, they quantify how much effort or process is necessary to break the cryptographic algorithms, and the systems offer a fixed security level. That goes from Level 1 which gives the least degree of security to the highest level of security which is Level 5 [19]. Table 1 also provides the sizes of the public keys, secret keys, and signatures, all of which are expressed in bytes. It is important to keep in mind that clients need to be aware of how resource needs and security level are balanced. This information can assist in selecting the appropriate algorithm for a certain security scenario.

Memory Usage Across Key Operations

The outcome is expressed in terms of mean values obtained from 50 performed operations demonstrating how the memory requirements change in the case of key pair generation, signing, and verification. To complement the quantitative results, graphs are presented to show the memory usage patterns of the algorithms as the file sizes vary and determine their suitability in environments where memory is a limiting factor. It offers a complete and repeatable approach to measuring the memory requirements of post-quantum digital signature algorithms in different application environments. To evaluate the memory footprint of post-quantum digital signature schemes, a controlled virtual machine environment was used to establish a standardized testing methodology. The focus was on measuring memory usage during three key operations: keypair generation, signing, and verification, across three algorithm families: Dilithium, Falcon, and SPHINCS+. Message files of varying sizes (1 KB to 1 MB) were generated using the Linux *dd* command with data from */dev/urandom* to simulate real-world use cases and assess memory scalability. Each cryptographic operation was repeated 51 times per algorithm, with the first result discarded to eliminate anomalies from cache warming and disk access. This ensured accurate measurement of intrinsic memory usage. Post-operation cleanup removed keypairs and signatures to maintain a consistent test state. Results were reported as average values from 50 runs and supported by graphs that illustrate how memory consumption changes with file size, highlighting each algorithm's suitability for memory-constrained environments. The approach provides a rigorous, repeatable framework for assessing the memory demands of PQC digital signature schemes in practical applications.

Group 1: Dilithium

The first family includes the Dilithium2, Dilithium3, and Dilithium5 algorithms. The memory footprint for the group is low for all operations, and particularly so when generating a keypair. Memory consumption for keypair generation, signing and verification as a function of message size across the three Dilithium algorithms are illustrated in Figure 2. Figure 2 shows that memory consumption during keypair generation is generally low, with Dilithium2 using almost 0 bytes and Dilithium5 requiring around 10 KB. For signing and verification, memory usage increases with larger message sizes, exceeding 1 MB for messages of 1,048,576 bytes. Although Dilithium5 shows a slightly higher peak memory usage compared to Dilithium2 and Dilithium3, all variants in the Dilithium family demonstrate efficient memory performance, even with large message sizes. This makes the Dilithium family well-suited for environments with strict memory constraints.

Group 2: Falcon

The second group is the Falcon-512, Falcon-1024 alongside several padded versions of these two. It can be seen from figure 3, that these algorithms have a higher memory requirements compared to the Dilithium group, mainly during keypair generation and signing operations. Falcon-1024 and its padded variations need considerably more memory than Falcon-512, which starts with about 9 KB for keypair creation. Like the Dilithium group, signing uses a lot of memory as message size increases, but at a greater starting memory consumption. For example, signing requires



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more than 1 MB of memory at the 1048576-byte message size. In contrast to signing, verification procedures show a more progressive memory rise as message sizes increase. Memory needs are directly impacted by key size selection, as Falcon-1024 constantly uses more memory than Falcon-512.

Group 3: SPHINCS+

The third family, includes a number of SHA2 and SHAKE-based variants of SPHINCS+. In contrast, SPHINCS+ algorithms typically require larger amounts of memory for their keypair generation, signing, and verification than either the Dilithium or Falcon groups. Memory used for SPHINCS+ algorithms is shown in Figure 3. Memory used by post-quantum signature schemes can be divided into three major operations: key generation, signature-generation and signature-verification. The memory demand in each operation varies also based on the algorithm used. Memory Consumption across SPHINCS+ Algorithms (Fig. 4). Among SPHINCS+ variants, for keypair generation the memory usage differs, and some algorithms such as SPHINCS+-SHAKE-192s-simple have a requirement of more than 6 KB in total. The difference is even more pronounced for signing, as SPHINCS+-SHA2-256s-simple requires well over 100 KB just to sign larger messages. As with the other groups, memory usage scales a lot for larger message sizes but remains lower when verifying than signing. SHAKE-based variants of SPHINCS+ are generally more memory expensive for keypair generation and signing than SHA2-based ones. Overall, Dilithium 2 is well-suited for devices with constrained memory resources as it continuously exhibits the maximum memory efficiency across every operation. When compared to other post-quantum digital schemes, Dilithium3 and Dilithium5 are still efficient while using a little more memory. Memory usage, however, for Falcon-512 and Falcon-1024 is substantially larger in correspondence to large key size. In particular, Falcon-1024 has a significantly higher memory footprint when generating keypairs and during signing, but it's no surprise that it offers the highest level of cryptographic security available, which may be worth the memory tradeoffs in high-security environments.

Post-Quantum Digital Signature Scheme Performance Analysis

Performance Metrics

With the same virtual environment configuration detail, we evaluated the performance of three critical cryptographic operations including key generation, signing, and verification for the three classes of the algorithms (Dilithium, Falcon, and SPHINCS+). This helped create some amount of control to ensure that measurements are not skewed by any external conditions. Each operation was examined when the messages varied in size from 1024 bytes through 10,240 bytes and then on to 102,400 bytes and 1,048,576 bytes to gauge scalability and responsiveness to applications of which time is an important factor. Systematically, this study can show how each of the algorithms reacts to different file sizes, showing their flexibility for problems that may come with different data loads. To enhance this performance analysis, there are graphs incorporated to indicate time disparities of the schemes during each of the operations presented in Figure 5, Figure 6, and Figure 7. These visualizations improve understanding since they offer direct insight into the variations of performance, and are useful for practical application insights of the best algorithms for a specific application. The time required for key generation with Dilithium algorithms is very low and therefore they are suitable for fast key generation purpose applications. On the contrary, Falcon algorithms have longer generation times since they deal with larger key sizes, especially Falcon-1024. As indicated in figure 5 the performance for SPHINCS+ algorithms differs widely; although some of its variations are fast than other ones, especially SHA2-based are relatively slow because the cryptographic functions that they are built on have a greater complexity. In situations where key generation is necessary often, Dilithium provides a clear speed advantage. The signing time for each algorithm at various message sizes are shown in Fig. 6. All the algorithms have similar performance for small messages. On the other hand, for large messages Falcon algorithms provide a stable behaviour with moderate time increase that makes them appealing when applications may use different message sizes. Although for messages of larger size, the signing time grows a little bit and therefore Dilithium schemes are also efficient when considering it as a special case. SPHINCS+ algorithms—particularly those based on SHAKE—for signing messages of larger size see a significant increase in the time it takes to sign, which may not be convenient for applications requiring high volume or real-time signing. Fig.7 shows the verification time of the algorithms for 1024 bytes, 10240 bytes, 102400 bytes, and 1048576 bytes message sizes. The algorithms based on Dilithium provide fast verification times across the board, and even for large messages, which qualifies them as one of the best schemes for



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interactive real-time verification applications. Falcon schemes tend to be a little slower than Dilithium, but they also offer consistent performance with only a little increase in verification time. SPHINCS+ algorithms, especially SHAKE-based configurations, are more pronounced, with the verification time increasing faster for larger messages. Dilithium could be the most time-efficient option for applications that need high-speed verification. Performance patterns in key generation, signing, and verification highlight the schemes' strengths and weaknesses. These trends help choose the optimal post-quantum digital scheme for a range of time-sensitive and resource-constrained applications.

Cumulative Memory-Time Impact Analysis of the Algorithms

Cumulative Memory-Time impact assessment provides a piecemeal view of the cumulative resource needs (time and memory usage) for each algorithm while working with different sizes of messages. A stacked area format gives, an effective visualization of how four message sizes (1024 bytes, 10240 bytes, 102400 bytes and 1048576) layered one on top of another will contribute to each algorithm's accumulated resource footprint. The distance between two layers in figure 8, represents the embedded message size and layer color indicates how much intensive they are with respect to increasing message sizes (the more intense a color is the larger the messages it encodes). This depiction serves as a birds-eye view comparing the various algorithms and their scalability with respect to memory and time. Using visual layering helps us visualize the additive effect of larger message sizes on each scheme, while this can be useful in uncovering potential scalability issues. In particular, as we compare schemes on the right-most side (especially in SPHINCS+ family), which significantly have a larger cumulative impact than all other schemes (particularly above messages size of 1048576 bytes). By comparison, digital schemes such as Dilithium2 and Dilithium3 on the far left exert a cumulative effect that is fairly small, and are therefore better suited for resource-constrained environments. The view gives key information for the decision maker in choosing the post-quantum digital schemes according to memory and performance needs as a function of message sizes. Table 2 describes a comparative evaluations of the average time it takes to generate a keypair, sign with that key and verify the signature with an estimated level of memory usage for each category (Low, Moderate or High). Although Figure 8 offers visual information, the Table 2 gives a summary of typical performance indicators to assist determine which scheme is best for a particular application. The streamlined resource features of Dilithium may result in certain security trade-offs, even if they are resource-efficient and ideal for settings with strict memory limitations. At the expense of slightly longer generation times, Falcon schemes provide a balanced option with better cryptographic qualities and a reasonable memory use. Finally, SPHINCS+ schemes show substantial cumulative memory and performance costs, especially for large message sizes, while having a strong security feature. This suggests that they would be appropriate for applications with less restricted resource availability.

Applications of Digital Schemes in Real-World Scenarios

Post-quantum digital signature schemes such as Dilithium, Falcon, and SPHINCS+, offer distinct advantages across various real-world applications based on their performance and resource requirements. In resource-constrained environments such as IoT devices and telemedicine systems, Dilithium is preferred for its low memory and computational needs, making it suitable for wearables, smart locks, and real-time health monitoring. Falcon, with its fast verification capabilities, fits well in financial services that demand high transaction throughput, such as online banking and trading platforms. SPHINCS+, though resource-intensive, is favored in settings where strong quantum resistance is essential, such as the long-term storage of health records or protecting sensitive financial and governmental data. In government, defense, and smart city infrastructures, where both extreme security and varying hardware constraints exist, a hybrid deployment strategy is effective. SPHINCS+ is ideal for securing centralized, high-value assets like defense databases and city data centers, while Dilithium supports secure field operations and distributed sensor networks under tight resource limits. Falcon provides a balanced option for backend systems in smart infrastructure and financial systems. Together, these schemes enable robust, quantum-resistant security tailored to the diverse needs of modern digital environments [21–25], as shown in figure 9. These case studies demonstrate that the selection of an appropriate digital algorithm largely depends on the particular resource and requirements for the security of the application domain. Dilithium excels in restrictive settings because the scheme has minimal memory and time demand, and is suitable for IoT gadgets. Falcon is less resource intensive yet





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optimally balances the security need making it suitable in businesses such as the financial sectors. SPHINCS+ is ideal for high-security applications where cryptographic resilience is essential but resource needs are lower.

CONCLUSION

The rise of quantum computing is looming and, therefore, becomes an albatross to classical cryptographic systems as it became evident that existing systems are susceptible to PQC. In this paper, post-quantum digital signature schemes have been considered relative to memory consumption and their performance efficiency; the three major families for discussion include lattice-based, hash-based, and code-based cryptography. These schemes are different from each other in terms of their benefits and drawbacks as applied to resource-scarce environments like IoT devices, healthcare, and FinTech. Out of all the schemes analyzed, lattice-based signatures, particularly the Dilithium family, show promising performances regarding the security that can be achieved per the amount of memory required by each operation, which makes them highly deployable in current widespread applications that are characterized by severe memory limitations. From this analysis, Falcon proves optimal in terms of verification speed, and its security requirements are fairly moderate. On the other hand, hash-based schemes such as SPHINCS+ provide a high level of security at the expense of memory use which makes them ideal for high-security applications where memory is a less important factor. The analysis also revealed that as message sizes grow, schemes require more memory and processing power with the largest cumulative impact continuously being displayed by SPHINCS+. This re-emphasizes the necessity to make the choice of post-quantum digital signatures tailored to the particular application domain and the functional resources available at the same time. Consequently, despite significant advancements made by current PQC algorithms toward attaining secure digital signatures in the post-quantum era, it is paramount that researchers enhance the mechanism of memory optimization so that definite parameters of performance benchmarks can be developed. A more seamless transition to a quantum-secure future would be made possible by such developments, which would allow for more effective implementations across a variety of fields

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Table 1: Specifications of Post-quantum Digital Signature Schemes base on NIST [20].

Algorithm	NIST Level	Public Key Size (Bytes)	Secret Key Size (Bytes)	Signature Size (Bytes)
Dilithium2	2	1312	2528	2420
Dilithium3	3	1952	4000	3293
Dilithium5	5	2592	4864	4595
Falcon-512	1	897	1281	666
Falcon-1024	5	1793	2305	1280
SPHINCS+SHA2-128f-simple	1	32	64	17088
SPHINCS+SHA2-128s-simple	1	32	64	7856
SPHINCS+SHA2-192f-simple	3	48	96	35664
SPHINCS+SHA2-192s-simple	3	48	96	16224
SPHINCS+SHA2-256f-simple	5	64	128	49856
SPHINCS+SHA2-256s-simple	5	64	128	29792
SPHINCS+SHAKE-128f-simple	1	32	64	17088
SPHINCS+SHAKE-128s-simple	1	32	64	7856
SPHINCS+SHAKE-192f-simple	3	48	96	35664
SPHINCS+SHAKE-192s-simple	3	48	96	16224
SPHINCS+SHAKE-256f-simple	5	64	128	49856
SPHINCS+SHAKE-256s-simple	5	64	128	29792

Table 2: Comparative Analysis of Cumulative Memory-Time Impact

Algorithm Group	Average Keypair Generation Time (s)	Average Signing Time (s)	Average Verification Time (s)	Cumulative Memory Usage (bytes)
Dilithium	0.00017	0.0012	0.0001	Low
Falcon	0.0073	0.00095	0.0001	Moderate
SPHINCS+	0.0128	0.0155	0.00085	High

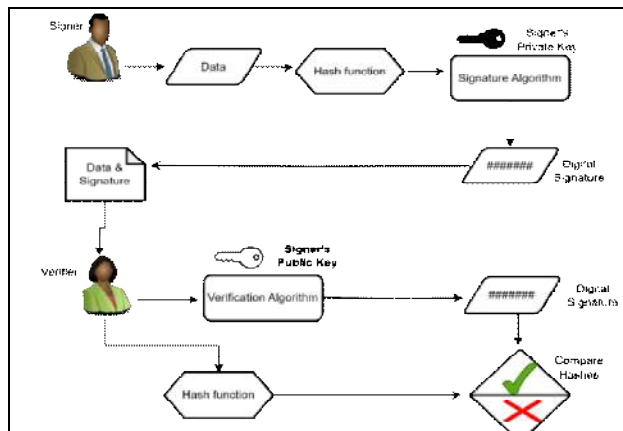


Fig. 1: Digital Signature Scheme

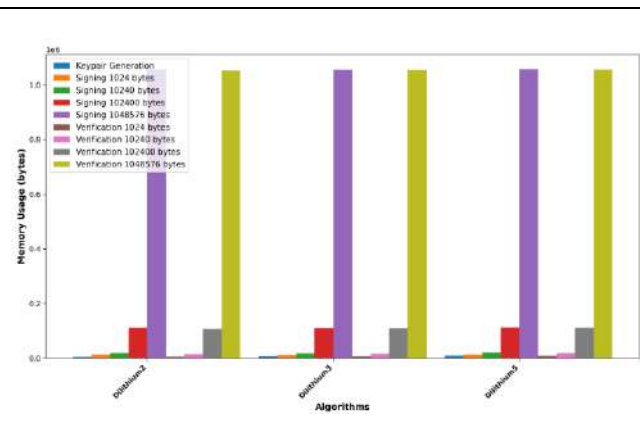


Fig. 2: Memory Consumption across Dilithium Algorithms



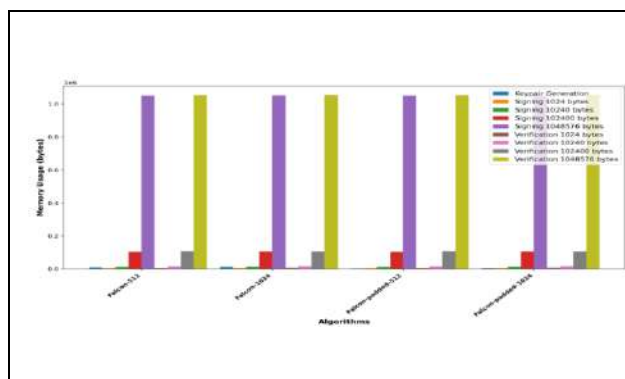
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Figure 3: Memory Consumption across Falcon Algorithms

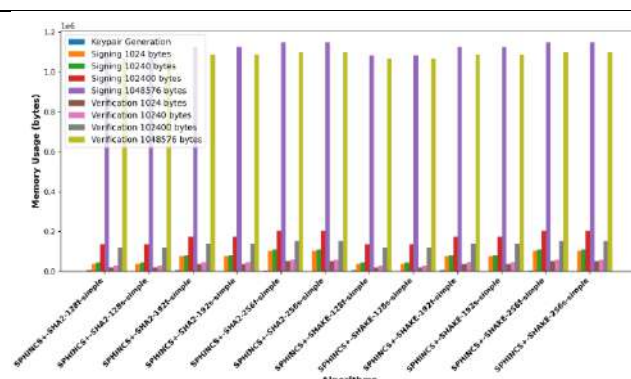


Fig. 4: Memory Consumption across SPHINCS+ Algorithms

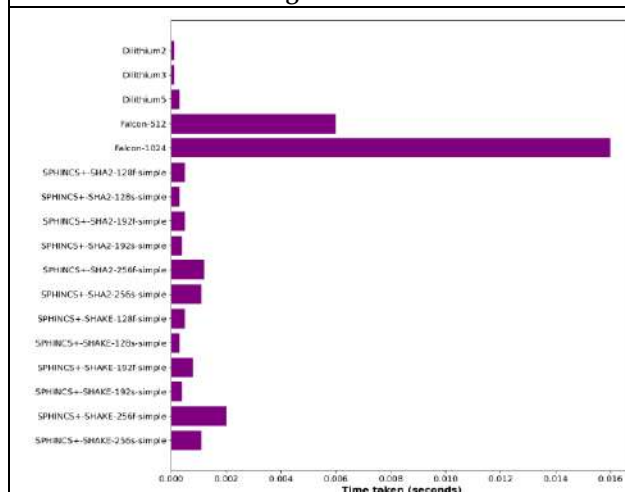


Fig. 5: Digital Signature Scheme Key pair generation

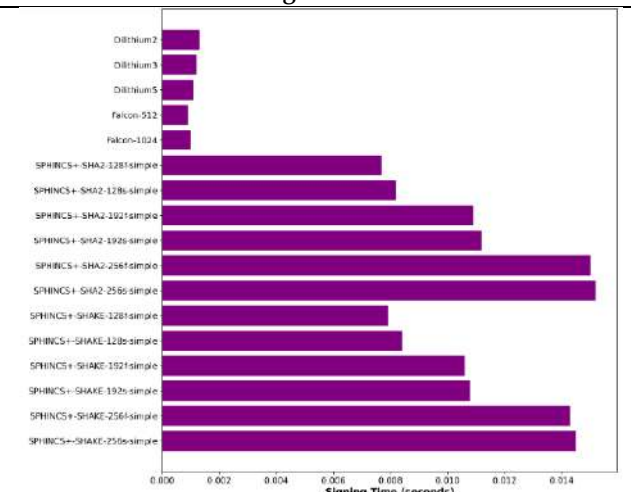


Fig. 6: Digital Signature SchemeKeypair signing

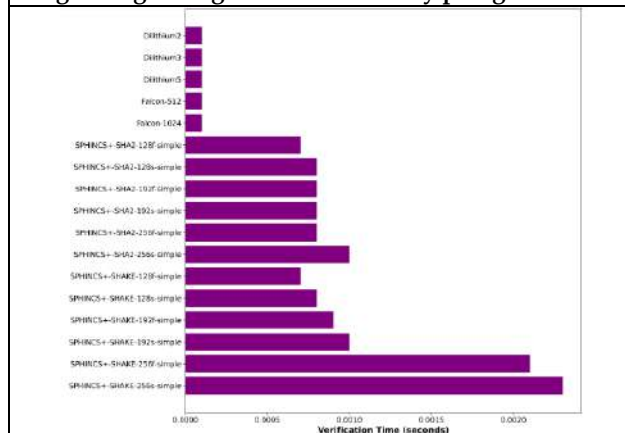


Fig. 7: Digital Signature Scheme Keypair verification

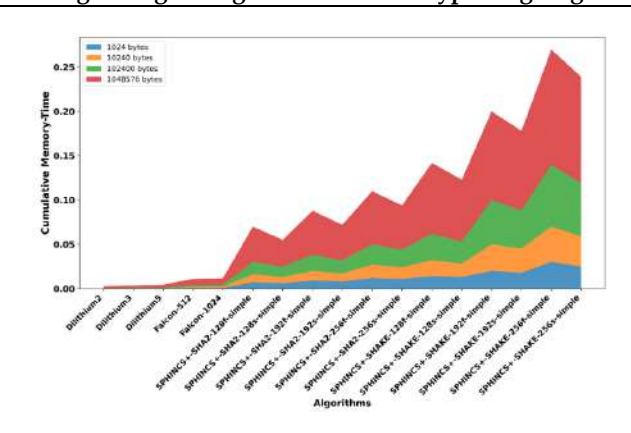


Fig. 8: Cumulative Memory-Time Impact Analysis of the Algorithms





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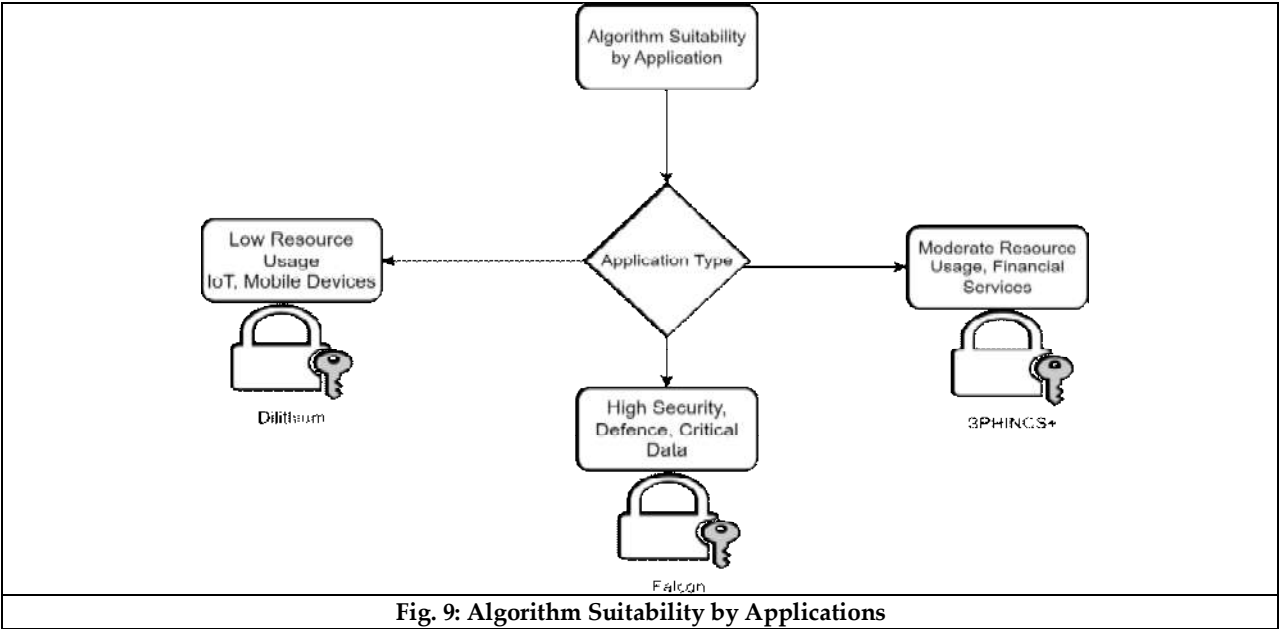


Fig. 9: Algorithm Suitability by Applications





RESEARCH ARTICLE

Fueling the Mind and Body : Keto as a Game - Changer for Autism and Obesity

A.M. Nishali¹, A.J. Hemamalini^{2*} and Soma Basu³

¹Postgraduate Student, Department of Clinical Nutrition, Sri Ramachandra Faculty of Allied Health Sciences, Sri Ramachandra Institute of Higher Education and Research, (Deemed to be University), Porur, Chennai, Tamil Nadu, India.

²Professor and Head, Department of Clinical Nutrition, Sri Ramachandra Faculty of Allied Health Sciences, Sri Ramachandra Institute of Higher Education and Research, (Deemed to be University), Porur, Chennai, Tamil Nadu, India.

³Ph.D. Research Scholar, Department of Clinical Nutrition, Sri Ramachandra Faculty of Allied Health Sciences, Sri Ramachandra Institute of Higher Education and Research, (Deemed to be University), Porur, Chennai, Tamil Nadu, India.

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*Address for Correspondence

A.J. Hemamalini

Professor and Head,

Department of Clinical Nutrition,

Sri Ramachandra Faculty of Allied Health Sciences,

Sri Ramachandra Institute of Higher Education and Research, (Deemed to be University),

Porur, Chennai, Tamil Nadu, India.

E.Mail: hemamalini.aj@sriramachandra.edu.in



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ABSTRACT

The ketogenic diet (KD) is a high-fat, low-carbohydrate, and moderate-protein dietary regimen that induces a metabolic state called ketosis, in which the body predominantly utilizes fatty acids as its primary energy substrate. Initially developed as a therapeutic intervention for epilepsy, the KD has garnered attention for its potential therapeutic applications in various pathophysiological conditions, including obesity and autism spectrum disorder (ASD). This review explores the role of KD in autism and obesity, with particular focus on the underlying mechanisms of action and their clinical implications. An extensive literature review was conducted using databases such as PubMed, Medline, Science Direct, and Google Scholar. A total of twenty peer-reviewed studies published between 2017 and 2024 were selected, encompassing observational studies, clinical trials, and meta-analyses. The primary focus of these studies was the effect of the ketogenic diet on obesity and autism spectrum disorder. The ketogenic diet has shown potential in ameliorating symptoms of ASD, possibly by modulating gut microbiota composition and reducing systemic inflammation. The production of ketone bodies, notably β -hydroxybutyrate, has demonstrated neuroprotective properties, enhancing sociability and cognitive



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function in individuals with ASD. Additionally, KD has proven effective in promoting weight loss in individuals with obesity by optimizing fat metabolism and suppressing appetite. Clinical data indicate significant reductions in body mass index (BMI), triglyceride levels, cholesterol, and fasting blood glucose following KD interventions in obese individuals. The ketogenic diet represents a promising therapeutic approach for both autism spectrum disorder and obesity. Beyond facilitating weight reduction, KD also offers potential benefits in addressing behavioral and cognitive impairments associated with ASD. While KD remains a valuable therapeutic strategy, its complexity necessitates careful management in clinical settings for optimal outcomes in both obesity and ASD management.

Keywords: Ketogenic diet, autism spectrum disorder, obesity, weight loss, metabolic health, gut microbiota, inflammation, neuroprotective, ketosis, β -hydroxybutyrate, metabolic syndrome, dietary intervention.

INTRODUCTION

The ketogenic diet (KD) is a high-fat, low-carb, and moderate-protein approach that forces the body into ketosis, a unique metabolic state where fat becomes the main source of energy instead of carbohydrates. Initially developed to manage epilepsy, it has since caught the spotlight for its potential in tackling a wide array of health issues, from obesity to autism spectrum disorder (ASD). Obesity, a widespread health challenge linked to chronic conditions and metabolic disorders, has drawn significant attention in KD research. Studies suggest that the KD can support weight management by encouraging fat loss and improving metabolic health. But the ketogenic diet isn't just about shedding pounds. It's also been investigated for its promising effects on neurological disorders like autism. Research has shown that the KD may alleviate key symptoms of ASD while helping to manage co-occurring issues, such as seizures. What makes the KD even more fascinating is its impact on inflammation, oxidative stress, and energy metabolism. Evidence points to its ability to reduce oxidative stress and boost mitochondrial function, amplifying its therapeutic potential for a variety of health challenges. This review article explores the role of ketogenic diet in autism spectrum disorder and obesity.

METHODS

A literature search was performed using databases PubMed, Medline, Science Direct, Google Scholar to locate peer-reviewed articles of observational studies, clinical trials and meta-analysis. Total 20 articles from 2017-2024 were reviewed in order to write this review paper.

RESULTS

Role of Keto Diet on Autism

Numerous studies have linked aberrant gut flora to the range of severity in ASD symptoms, indicating a role for the gut-brain axis in the pathogenesis of ASD. Certain ASD children may do better with treatments that influence the gut microbiota, such as the ketogenic diet (KD), which raises blood levels of ketone bodies. Ketone bodies with neuroprotective properties, such as β -hydroxybutyrate, have the capacity to pass the blood-brain barrier and improve sociability in individuals with ASD. Less is known about the precise method by which hepatically generated ketone bodies interact with intestinal flora. Interestingly, butyrate, a short chain fatty acid generated in the stomach that has been linked to β -hydroxybutyrate, may be a useful supplement for ASD. A study following 4 months on keto diet looked at changes in seven children's microbiota, inflammatory markers, and microRNAs. Blood and stool samples that were taken both before and after the KD were included in their study. They discovered that the KD resulted in lower plasma levels of brain-derived neurotrophic factor (BDNF) and proinflammatory cytokines (IL-



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12p70 and IL-1b) during a 4-month follow-up. They also noticed modifications to the gut flora, elevated butyrate kinase expression in the gut, and changed plasma levels of BDNF-associated miRNAs. These cohort results imply that the KD may, as previously noted, favourably enhance ASD sociability by lowering inflammation, rectifying gut microbial dysbiosis, and influencing the brain activity-related BDNF pathway. [8] . Beyond the direct impact of ketones on brain metabolism, an interventional pilot research suggests an additional mechanism by which a KD may affect behavioural symptoms in adolescents with ASD. This study demonstrated that a KD not only boosted butyrate production but also increased the variety of gut microbes. After being metabolized in the stomach, butyrate can enter the bloodstream and the brain to either directly or indirectly promote an anti-inflammatory state by acting on cytokines like IL-1 β [9], interacting with receptors like TLR2, neurotransmitters like acetylcholinesterase, or miRNAs like those linked to BDNF. For neurological conditions including epilepsy and ASD, a dietary intervention therapy is known as a KD. Given that a KD may help with ASD's comorbidities, such as seizures, and perhaps alleviate the disorder's basic symptoms, it might be a useful therapy for ASD. Beta-hydroxybutyrate (BHB) in the serum and urine ketones must be used to track a KD's effectiveness. Based on some data, patients with ASD had better core characteristics after receiving a KD. According to El-Rashidy *et al.*, a KD improved autistic symptoms, as seen by improvements in scores on the Childhood Autism Rating Scale (CARS) and the Autism Treatment Evaluation Test (ATEC) scales, particularly sociability improvement [12] .

Mechanism of Action of Kd in Autism

A KD has a high fat content and causes the liver's mitochondria to produce acetyl-CoA through fatty acid oxidation. Consequently, an excess of acetyl-CoA is diverted to the liver's ketone bodies (acetone, β -hydroxybutyrate, and acetoacetate). In the brain, ketones have neuroprotective properties. A ketogenic diet produces acetone, β -hydroxybutyrate, and acetoacetate-containing ketones that can penetrate the blood-brain barrier. First off, ketone bodies boost the synthesis of adenosine triphosphate (ATP) and increase energy metabolism. Second, they prevent neuronal death by lowering oxidative stress and promoting mitochondrial biogenesis, which restores normal mitochondrial function. Thirdly, ketone bodies raise levels of γ -aminobutyric acid (GABA) and control neurotransmitters. Additionally, they lessen seizures by blocking the activation of the mTOR signaling pathway, which is the fourth benefit. Finally, ketone bodies adjust the gut microbiota.[8]

According to El-Rashidy, (2017) Modified Atkins diet and gluten-free casein-free diet regimens may safely improve autistic symptoms and could be recommended for children with ASD, depending on the criteria determined in the study.[12]. According to the study (Mayengbam *et al.*, 2021) KD changed the brain metabolic profiles of BTBR – Black and Tan Brachyury and B6 mice which exhibits autism-like behaviours. Both BTBR and B6 mice's brains had higher glutamine levels, which is in line with earlier research (Yudkoff *et al.*, 2007). The primary inhibitory neurotransmitter in the brain, GABA, is made possible only by glutamine production. One-carbon linked B vitamins and folate have been shown to improve clinical assessments in ASD patients when taken as supplements. Li, Q *et al.*, (2021) concluded that by stabilizing GABA, enhancing mitochondrial function, reducing oxidative stress and inflammation in the brain, blocking the mTOR signaling pathway, and adjusting the gut flora, a KD may help people with ASD behave better in social situations.

Role of Keto Diet in Obesity

The most conventional form of KD is Classical Ketogenic Diet, which is often used in therapeutic settings. The ratio of fat to protein plus carbohydrate is 4:1 (in grams). Ninety percent of calories come from fat; the most popular source is LCT produced from food, which can be used in a 3:1 or lower ratio. In addition, infants respond best to low ratios for KD introduction, whereas older children may benefit more from a 4:1 ratio initiation followed by a decreased ratio. [14,16]. A variety of diets were employed, such as the Mediterranean diet, reduced CHO, KD, and nonketogenic diet. In contrast to the other diets, the ketogenic diet was associated with weight reduction and lower fat percentages. In a study, individuals with a mean BMI of 43 kg/m² who were obese and had metabolic syndrome and followed a ketogenic diet lost more weight than those on conventional diets. This suggests that weight loss is more likely to be caused by a significant reduction in total calorie consumption than by changes in macronutrient composition. [14,17]



Nishali *et al.*,**Mechanism of Action of Kd in Obesity**

Diminished hunger as a result of elevated levels of "satiety" hormones, including cholecystokinin, glucagon-like peptide-1; moreover, appetite may be directly suppressed by KBs, such β -HB, which function in both energy/satiety signaling and central satiety signal mediation. Since they appear to have an impact on both orexigen and anorexigen signals, particularly BHB, ketosis may have a direct or indirect influence on the production of hormones related to hunger. KD raises adiponectin levels in the bloodstream while acting in the central nervous system (CNS) to regulate eating behavior through increased GABA and AMP-activated protein kinase (AMPK) phosphorylation in the orexigen pathways. The anorexigenic pathway includes an increase in circulating free fatty acids after meals, which is followed by a reduction in NPY, a neuropeptide that acts on the hypothalamic arcuate nucleus (ARC) to regulate appetite. KD lowers the blood levels of the hunger hormone ghrelin, but it has no effect on the CCK postprandial anorexigenic response. Due to the net balance of the opposing impulses, there is a general decrease in perceived hunger and, thus, a decrease in food consumption. While increased expression of lipolytic enzymes including adipose triglyceride lipase, hormone-sensitive lipase, and lipoprotein lipase enhances lipolysis, improved insulin resistance decreases lipogenesis. KD alters the subject's metabolic pathways, decreasing lipogenesis and enhancing lipolysis, which has an influence on adipose tissue and dyslipidemia. Reduced resting respiratory quotient, a sign of improved metabolic efficiency in ingesting fats; and Increased usage of energy enhanced gluconeogenesis, a high-energy process that consumes 400–600 Kcal/day, and protein's thermic effect, which has the highest energy cost of the three macronutrients, both contribute to increased energy consumption. Because KD ingestion raises levels of bacterially produced SCFA, which are known to reduce hunger and calorie intake, gut bacteria may potentially be involved in weight reduction. of increasing the bacterial population that produces SCFA.[14]

Baylie, T *et al.*, (2024) concluded that in the short to medium term, KDs have proven to be a helpful strategy against obesity, hyperlipidemia, and some cardiovascular risk factors. KD is seen to be the most effective strategy for reducing obesity, despite the fact that several weight-loss strategies have been proposed. [14] According to the Li, S *et al.*, (2022), although many different weight-loss plans have been put forth, KD is believed to be the most successful approach in achieving weight loss. The mechanisms of the KD effect on obesity include decreased appetite, reduced lipogenesis [10]. Choi *et al.*, (2020) concluded that compared to low-fat-based comparator diets, the ketogenic diet was more successful in improving weight management and metabolic parameters linked to glycemic and lipid controls in individuals with overweight or obesity, particularly those who already had type 2 diabetes.[7]

DISCUSSION

In this review of 20 articles, investigated the efficacy of ketogenic diet on ASD and obesity, the ketogenic diet (KD) has possible therapeutic benefits that go beyond weight loss, especially when it comes to managing obesity and autism spectrum disorder (ASD). This conversation explores the ramifications of current research on the KD's influence on behavioral and cognitive characteristics in autistic people, its function in preventing obesity. The knowledge of the gut–brain axis and the process by which a KD may influence ASD symptoms may be expanded by the ability of gut microbiome to influence the expression of epigenetic markers (such as miRNAs) that may indirectly effect brain activity. [8]. The majority of children with ASD are picky eaters, which causes feeding issues. As a result, it is challenging to use a KD with ASD kids. When a KD is implemented over an extended period of time in youngsters, there are additional negative effects. Constipation, vomiting, lethargy, and hunger are the primary adverse effects of KD therapy in children [18]. Suppression of physical development is one major negative effect of a KD in youngsters [10].

And also this review shows the relationship between the keto diet and obesity such as,



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Li, S., Lin, G., Chen, J., *et al.*, (2022) Following the intervention, there was a significant decrease ($P < 0.05$) in the following measures: weight, body mass index (BMI), waist, TG (triglyceride), TC (cholesterol), LDL (low-density lipoprotein cholesterol), HDL (high-density lipoprotein cholesterol), FBG (fasting glucose), FINS (fasting insulin), and HbA1c (glycosylated hemoglobin). The KD group experienced a greater decrease in these metrics than the control group. Serum uric acid, or UA, did, however, indicate an increased trend in the KD group while remaining relatively unchanged ($P > 0.05$) in the control group.[10]. Baylie, T., Ayelgn (2024), demonstrated that ketogenic diet reduces lipogenesis and increases lipolysis which plays a role in obesity. A complicated relationship between diet length and metabolic outcomes is suggested by the varied effects of KD in the short and long term. It is consistent with the diet's potential to swiftly alter metabolic pathways that the first rapid weight loss and improved metabolic profiles observed with KD. Nonetheless, the slowdown of weight loss rates over time suggests that physiological reactions that are adaptive may limit its efficacy. This emphasizes the necessity of continuing study to enhance KD procedures and comprehend the elements affecting sustained adherence and effectiveness.

CONCLUSION

The ketogenic diet has a lot of potential as a multimodal therapy strategy for obesity and autism spectrum disorders. KD not only helps autistic people achieve notable gains in their cognitive and behavioral functioning, but it also provides a useful management approach for obesity and associated metabolic diseases. Although many different weight-loss plans have been put forth, KD is believed to be the most successful approach to improving obesity. For obese patients who have tried ineffective diets to reduce unhealthy weight rapidly, KD is often a useful therapeutic strategy. Further, research needs to be done to see the long term effect of ketogenic diet in autism and obesity.

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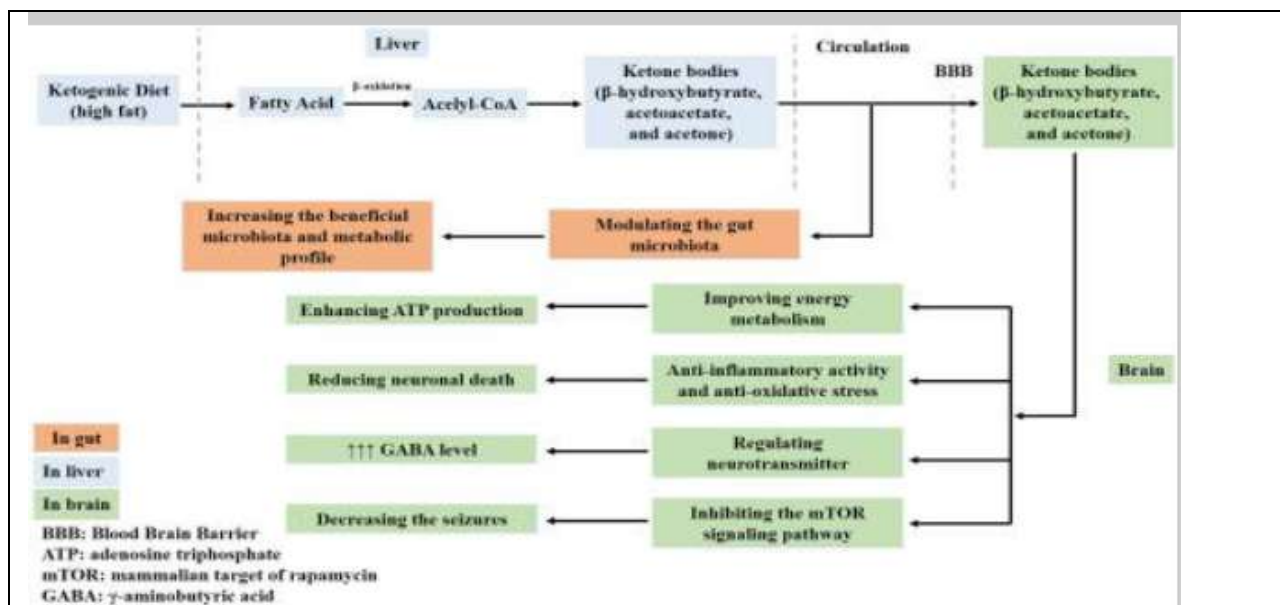


Figure 1: Ketone bodies and neuroprotective properties

Reference: Li, Q., Liang, J., Fu, N., Han, Y., and Qin, J. (2021). A Ketogenic Diet and the Treatment of Autism Spectrum Disorder. *Frontiers in pediatrics*, 9, 650624.





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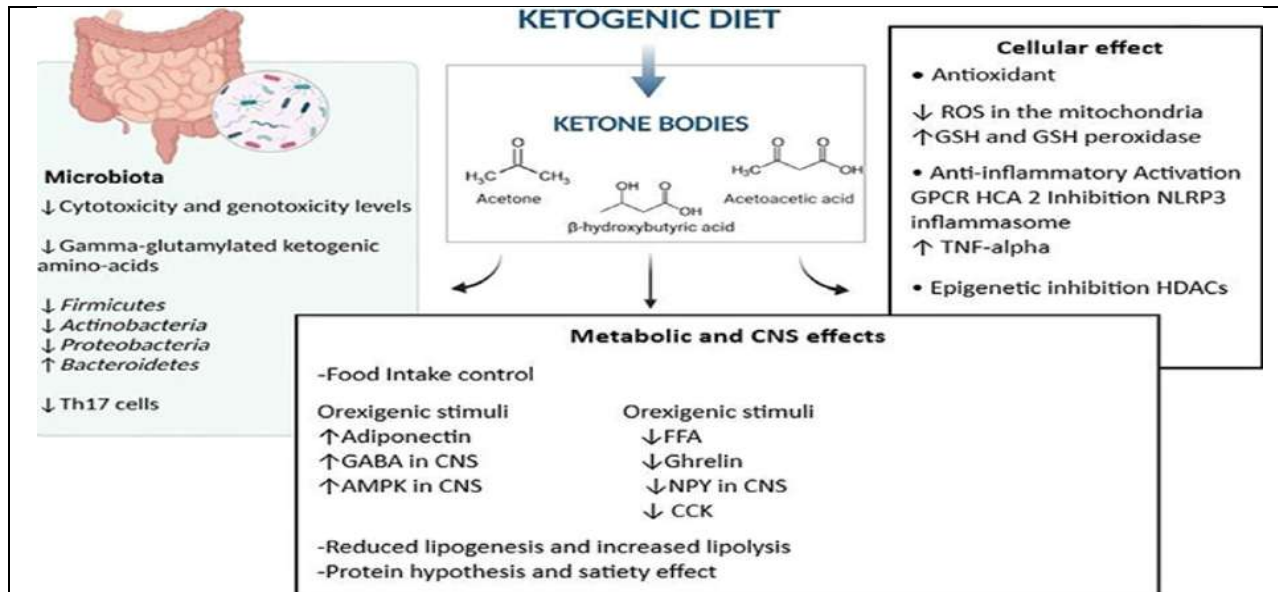


Figure 2: Mechanism of ketogenic diet for weight loss.

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RESEARCH ARTICLE

Role of Herbo Mineral Drug for Symptomatic Relief in a Lung-Carcinoma - Single Case Study

Bharadhwaj Pancholi¹ and Anitha Hosur^{2*}

¹P.G. Scholar, Department of RBSK, Parul Institute of Ayurved, Parul University, Limda, Vadodara, Gujarat, India.

²HOD and Professor, Department of RBSK, Parul Institute of Ayurved, Parul University, Limda, Vadodara, Gujarat, India.

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*Address for Correspondence

Anitha Hosur

HOD and Professor,

Department of RBSK,

Parul Institute of Ayurved, Parul University,

Limda, Vadodara, Gujarat, India.

E.Mail: bharadhwaj.researchwork@gmail.com



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ABSTRACT

The prevalence of Lung cancer is around 2 million diagnosed and 1.8 million deaths.(In India) Malignancy of the lungs is the second most common cancer diagnosis in men and women, after prostate and breast cancer, respectively. We are presenting a case of adenocarcinoma of the lung which was managed with a combination of herbo-mineral drugs. The Primary aim of this study is to observe the effect of the herbo-mineral drug combination in the management of lung adenocarcinoma. An 80-year-old female patient from Morbi, Gujarat. having complaints of severe pain and swelling over the left side of the chest region, difficulty in swallowing, dysphonia, etc.Patient diagnosed with adenocarcinoma of lung on the left side.15-day treatment was carried out according to the present complaints of the patient. Treatment outcome was assessed qualitatively and quantitatively. After 15 days, moderate symptomatic relief was achieved in qualitative parameters. In quantitative parameters improvement in CBC, CRP, WBCs reports were observed. The treatment principle includes *Lekhana*for executing *Srotosodhana* and *Rasayana*for accomplishing *Dhatu Vardhana*. The effect of the Herbo-mineral drug for symptomatic relief in adenocarcinoma of lung was well established in this case study.

Keywords: Lekhana, Rasayana, Adeno lung carcinoma





INTRODUCTION

Lung cancer is the leading cause of cancer death. The prevalence of Lung cancer is around 2 million diagnosed and 1.8 million deaths[1]. Malignancy of the lungs is the second most common cancer diagnosis in men and women, after prostate and breast cancer, respectively[2]. About 90% of lung cancer cases are caused by smoking and the use of tobacco products. Other Causative factors of lung cancer are family history of lung cancer, passive smokers, exposure to chemicals like radon and asbestos, environmental exposures such as air pollution. In addition, multiple inherited and acquired mechanisms of susceptibility to lung cancer have been proposed[3]. According to cell lung carcinoma, it is classified into small cell lung carcinoma and non-small cell lung carcinoma. Non-small cell carcinoma is further divided into adenocarcinoma, squamous cell carcinoma, and large cell carcinoma. Non-small cell lung carcinoma is more common, accounting for about 80 to 85 % of lung cancers[4]. Adeno lung carcinoma occurs mainly in smokers but it is also most common in non-smokers. It is more common in women than men. Previously adenocarcinoma of lung, called bronchioloalveolar carcinoma. Adenocarcinoma is usually found in the outer parts of the lung. Mostly, it was diagnosed before it has spread it. The responses to current standard therapies are poor except for the most localized cancers. Treatment options for lung cancer include surgery, radiation therapy, chemotherapy, and targeted therapy[5]. Despite the improvements in diagnosis and therapy made during the past 25 years, the prognosis for patients with lung cancer is still unsatisfactory[6]. In *Ayurveda*, carcinoma may be correlated with the *Arbuda*. Many Herbo-mineral medicines also described for the management. Many herbs in *Ayurveda* have antibacterial, anti-carcinogenic, anti-inflammatory properties that have been revalidated and confirmed by modern scientists in various studies. The present single-case study will throw light on the *Ayurvedic* management of lung carcinoma, which is helpful for a symptomatic relief and better patient life.

Case details

An 80-year-old female patient having a pain over the left side of the chest region on 09/05/2022. She went to a multi-specialty hospital for a checkup. Physician prescribed her painkillers and advised her to take rest. But there was no relief in pain. So, she had a re-check up on 17/05/2022. This time the physician suggested a chest x-ray (PA). X-ray revealed a mass over the left side of the chest region. As a further investigation, she was advised to undergo an HRCT of chest to rule out the malignancy. HRCT finding suggested malignant mass lesion in the left upper lobe of the lung. For a further Histopathological investigation, she went to a super specialty hospital and was diagnosed with adenocarcinoma of the left lung. Her presenting complaints include severe pain and swelling over the left side of the chest region, difficulty in swallowing, and hoarseness in her voice. Oncologist suggested for chemotherapy. However, the patient's relatives refused it due to her old age. After that, the patient was given allopathic treatment as symptomatic, but the symptoms began increasing day by day. She has then opted for Ayurvedic medicine for a symptomatic relief.

Past History

Patient has hypertension for 4-5 years; on Rx. Tab. Atenolol 50 mg 1 OD at morning and Cataract surgery done on both eyes before 2 years.

Family history

No family history regarding carcinoma.

General examination

Pulse rate: 64/min

B.P.: 100/70 mmhg

SPO2: 92%

R.R: 25/ min

Temp.: 98.4 F

Eyes: slightly pale





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Nails: normal

Diagnosis

Diagnosis was done based on the HRCT of the chest and biopsy.

IHC (immunohistochemistry) has been done to investigate which kind of carcinoma occurs.

Therapeutic management

Treatment modalities applied through external and internal both ways for 15 days. Oral treatment was planned after considering the symptoms. A formulation mixture was designed based on the properties of different drugs. Table no. 1 gives a detailed description of treatment.

RESULT

Result of treatment was assessed after 15 days both qualitatively and quantitatively. For Qualitative assessment, the Outcome variables include – Loss of appetite, Pain, Burning sensation on chest, Difficulty in swallowing, weakness, and daily activity. The changes observed in a blood report given in a below table no. 2. For Quantitative assessment, the outcome variables include blood hematological parameters. The changes observed in a blood report given in a below table no. 3.

DISCUSSION

Carcinoma may be correlated to *Arbuda* in Ayurvedic literature. *Arbuda* is a type of *Granthi*, which is *Tridoshaja* associated with *Mamsaadi dathus*, that are vitiated by different external and internal factors and presented as lumps in the body surfaces. It may be concluded that *Arbuda* may more likely to be benign tumours. But the principle of uncontrolled growth in the tissues as a pathology may be superimposed with the *Mahabhtua Siddhantha* of *Garbhavakranthi*. Among them, vitiation in *Vayubhuta* is related to *Vibhajana* (cell division) and *Akashabhuta* is related to *Vivardhana* (growth). These are supported by *Apbhuta* for *Kledana* (Nourishment), *Prithwimahabhuta* for *Samhanana* (compactness), *Tejibhuta* for *Pachana* (metabolism)[13]. Malignant tumours (*Tridoshaja*) are very harmful because all the three major bodily systems lose mutual coordination and thus cannot prevent tissue damage, resulting in a deadly morbid condition. Metastasis in cancer may lead to acceleration in metabolic crisis, through aggravation of *Vata* and suppression of *Kapha*, both interacting with one another resulting in proliferation. Based on these principles suitable formulations should be selected. The selected formulations must not only perform *Vyadhiharatwa*(cure), but also *Rasayana* (tissue nourishment). After analyzing the *Samanya* and *Vishesha karma* of *yogas*, opted certain assumptions may be made *Rasasindura* is a unique mercurial preparation, which has properties like *Sarvarogahara*, *Rasayana*, *Prabalashoolanashak*, *Tridoshsamaka*, etc. *Tamragarbha pottali* retain action like *Lekhana* which is helpful to reduce the size of the tumor. *Sothahara*, (Anti-inflammatory), *Shoolahara* (Analgesic), *Amlapittahara* (Hyper acidity), *Agnimandhyahara* (appetizer). *Tamragarbha pottali* contains a main component as a *Tamra Bhasma*. *Tamra Bhasma* is specially mentioned in a *Urdhvajatrugata Vata Kapha Janya Roga*. So, it is helpful in *Swasa* (dyspnea), *Swarabhedha* (dysphonia). *Amalaki churna* is therapeutically used in *Amlapitta*, *Agnimandhya*, *Aruchi*, *Dahaprasaman* and also has *Rasayana* property. *Sariva churna* used in *Jaravyadhi*, *Rasayana*, *Amavishnasana*, *Swashara*, *Kasahara*, *Agnisada*, etc. *Guduchi sattva* is used as *Rasayana*, *Jwarahara*, *Soshahara*, *Vibandhahara*, *Sothahara*, etc. below table no. 4 describes the chemical constituents of formulations and their respective action. Chemical constituents of formulations and their respective action (Table no. 4).

CONCLUSION

Herbo-mineral drugs are useful to improve the quality of life in a lung carcinoma patient. *Rasayana* property of a herbo-mineral drug is useful to increase life span of a patient. Given combination was *Shadrasatmaka* which is helpful to pacify the *Tridosha*. If treatment was given in the initial stage, it may give a significant symptomatic relief.





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Table No. 1: List of medicines given to the patient

Formulations	Proportion of formulation in mixture (15 days)	Dose and time of administration
<i>Tamra Garbha Pottali</i> [7]	250 mg (Rubbed with water)	All these formulations were mixed together, and 2.5 gm was administered every 2 hours to the patient with hot water as <i>Anupana</i> .
<i>Rasa sindoor</i> a[8]	250 mg	
<i>Sarivachurna</i> [9]	30 gm	
<i>Guduchisatva</i> [10]	30 gm	
<i>Amlakichurna</i> [11]	40gm	
<i>Sitopladiichurna</i> [12]	30 gm	
<i>Guduchikshirpaka</i>	Prepared according to <i>Kshirapakavidhi</i>	Every 4 hours
<i>Dashmoola taila</i> and turpentine oil	For External Use	2 times a day

Table no. 2: Qualitative analysis of before and after treatment

Sr.no.	Symptoms	Before treatment	After treatment
1.	Loss of appetite	Half chapati taken at afternoon At night taken half bowl khichdi	At morning murmure 2 chapati taken at afternoon At night taken a 1 bowl khichdi, milk, 1/4 th rotlo
2.	Pain	Taken a pain killer everyday	Taken a pain killer once in 2-3 days
3.	Burning sensation on chest	Severe	Mild
4.	Difficulty in swallowing	Pain occurs while swallowing foods	Easily swallowing foods
5.	Weakness	Severe	Mild
6.	Daily activity	Without support not able to stand or sit and walking	Without support able to sit and stand

Table no. 3: Quantitative analysis of before and after treatment

Quantitative variables	Before treatment	After treatment
Hb%	9.4gm%	10.00gm%
RBCS	3.46/ cumm	3.52/ cumm
WBCS	15850	9000
Lymphocytes	15	20
Neutrophils	79	72
C.R.P.	139.7 mg/l	89.2 mg/l

Table no. 4: Chemical constituents of formulations and their respective action

Formulation	Action	Chemical constitute
<i>Amalaki churna</i> [14]	Antimicrobial action	Flavonoid specially quercetin
<i>Guduchi satva</i> [15]	Anti-cancerous effect[16], Anti-microbial, Anti-toxic effect, Radio protective	Magnoflorine, isocolumbin, palmetine, aporphine
<i>Sitopladi churna</i> [17]	Anti-tussive	Eugenol
<i>Sariva churna</i> [18]	Anti-inflammatory[19]	Tannins, alkaloids
<i>Tamra bhasma</i> [20]	Inhibit tumor growth	Copper oxide(Cuo)





RESEARCH ARTICLE

Effect of Deep Slow Breathing vs Music (528HZ) on Stress and Fatigue in University Students

Debojeet Nath¹, Madhumita Das^{2*}, Somyata Satpathy Sarma³ and Kangkana Goswami²

¹Physiotherapist Intern, Department of Physiotherapy, The Assam Royal Global University, Guwahati, Assam, India.

²Assistant Professor, Department of Physiotherapy, The Assam Royal Global University, Guwahati, Assam, India.

³Associate Professor, Department of Physiotherapy, The Assam Royal Global University, Guwahati, Assam, India.

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*Address for Correspondence

Madhumita Das

Assistant Professor,

Department of Physiotherapy,

The Assam Royal Global University,

Guwahati, Assam, India.

E.Mail: dasmadhumita141@gmail.com



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ABSTRACT

Fatigue of the CNS leads to stress in everyday lifestyle. Long standing illness was observed in majority of students going to university. Exposure to stress for a prolonged time leads to mild inflammatory changes which suppresses the immune response and overall function of the immunoprotective cells. The study aims to analyze the effects of Deep Slow Breathing (DSB) vs. Music (528 Hz) on stress and fatigue in university students. 50 University students of both genders aged 18 to 28 years were taken according to inclusion criteria. Subjects were divided into 2 groups, Group A and Group B with 25 subjects in each group. Group A received a 20-minute session of Deep Slow Breathing (DSB) and Group B received high frequency music (528Hz) exposure for 20 mins. The intervention was given for a period of 8 weeks with sessions once per week. Fatigue Severity Scale (FSS) and Perceived Stress Scale (PSS) measured the pre and post Fatigue and Stress respectively. Post intervention of 8 weeks, fatigue and stress level decreased significantly in the group with music (528 Hz) exposure with mean values 24.08 than the group with DSB with mean value 37.56 at p value 0.000. The study concluded that the high frequency music exposure of 528Hz is effective in reducing fatigue and stress as compared to the deep slow breathing group in university students.

Keywords: Deep Slow Breathing, Fatigue, Music, Stress



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INTRODUCTION

Students face many physiological and psychological health related problems as they experience different challenges in their academic career. Stress is considered to be one of the long-standing illnesses faced by students which affect their ability to cope with external environmental challenges[1]. Decreased immunoprotective response of the body along with mild chronic inflammation is seen on chronic exposure to stress[2]. Stress has an effect on the body mechanism it leads to mental problems such as insomnia, headache, personality changes, anxiety, depression, Cardiovascular diseases, musculoskeletal aches, Gastrointestinal problems, Menstrual disorders and also a neurotoxic effects of stress hormones is seen in brain[3]. Studies to analyze mental health issues concluded that medical students of Asian countries suffer more with anxiety, depression and stress compared to students with other countries[4]. Fatigue is subjective experience which means lack of energy, tiredness and weariness. There are four major classes of Fatigue Physiologic Fatigue, physical fatigue, psychological fatigue and Mixed fatigue. Among this physiologic fatigue is most common type found in students which is due to overwork lack of sleep and psychological fatigue results from depression, anxiety and persistent stress. Studies have highlighted that student population shows intense level of fatigue and eventually show difficulty in studies due to stress and fatigue. Major factors which contribute to stress, anxiety and depression are performance in exams and future[5,6]. The amount of pain perceived by individual and the regulation of sympathetic system are seen to be influenced by Deep Slow Breathing exercises and relaxation. Therefore, these techniques can be included in pain management. Diaphragmatic Breathing is one such non-pharmacological intervention which has proven to decrease physiological and psychological stress when measured by biomarkers of respiratory rate and psychological self-report tools[7,8]. Deep Slow Breathing (DSB) has effect on parasympathetic nervous system which reduces the vagal tone and helps in management of anxiety in younger and older adults[9]. Listening to music reduces stress and arouses different emotions depending on melody, dynamism and rhythm of the music. Studies have shown listening to high frequency music increases the activity of the parasympathetic system and reduce stress. Frequency 528 Hz is known as solfeggio music also called as healing music which helps transformation and DNA repair and reduces stress even when heard for a short duration. It also decreases stress related hormone cortisol and increases happiness hormone oxytocin[10, 11]. Fatigue severity scale used to measure Fatigue and perceived stress scale used to measure Stress have been shown to have acceptable psychometric properties[12, 13]. Obstacles to exercise among the students were the motivation level, accessibility of suitable places and availability of time[14]. Performing deep breathing requires a peaceful environment and active involvement of the individual on the other hand music through mobile phones is easily accessible and requires passive listening. Deep Slow breathing and listening to music of 528 Hz has individually shown positive effects on reducing stress and fatigue among young and older adults so the objective of our study is to compare and analyze which therapy shows more effective for reducing stress and fatigue in University students.

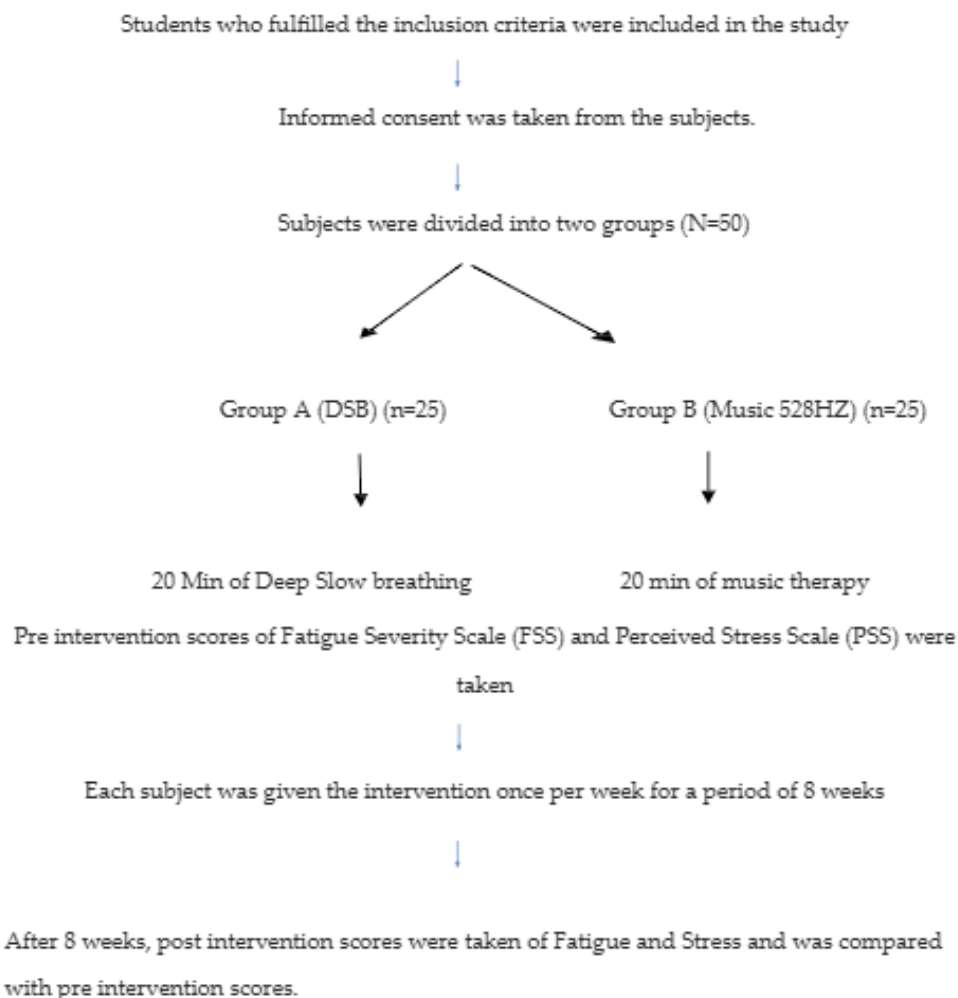
MATERIAL AND METHODS

50 University students of Age group 18 to 28 years were conveniently chosen for the study based on the inclusion and exclusion criteria after obtaining the informed consent. Approval for the study was taken by the Institutional Ethical committee (RGU/IECHR/BPT/2024/03) The Assam Royal Global University as per the ethical guidelines for biomedical research on human subjects. All the male and female students of age>18 -28 years participated in the study except those who had documented history of pulmonary disease, cardiac condition, neurological disorders, severe psychiatric disorders, using any complementary therapy modalities such as massage therapy, relaxation techniques, recreational gym and sport activities.

PROCEDURE

Base line data of fatigue and perceived stress was measured in the beginning and at the end of 8 weeks in both the groups.



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RESULTS

SPSS Version 27 was utilized to check the results with the significance level of 95%. Descriptive statistics of gender of both the groups is shown in table 1 and table 2 and mean of variables (FSS) Fatigue Severity Scale and Perceived Severity Scale (PSS) Scores represented with a bar diagram is shown in Fig 1 and Fig 2. Pre-test and Post-test analysis of FSS and PSS was done using Wilcoxon signed rank test in between the group A as shown in table 3. Significant difference between pre post data of FSS and PSS scores in group A Significant level $p < 0.001$ so we conclude that there is significant effect of deep slow breathing exercise in reduction of stress and fatigue among university students. Paired t-test was used to assess the pre-post data of FSS in group B. As $p < 0.05$, so we will reject the null hypothesis and accept the alternative at 5% level of significance. Hence conclude that there is significant difference between pre post data of FSS in Group B as shown in table 4. Wilcoxon signed rank test was used to assess the pre-post data of PSS in group B. Since $p < 0.05$. Hence conclude that there is significant difference between pre post data of PSS in Group B as shown in table 5. t-test was performed to assess the Pre -Post data of FSS across the groups since the p value for FSS is less than 0.05. We conclude that there is significant difference between GROUP A and GROUP B values FSS (post) as shown in table 6.



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DISCUSSION

Stress and fatigue in today's generation is evident everywhere and mostly among the students where they are facing lot of academic stress causing fatigue and also there is a constant thought to achieve success in near future among students financially and academically which burdens them more. The objective of the present study was to compare the effectiveness of Deep Slow breathing vs. Music (528Hz) on stress and fatigue levels in university students. After a session of exposure to music the relaxation experience by the subjects was noticeably more as compared to the deep breathing group, there was a calmness in the subjects voice after the intervention, as the intervention progressed from week to week there were noticeable changes in subjects presence and eagerness to treatment as it was providing them more relaxation which was comparatively less in the Deep Slow Breathing group and after the completion of 20 min they were already in a state where they verbally stated that a feeling of sleep was evident at that point of time. Within the groups both the interventions were effective but across the groups there was a significant difference among the mean scores of FSS as seen in Table 6 .Group B (Music) had a mean score of 24.08, while Group A had a mean score of 37.56 in terms of FSS post intervention with p value of 0.000, this suggests that the Group B who had the high frequency exposure of Solfeggio frequency 528 Hz had better results in reducing fatigue as compared to the DSB group. Sympathetic nervous system activity is suppressed by release of dopamine which is induced by high frequency sound.¹⁰ Deep Slow breathing also activates the parasympathetic nervous system but performing deep breathing requires active involvement whereas music is just passive listening. The findings of the study can be used as an awareness to include high frequency music as a strategy to relieve stress which will ultimately help them to focus and improve academic performance.

CONCLUSION

The findings of the study conclude that there is significant difference between the effect of Deep Slow breathing vs. Music (528 Hz) on stress and fatigue in university students.

LIMITATION

- Overall stress was taken into consideration so results cannot be generalized
- Study was done for over 8 weeks with only a single time follow-up , so long term effects are unknown

FUTURE STUDIES AND RECOMMENDATIONS

- The study can be conducted in other populations like post-partum women
- The study can be specific to a certain type of stress and results would be more specific

SOURCE OF FUNDING

None

CONFLICT OF INTEREST

None



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Group A

Table 1: Descriptive Statistics of Age Gender Wise

Age			
Gender	Mean	N	Std. Deviation
Female	22.27	11	.905
Male	22.64	14	1.008
Total	22.48	25	.963

Group B

Table 2: -Descriptive statistics of age gender wise

Age			
Gender	Mean	N	Std. Deviation
F	22.27	11	.905
M	22.64	14	1.008
Total	22.48	25	.963



**Group A****Table 3: Wilcoxon signed rank test**

-Wilcoxon Signed Rank Test			
	Z	p values	Remark
FSS (POST) - FSS (PRE)	-4.377	.000	***
PSS (POST) - PSS (PRE)	-4.383	.000	***

Table 4: FSS:Pre-Post Paired t test for Group B

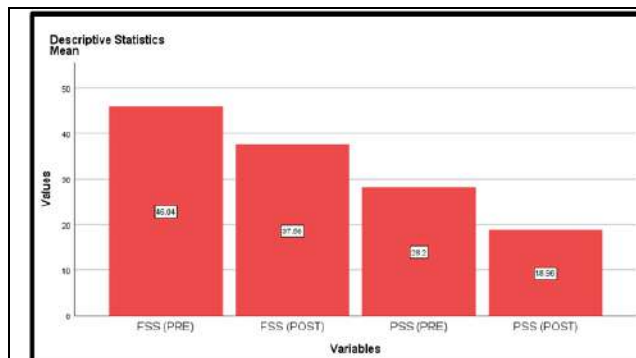
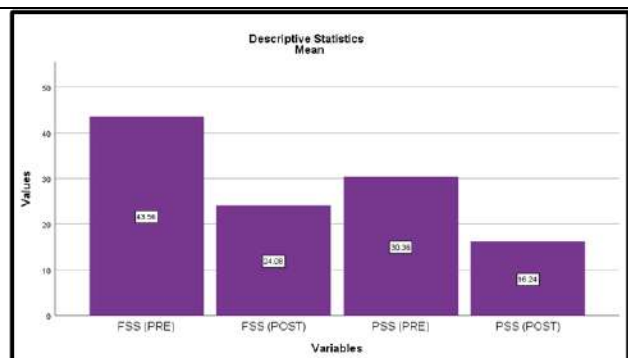
Paired Samples Test						
	Paired Differences		t	df	p value	Remark
	Mean	Std. Deviation				
FSS (PRE) - FSS (POST)	19.480	4.104	23.733	24	.000	***

Table 5: PSS: Pre- Post Wilcoxon signed rank test

Wilcoxon Signed Rank Test			
	Z	p value	Remark
PSS (POST) - PSS (PRE)	• 4.375	.000	***

Table 6: Statistics analysis for FSS (post) across groups

t-test for Equality of Means						
	t	df	p value	Mean Difference	Std. Error Difference	Remark
FSS (POST)	4.633	48	.000	13.480	2.910	***

**FIG 1: Descriptive statistics of mean variables (FSS) Fatigue Severity Scale and Perceived Severity Scale (PSS) Scores (GROUP A)****FIG 2: Descriptive statistics of mean variables (FSS) Fatigue Severity Scale and Perceived Severity Scale (PSS) Scores (GROUP B)**



RESEARCH ARTICLE

Management of Bacterial Folliculitis by Jalaukavcharan: A Case StudyMegha Jadhav¹, Pawar Chandrakant^{2*}, Shailesh Jaiswal³ and Shalaka More³¹Assistant Professor, Department of Shalya Tantra, Parul Institute of Ayurved and Research, Parul University, Limda, Waghodia, Vadodara, Gujarat, India²Professor, Department of Shalya Tantra, Parul Institute of Ayurved and Research, Parul University, Limda, Waghodia, Vadodara, Gujarat, India³Associate Professor Department of Shalya Tantra, Parul Institute of Ayurved and Research, Parul University, Limda, Waghodia, Vadodara, Gujarat, India

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Address for Correspondence*Pawar Chandrakant**

Professor,

Department of Shalya Tantra,

Parul Institute of Ayurved and Research,

Parul University,

Limda, Waghodia, Vadodara, Gujarat, India

E.Mail: drchandrakantpawar@gmail.com



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ABSTRACT

This case study compares bacterial folliculitis with the Ayurvedic condition of Vidradhi, focusing on their pathophysiology, treatment options, and potential therapeutic approaches. Bacterial folliculitis is an infection of the hair follicles caused by bacteria, leading to inflammation, redness, and pus-filled blisters. If untreated, it can progress to boils, causing significant discomfort and pain. Modern treatment options include antibiotics, antiseptics, light therapy, and surgical intervention. In contrast, Vidradhi in Ayurveda refers to a spreading inflammation of the skin and subcutaneous tissue, often correlated with conditions similar to abscesses or boils. This study explores both conditions and evaluates the potential of Ayurvedic treatments such as Jalaukavacharana (leech therapy) to address inflammation effectively. Bacterial folliculitis occurs when bacteria infect hair follicles, typically resulting in red, swollen areas with pus-filled blisters. Commonly affecting visible areas of the body, it can lead to more severe conditions like boils if left untreated. Conventional treatments include antibiotics, antiseptics, and, in some cases, surgical procedures. Vidradhi, as described in Ayurveda, involves inflammation that spreads within the skin and subcutaneous tissues, with no direct modern equivalent for its treatment. Ayurvedic therapies, including Jalaukavacharana (leech therapy), offer an alternative by removing impure blood and balancing doshas, particularly Pitta, associated with inflammation. Leech therapy is believed to inhibit pro-inflammatory enzymes, providing relief from swelling and pain. Both bacterial folliculitis and Vidradhi involve inflammatory processes but differ in their etiologies and treatment paradigms. While bacterial folliculitis is effectively managed through modern medical treatments, Ayurvedic approaches,



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such as Jalaukavacharana, provide a holistic option, targeting the underlying doshas and promoting natural healing. The comparative study of these two conditions highlights the value of integrative approaches to inflammation and infection, encouraging further exploration of Ayurvedic treatments in managing modern dermatological conditions.

Keywords: Folliculitis, Vidradhi, Jalaukavacharan, Leech Therapy, Bloodletting

INTRODUCTION

Skin conditions can significantly affect a person's overall well-being, mental health, functional abilities, and social life. Healthy skin not only improves appearance but also reflects internal health. Today, factors like environmental pollution, lifestyle changes, and stress can negatively impact the skin. Ayurveda offers various treatments for skin diseases, with one of the most notable being Raktamokshana (bloodletting), which is believed to cleanse the body of toxins and restore balance to the doshas. Raktamokshana can be carried out using different methods, such as Shriga, Alabu, Jalauka (Leech therapy), and Siravedha (venesection). Of these, Leech therapy is considered the gentlest, making it suitable for individuals who are physically or mentally frail[1]. The use of leeches for therapeutic purposes dates back to ancient times, with the first reference found in Ayurvedic texts, where the legendary physician Lord Dhanvantari is said to have introduced leech therapy during the Samudra Manthan (Churning of the Ocean). Today, Jalaukavacharana or Hirudotherapy has gained global recognition due to its wide-ranging therapeutic benefits, especially in the field of medicine. Leeches are aquatic creatures that obtain their nourishment from water, which is why they are referred to as Jalauka in Ayurvedic texts[2]. This ancient practice continues to be valued for its ability to treat various health conditions, including those related to skin diseases, by promoting detoxification and restoring balance within the body. The superficial infection involving the hair follicle, with a central region of purulence surrounded by induration and erythema, is known as Folliculitis[3]. Doshas can be located around the bone tissues on getting vitiated will contaminated skin, muscle, fat, Blood and then produce inflammation (blisters). Vidradhi are deep located and symptoms is pain, swelling, pus formation etc. Gudavidradhi is coming related with anal abscess on the basis of symptoms. Anal abscess origin is mostly infection or blockage at a anal gland many times resulting from blood born infection[4].

AIMS AND OBJECTIVES

- The primary aim of this study is to assess the effectiveness of Jalaukavacharana (leech therapy) in treating Bacterial folliculitis.
- management of bacterial folliculitis and correlating it with the management of Vidradhi as per Ayurveda

MATERIALS AND METHODS

A 25-year-old female patient presented to our Shalya OPD with multiple boils on her left armpit. She had 8-10 painful boils, along with tenderness, itching, and a serous discharge mixed with mild pus and an unpleasant odour. These symptoms had been ongoing for 15 days, with associated pain and swelling. The patient was advised to undergo weekly applications of leech therapy at the affected site. Before initiating the treatment, routine blood tests were conducted, including haemoglobin levels, bleeding time (BT), clotting time (CT), erythrocyte sedimentation rate (ESR), complete blood count (CBC), HIV, and HBsAg. All investigations were within normal limits. The materials used for the treatment procedure included: Jalauka (Leeches), Haridra (turmeric) powder, Sterilized drapes, Gauze pieces, Dressing pads, Cotton, Gloves, Disposable syringes, Kidney tray, Distilled water, Needles, A container of sterile water for placing the leeches after feeding, which was labeled with the patient's name.



**Patient's Information**

A 25 years female patient, resident of Waghodia road, Vadodara came to OPD of Shalyatantra of Khemdas Hospital with chief complaints of multiple boils in left armpit along with pain and itching for 15 days. She took antibiotic and analgesic medications for 3 days but there was no significant relief hence visited the hospital for further ayurvedic management. Table 1 shows details of the patient.

On Examination

Patient had multiple boils in the left armpit region. Which was very tender and red. These boils were 8-10 in number, along with tenderness, and a serous discharge mixed with mild pus and an unpleasant odour. These symptoms had been ongoing for 15 days, with associated pain, swelling and itching.

Clinical Examination and Findings

The general examination was normal and no significant finding was observed. On inspection of the site of the lesion, there were multiple numbers of irregular boils varying in sizes from 2mm-5mm in the left armpit. During the earlier days of treatment, two pustules erupted over which subsided on their own during the course of therapy. Table 2 shows Findings on Clinical Examination.

Diagnostic Assessment

The signs such as pustules followed by disruption and release of pus contents over the hairy area in armpit or axillary region, resulting in red, swollen, painful lesions; associated with mild itching and pain assist to determine the presence and strongly suggestive of bacterial folliculitis

Ayurvedic Assessment of Diagnosis

Excess intake of lavana (salty), Katu (spicy), Tikshna Aahara Sevana, due to friction of tight clothes and irritation to skin since it is a sweaty area all the causative factors and symptoms mimicking Pittaja Vidradhi

Parasurgical Intervention

Raktamokshan is recommended for Pitta Pradhana diseases and Jalauka is indicated for bloodletting of localized area[5]. Bloodletting with Jalauka is also recommended for Rakta that has been vitiated by Pitta[6]. The procedure, mechanism, and its consequences were described to the patient before signing the consent form, and she was mentally prepared for the therapy. The jalaukavacharana also known as Leech therapy was performed by applying two Jalauka over the affected site on a weekly basis for a total of only 2 sittings. The patient was instructed to keep the affected site clean and ensure aeration.

Leech Therapy in Ayurveda in *Ayurveda* Leech therapy is known as *Jalaukavacharan*. The etymological meanings of both the words are following

Jalauka (Leech); Jalauka means Which is having water as its housing place.

Avacharana; Avacharana means Application Hence the application of *Jalauka* or leech for therapeutic purposes has been described as word Leech Therapy or *Jalaukavacharan*[7].

Purvakarma (preceding procedure)

The leeches were collected from a container and purified by immersing them in turmeric-infused water (SS.Su.13/19) for around 1 Muhurta (around 48 min)[8]. They were then washed with water and placed in an aerated transparent container filled with fresh water to make them active. A silent atmosphere was established inside the Jalaukavacharana room, and the patient was advised to remain calm so that the leech can suck comfortably.

Pradhana Karma (main procedure)

The necessary materials, such as leeches, medications, and instruments, were prepared following aseptic methods. The site of the lesion was cleaned. The leech's head was positioned over the infected area and covered with wet



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cotton to prevent the leech from moving to the other side. The peristalsis-like movement from the head to the posterior end of the leech was observed during sucking.

Paschata Karma (post-procedure)

Immediately after detachment of leech, the turmeric powder was spread over the wound to control bleeding[9]. The detached leech was kept in hand (sometimes in the tray) and powder of turmeric was spread over its frontal end for Vamana. Residual blood after Vamana was then again regurgitated by pressing the body from posterior to the frontal end of the leech. This resulted in its purification so that the same leeches can be used for the same patient again in the next sitting. After proper Vamana, it was placed in an aerated jar half filled with fresh air. If the leeches swam freely with an elongation of the body, then the condition was evaluated as normal. The water in the container was replaced every 2-3 days. (Su.Su.13/17). Turmeric has Vranaropaka properties which help to heal the wound. Beside this, turmeric has also Raktastambhana (haemostatic) and Krimighna (anti-microbial) activity that controls the bleeding and combats the infection[10]. After two sittings of Jalaukavacharan only significant reduction was seen in the symptoms.

Oral Medication(Table: 4)**Follow-Up and Outcomes**

The follow-up and outcomes are summarized in the figures below. After significant improvement in redness, swelling, and pain, the discharged pus completely dried up and patient got relief within 15 days. The patient continued the same medication, and a second session of Jalaukavacharan was performed. Follow-up visits were conducted regularly for a month. After two sessions of Jalaukavacharan, treatment was concluded, and the patient was monitored for another month to check for any pathological changes. No signs of new folliculitis or adverse effects were observed during this period. The patient experienced relief from pain, itching, and redness and is in complete remission.

DISCUSSION

Ayurveda is a system of medicine with historical roots in the Indian subcontinent and practiced from 5,000 years ago[11]. Leech sucks only impure blood so this is considered as blood purification therapy. Sushruta Samhita (dating 800 BC) is the treatise of surgery in which "Jalaukavacharniya" is one of its chapters, where everything about Jalauka and its application are scientifically described[12]. Jalaukavacharana forms by the addition of two words: Jalauka and Avacharana. Jalaukavacharana means the application of Leeches. The word 'leech' is derived from an old English word for physician, "laece"[13][14]. Therapeutic application of leech is practiced among the other system of medicine such as in Unani and Siddha also[15]. The treatment of disease with medicinal leeches is also known as Hirudotherapy (HT)[16]. The bioactive substances that found in leech's saliva - commonly known as "hirudo substances" and also called Salivary Glands Secretion (SGS). SGS contains more than 120 bioactive substances, which have strong anaesthetic, anti-inflammatory, analgesic properties some of them are still being examined. Haycraft (1984) discovered "hirudin" which is most important component[17]. In Modern Medicine number of Steroids and Antibiotics used to treat above problem which may cause serious side effect on body. Raktamokshana (bloodletting) is significant therapy available in Ayurveda to avoid this problem. It is a type of Panchakarma. It is one of the best treatments for vitiated Pitta and Rakta. Acharya Sushruta has told that a person who performs the Raktamokshana (bloodletting) periodically, unable to suffer with Raktapradoshaja Rogas (Blood disease) like Twachavikar (Skin disease), Shopha etc[18]. Jalaukavacharana (Leech therapy) is mild and safe therapy of Raktamokshana (bloodletting). Jalauka imbibe the impure blood into affected area of body and inject some bioactive components at that place. Leech saliva contains Hirudin which inhibits the blood coagulation by binding to Thrombin, Anti-inflammatory B-dellins, and Vasodilator Acetylcholine, thus increases the blood flow of that place. Jalaukavacharana not only assist in elimination of Pitta and Rakta Dosha but also remove the obstruction cause by vata and Kapha Dosha.



**Megha Jadhav et al.,****Mode of Action of Jalaukavacharana****According To Ayurveda**

In majority of skin disease, more than one Dosha participated. At that time, Pitta Dosha should be treated first following the Dosha that is comparatively more vitiated. Rakta and Pitta have Ashraya Ashrayibhava, the relation between them is inseparable. Raktamokshana helps to the eliminate vitiated Pitta. When vitiated Rakta is eliminated, skin gets nourished by Shuddha Rakta and free from disease.

This flowchart summarizes the key steps and effects of Jalaukavacharana, highlighting how leech saliva facilitates tissue healing and reduces inflammation[19] Table 3.

Probable mode of action of GandhakRasayanavati[20] Gandhak Rasayan is a great antibacterial, antiviral and antimicrobial ayurvedic medicine that is primarily used for the treatment of Eczema, Scabies, Skin Disorders. GandhakRasayana mainly consists of Sulphur along with other herbal ingredients. Gandhaka is mentioned as Kandughna and Krimighna in ancient Ayurvedic texts. In Gandhaka Rasayana, Sulphur has been detoxified with ancient shodhana process mentioned in the text of Rasashastra, so that the toxic effect of Sulphur is reduced. Sulphur is also known to have an antimicrobial property and have been proved to act by inhibiting Folic acid metabolism in the susceptible bacteria and preventing their growth. Sulphur is also widely used topically as a scabicide and pediculocide, because one of the metabolites of Sulphur i.e., Pentathionic acid, which was supposed to cause lysis of cuticle. Thus, Sulphur is effective both systematically and topically as a microbicidal agent[21].

CONCLUSION

Folliculitis which can be correlated with Vidradhi told I ayurveda was cured successfully and complete remission was achieved by Ayurveda medicine along with Jalaukavacharana and it is highly effective compared to contemporary allopathic treatment. Further research studies need to be done to validate this finding before incorporating it into the treatment protocol.

Patient Perspectives

"I was very worried about the lesions in my axillary region as it was my main concern cosmetically. As modern medicines were not giving me any relief. Pain, itching and local discomfort was increasing day by day. After that I went to Shalyatantra OPD of Khemdas Hospital, Ishwarpura for treatment and took Ayurvedic medicines along with Jalaukavacharan procedure. It gave me 70% relief from my complaints within first sitting of Jalaukavacharan. Later, after going through one more sitting with gap of 7 days, all my complaints got cured and skin started looking normal. Now, I am very happy that my armpit area is looking like before and for this I am thankful to the doctors."

Informed Consent

The patient had signed an informed consent form for the treatment procedure, study, and publication.

CONFLICTS OF INTEREST

None.

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Megha Jadhav *et al.*,**Table 4: Shows details of the patient**

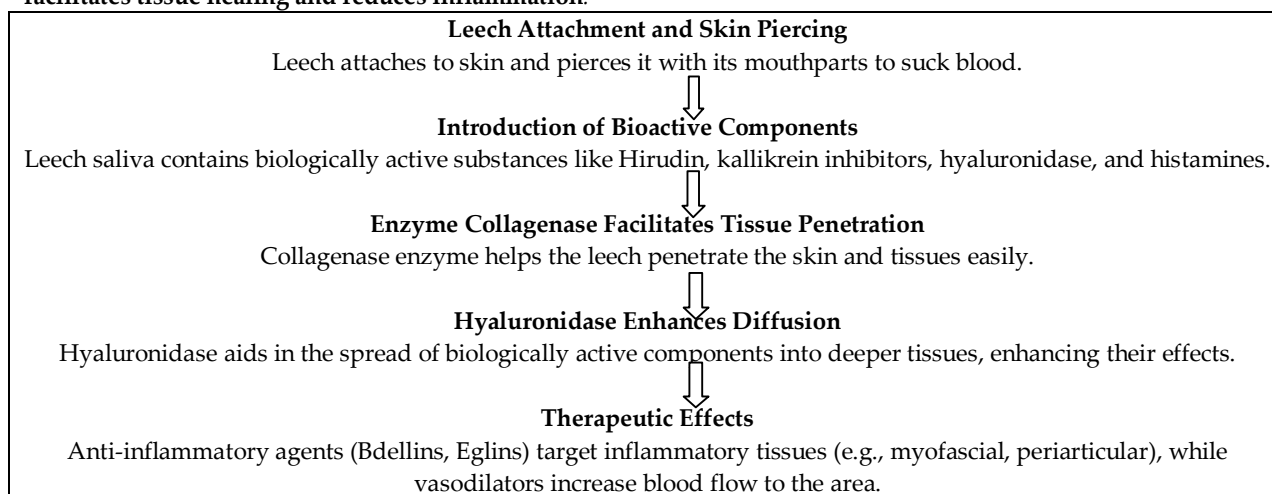
Gender	Female
Name	XYZ
Occupation	Student
Sleep	Disturbed
B.P.	110/70 mm of hg
Pulse	82/min
Respiratory rate	17/min

Table 5: Shows Findings on Clinical Examination

Sr.No.	Features	Observation
1)	Site	Left axillary Region
2)	Number	8-10
3)	Distribution	Asymmetrical
4)	Type of lesion	Multiple boils
5)	Color	Atasipushpavarna (reddish brown)
6)	Flat or raised	Raised

Table 3: Oral Medication

Sr.No.	Medicine	Dosage	Kaal	Administration	Anupan
1)	GandhakRasayanaVati250mg	2 tablets two times a day	After food	Oral	Koshmajala

Table 4: This flowchart summarizes the key steps and effects of Jalaukavacharana, highlighting how leech saliva facilitates tissue healing and reduces inflammation.



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Figure No. 1: Shows Condition Before Treatment (1 st Day)	Figure No. 2: First Sitting of Jalaukavacharan (1 st Day)
	
Figure No. 3: Condition after Jalaukavacharan (8 th Day)	Figure No. 4: Second sitting of Jalaukavacharan (8 th Day)





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Figure No.3: Condition after Jalaukavacharan (11th Day)



Figure No.4: Condition after treatment (14th day)





RESEARCH ARTICLE

Synthesis and Characterization of Biolubricants from Waste Cooking Oil

N. Sharma¹, J. D. Patel², V. C. Patel³, J.R. Avalani³, A. J. Patel⁴, M.A. Patel⁵, D.M. Patel⁶ and D. S. Patel^{3*}

¹M.Sc Student, Department of Organic Chemistry, Shri Alpesh N. Patel P.G. Institute of Science and Research, (Affiliated to Sardar Patel University), Anand, Gujarat, India.

²Principal, Shri Alpesh N. Patel P.G. Institute of Science and Research, (Affiliated to Sardar Patel University), Anand, Gujarat, India.

³Associate Professor, Department of Organic Chemistry, Shri Alpesh N. Patel P.G. Institute of Science and Research, (Affiliated to Sardar Patel University) Anand, Gujarat, India.

⁴Assistant Professor, Department of Organic Chemistry, Shri Alpesh N. Patel P.G. Institute of Science and Research, (Affiliated to Sardar Patel University) Anand, Gujarat, India.

⁵Adhoc Lecturer, Department of Organic Chemistry, Shri Alpesh N. Patel P.G. Institute of Science and Research, (Affiliated to Sardar Patel University) Anand, Gujarat, India.

⁶Assistant Professor, Department of Advanced Organic Chemistry, P. D. Patel Institute of Applied Sciences, (Affiliated to Charotar University of Science and Technology) Changa, Anand, Gujarat, India.

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*Address for Correspondence

D. S. Patel

Assistant Professor,
Department of Advanced Organic Chemistry,
P. D. Patel Institute of Applied Sciences,
(Affiliated to Charotar University of Science and Technology),
Changa, Anand, Gujarat, India.
E.Mail: darshanswami@gmail.com



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ABSTRACT

Vegetable oils are noticed to be potential alternatives to mineral oils for lubricant base stocks because of certain inherent properties viz. high viscosity, higher lubricity and low evaporative losses and biodegradability. Conventional mineral oil-based lubricants can be replaced by high molecular weight esters, which are created by chemically modifying the fatty acids found in oil. The primary structural changes shown by this study are the esterification and transesterification of the fatty acids found in Waste cooking oil (WCO). In order to verify the intended structure of the transesterified products (Bio lubricants) were analyzed using infrared spectroscopy. Using a pin-on-disc tribometer, a tribological analysis of the biolubricants was conducted. When compared to commercial lubricants, the synthesized bio lubricants showed a superior coefficient of friction. According to the results of a thermogravimetric examination, biolubricants have higher thermal stability as compare to commercial lubricants.

Keywords: Waste cooking oil, transesterification, bio lubricants, thermal stability, co-efficient of friction.





INTRODUCTION

Lubrication has been necessary since the very start of human beings becoming intelligent sufficient to use tools with moving parts. In other words; a lubricant was needed to reduce the effort [1, 2]. Even-though lubricant causes harmful effect to our environment. According to National Oceanic and Atmospheric Administration (NOAA) estimates that over 700 million gallons of petroleum enter the environment each year[3]. Industry experts estimate that 70% to 80% of hydraulic fluids leave through leaks, spills, line breakage and fitting failure, and about 40% of that ends in the environment [4]. Lubricating oils, greases comprises of base fluid, additives, thickening agents, among which base fluid is mainly a petroleum oils and rest is additives to give desirable properties. Lubricants made from petroleum oil have a significant harmful effect and are not very biodegradable. These lubricants' overabundance from the work area into the nearby water or soil negatively impacts the ecological system, which is intolerable given the growing environmental concerns[5]. Reducing the consumption of lubricant, which is nearly impossible, or creating a bio-based lubricants are the only viable solutions to the issues. A lot of development and research is being done on vegetable oils for bio lubricants, to meliorate the physicochemical properties so that they may prove to be a cheap and good substitute of petroleum based lubricants were developed for various sectors of industry. Vegetable oils have improved lubricity and natural viscosity, temperatures properties compared with petroleum based mineral oils. Vegetable oils in general possess high flash point, high viscosity index, higher lubricity and long hydrocarbon chain makes vegetable oil amphiphilic in nature, allowing it to be used as a boundary lubricant. However, serious negative characteristics of vegetable oils are poor oxidation stability and low temperature properties [6-10]. Numbers of researchers have contributed to make vegetable oil based bio lubricants by chemical modifications of the natural oil or fats. These modifications involves trans esterification [11], epoxidation[12], enzyme catalyzed esterification [13] and estolide formation [14]. Traditional method which uses thickeners is also reported by number of authors in which mineral oils are replaced by vegetable oils and fats[15]. But use of thickeners will leach heavy metals into water resources after disposing the lubricants. So the most common ways for altering vegetable oils are esterification /transesterification processes, epoxidation etc[16]. In the present work the attempt has been done to produce a bio lubricants by chemical modification of Waste cooking oil (WCO). Waste cooking oil was converted into its methyl ester which was then further modified by trans esterification with different alcohols viz. Heptanol, Isoamyl alcohol and Neopentyl glycol. The trans esterified products were confirmed by IR spectra and bio lubricants thus produced were characterized by viscosity, kinematic viscosity, thermogravimetric analysis (TGA) and Coefficient of friction. Commercial lubricant of M/s Hindustan petroleum limited was used as a standard to compare various properties of biolubricants.

MATERIALS AND METHODS

Waste cooking oil was received from farsan house of rural market at Anand, Gujarat, India. It was evaluated for Acid value, Iodine value, Saponification value and Peroxide value as per ASTM D974, ASTM D5554, ASTM D5558 and ISO 3960 respectively. Sodium hydroxide, Methanol, Sodium methoxide, Heptanol, Isoamyl alcohol and Neopentyl glycol were laboratory grade reagents and used without modification.

Gas chromatography analysis

Gas chromatography of vegetable oil was carried out using Perkin Elmer Auto System XL. The column used was BP-225, having 25 meters length and 250 mm diameter. Nitrogen as carrier gas at head pressure of 6 psi Temperature programming was initiated at 60 °C at the rate of 10°C per min to reach a temperature of 220°C. The inlet temperature was 250°C and detector temperature was 280°C.

Synthesis of Waste cooking oil methyl esters

Esterification of Waste cooking oil was done using methanol to form fatty acid methyl ester (FAME). Catalyst used in this process was NaOH, 1% (w/v) of oil. Alcohol to Oil ratio was 6:1. Temperature of the reaction mass was maintained at 60-65°C for 90 min [17]. After the completion of reaction the mixture of methyl esters and glycerol was



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separated in a separating funnel. The upper layer of methyl esters was washed with distilled water to remove excess methanol and catalyst until the fatty acid methyl esters became completely translucent. The methyl esters were further trans esterified with alcohols to form high molecular weight esters.

Synthesis of Bio lubricants - Trans esterification of Waste cooking oil methyl esters

Methyl esters of Waste cooking oil were trans esterified using various alcohols namely Heptanol, Isoamyl alcohol and Neopentyl glycol (Fig. 1-3). Methyl ester to alcohol ratio was kept as 1:1 for Heptanol, 1:1 for Isoamyl alcohol and 1:0.5 for Neopentyl glycol. Sodium methoxide 3% (w/v) was used as catalyst. Initially methyl-esters were charged in the reactor and were heated up to 50°C. Alcohol was added along with stirring once the temperature has reached 50 °C, along with the catalyst. The assembly which could lead to loss of vacuum was sealed with silicone grease to maintain vacuum in the entire system. After the completion of reaction, entire reaction mass was washed repeatedly with hot water to wash out the catalyst.

TGA analysis

Heat stability is an important characteristic for any lubricant. For this purpose, thermo gravimetric analysis (TGA) of the Waste cooking oil ester was done using a Pyris-1 thermogravimetry analyzer of Perkin Elmer. Around 10-20 milligrams of sample was taken and heated up to a final temperature of 550°C and a residence time of 1 min at 550°C was allowed. TGA was performed in air atmospheres at a heating rate of 10°C/Min. Thermo gravimetric weight loss curve was plotted against temperature. It provides a range of temperature in which the sample has maximum thermal stability and minimum weight loss.

Viscosity measurement and viscosity index

Viscosity is measured by using Ostwald's viscometer at 40°C and 100°C. The absolute viscosities were converted into kinematic viscosity by using the density of the Waste cooking oil, bio lubricant and commercial lubricant.

Co-efficient of friction

Co-efficient of friction of the bio lubricants was measured by using Ducom Wear and Friction Monitor pinon disc equipment. A baseline was run without any lubricant sample to check the actual friction generated between pin and disc. Then after a thin coat of sample was applied on disc and then it was allowed to rotate against pin for 1000 seconds at 500 rpm speed. The friction factor was obtained for all the samples using the same procedure. Commercial lubricant of M/s Hindustan petroleum limited was used as a standard.

Operating Conditions was as follows

Name of equipment: Ducom Wear and Friction Monitor; Model no TR-20LE-PHM-200; Operating time: 1000 sec;

Operating Temperature: Room Temperature (38°C); Operating Speed: 500 RPM; Track Diameter: 10mm; Pin

Diameter: 3mm; Material of pin: Aluminum; Material of Disc: EN31.

RESULTS AND DISCUSSION

Physicochemical properties

Physicochemical properties of Tobacco oil viz. Saponification value, Iodine value and Peroxide value were calculated which are tabulated in Table 1.

Fatty acid profile

Fatty acid profile of Waste cooking oil was done by Gas Chromatography. The results of fatty acid profile shows the presence of oleic acid upto 44.31%, other fatty acids are also present which are tabulated in Table 2. Figure 4 is the gas chromatogram of Waste cooking oil in which peak at retention time 18.15 minute is of oleic acid, having the highest concentration amongst other fatty acids.





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Spectral analysis

In IR Spectra of different Bio Lubricants from WCO showed the characteristic bands at around $1600 - 1650\text{ cm}^{-1}$ indicates C=O stretching in ester group. Bands at around $2850 - 2950\text{ cm}^{-1}$ for CH stretching in alkanes group are visible. A band at around 1450 cm^{-1} was observed for carbomethoxy group. A band at around $1050 - 1100\text{ cm}^{-1}$ was observed for -C-O band stretching band at around 3000 cm^{-1} was observed for CH Stretching in unsaturated -CH=CH- bonds (Fig. 5-7).

Viscosity and kinematic Viscosity

Viscosity is a measure of a fluid resistance to flow. If lubricants have low viscosity, it causes wear and friction which generate heat. Viscosity decreases (thins) with increasing temperature and increases (or thickens) with decreased temperature. Viscosity of lubricants is measured most commonly by kinematic viscosity. Kinematic Viscosity is a measure of a fluid internal resistance to flow under gravitation forces. Viscosity and kinematic viscosity are tabulated in Table 3. Viscosity and kinematic viscosity of bio lubricants are higher than that of commercial lubricant.

Thermo gravimetric Analysis

Thermo gravimetric analysis (TGA) measures the amount rate of change in the weight of a material as a function of temperature. TGA is helpful in determining the range of temperature under which the moisture and the volatile content of the substance is driven out. It also helps to study the decomposition of the material with increase in temperature and hence, to know about the thermal stability of a material. Figures 8-11 represents the thermograms of Heptanol, Isoamyl alcohol, Neopentyl glycol esters of WCO and commercial lubricant respectively. The thermograms show that all the three esters (Bio lubricants) have sufficient thermal stability. The Neopentyl glycol ester of WCO is comparatively more stable than the commercial lubricant.

Co-efficient of friction

The co-efficient of friction, often symbolized by the Greek letter μ , is a dimensionless scalar value which describes the ratio of the force of friction between two bodies and the force pressing them together. The co-efficient of friction obtained after applying Waste cooking oil esters (Bio lubricants) and commercial lubricant on pin on disc apparatus. Results of the coefficient of friction are tabulated in Table 4. The friction factor for the dry condition (without any type of lubricant) was 0.350. The Waste cooking oil ester from Heptanol has the least co-efficient of friction indicating its highest lubricating tendency. The co-efficient of friction obtained using Waste cooking oil ester from Heptanol on pin on disc apparatus was 0.072, which is better than that of commercial lubricant (0.098) under same operating conditions. The co-efficient of friction obtained after applying Waste cooking oil ester from Isoamyl alcohol on pin on disc apparatus was 0.080, which is also better than that of commercial lubricant (0.098) under same operating conditions. The co-efficient of friction obtained after applying Waste cooking oil ester from Neopentyl glycol on pin on disc apparatus was 0.100, which is almost same as that of commercial lubricant (0.098) under same operating conditions. So we can use of such natural materials for deriving a value added product like bio lubricants can eliminate various problems related to environment and depletion of finite resources; which are still in search of a legitimate solution.

CONCLUSION

Waste cooking oil methyl esters were successfully trans esterified using various alcohols viz. Heptanol, Isoamyl alcohol and Neopentylglycol. Thus biolubricants can be successfully prepared from Waste cooking oil- a renewable source. These biolubricants have superior performance property such as co-efficient of friction compared to commercial lubricant which proves that WCO is a potential starting material for biolubricant. Thermogravimetric analysis results shows that prepared biolubricants had more thermal stability against standard commercial lubricant.





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Table 1. Physicochemical properties of Waste cooking oil (WCO)

Sr. No.	Characteristics	Unit
1	Acid value	3.89 mg of KOH/ gm of sample
2	Saponification value	330 mg of KOH/gm of sample
3	Peroxide value	5.94 meq peroxides/kg
4	Iodine value	43.78 gram of I ₂ absorbed/100g





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Table 2: Fatty acid composition of WCO

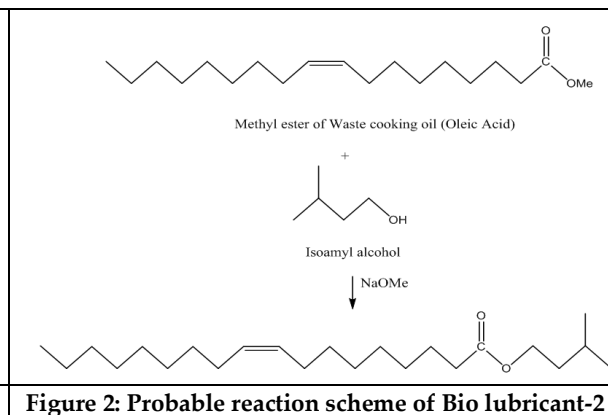
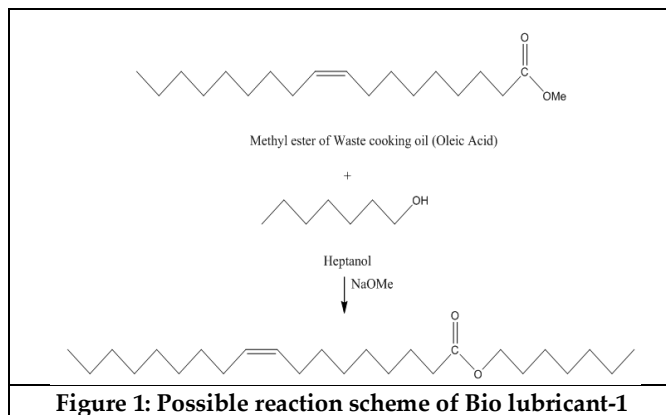
Sr. No.	Fatty Acid	Percentage (%)
1	Myristic Acid	0.87%
2	Palmitic Acid	37.33%
3	Palmitolic Acid	0.15%
4	Stearic Acid	4.26%
5	Oleic Acid	44.31%
6	Linoleic Acid	10.48%
7	Linolenic acid	0.20%

Table 3: Viscosity and Kinematic Viscosity

Sr. No.	Sample	Viscosity	Kinematic viscosity
1	WCO	71.60 Pa's	65.96 m ² /s
2	Bio Lubricant	47.96 Pa's	60.66 m ² /s
3	Commercial lubricant	24.604 Pa's	29.11 m ² /s

Table 4: Co-efficient of friction

Sr. No.	Sample	Co-efficient of Friction
1	Dry condition (without lubricant)	0.350
2	Bio Lubricant-1	0.072
3	Bio Lubricant-2	0.080
4	Bio Lubricant-3	0.100
5	Commercial lubricant	0.098





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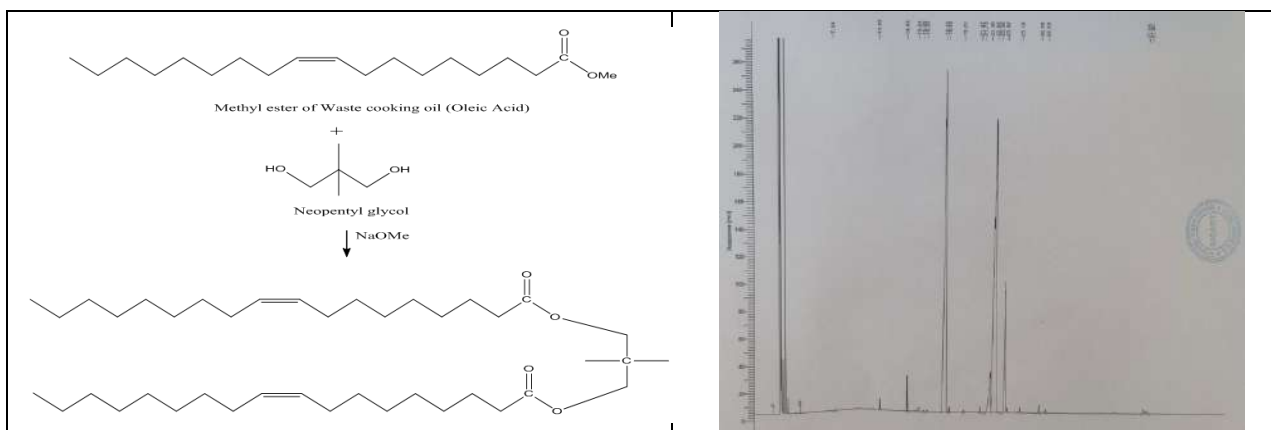


Figure 3: Postulated reaction scheme of Bio Lubricant-3

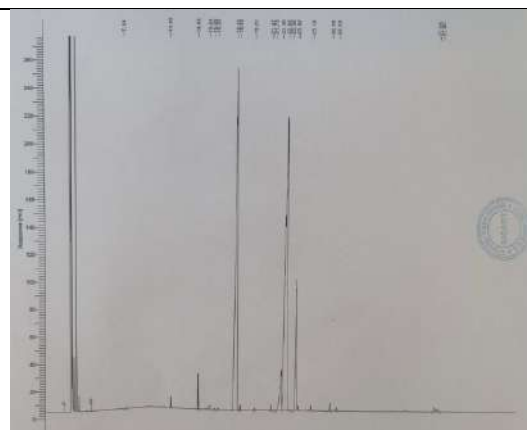


Figure 4: Gas Chromatogram of Waste cooking oil

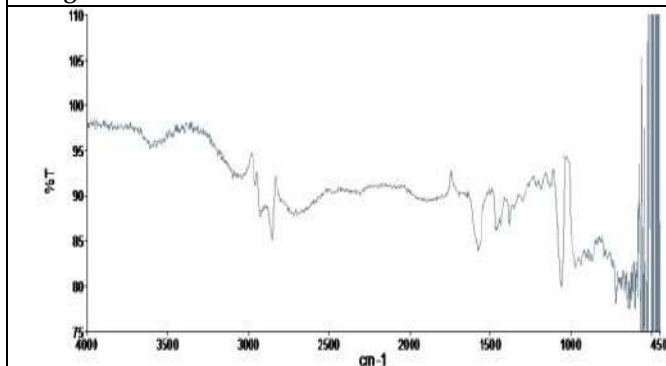


Figure 5: IR spectrum of Bio Lubricant-1

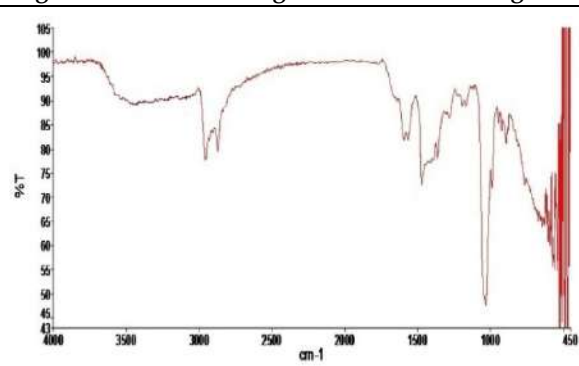


Figure 6: IR spectrum of Bio Lubricant-2

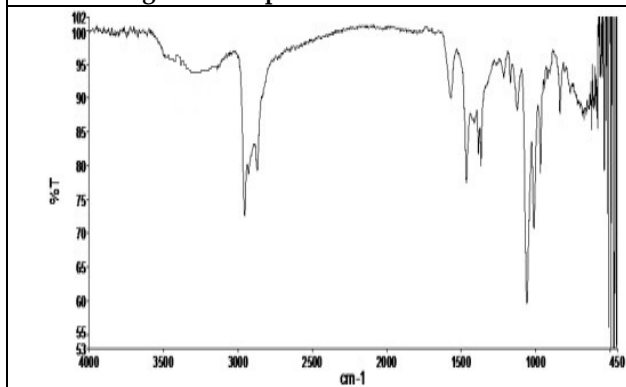


Figure 7: IR spectrum of Bio Lubricant-3

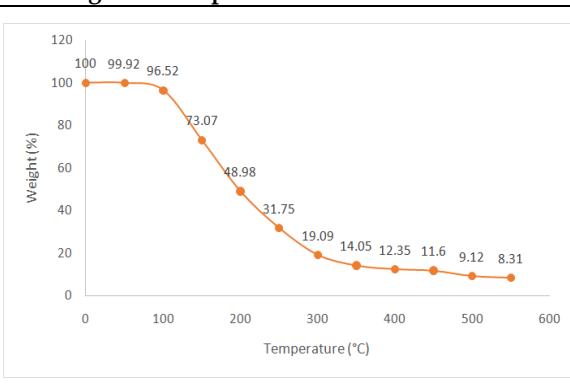


Figure 8: The temperature v/s percentage weight thermo gram of Bio Lubricant-1





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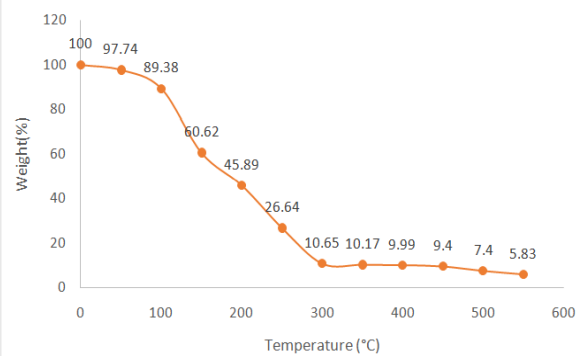


Figure 9: The temperature v/s percentage weight thermo gram of Bio Lubricant-2

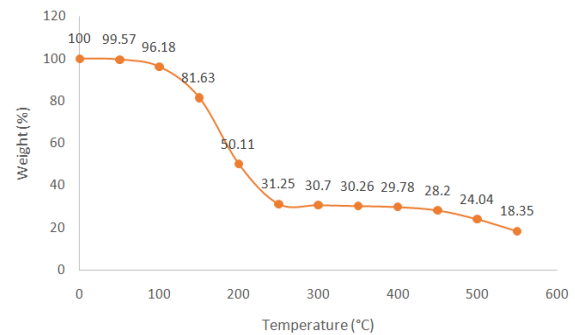


Figure 10: The temperature v/s percentage weight thermo gram of Bio Lubricant-3

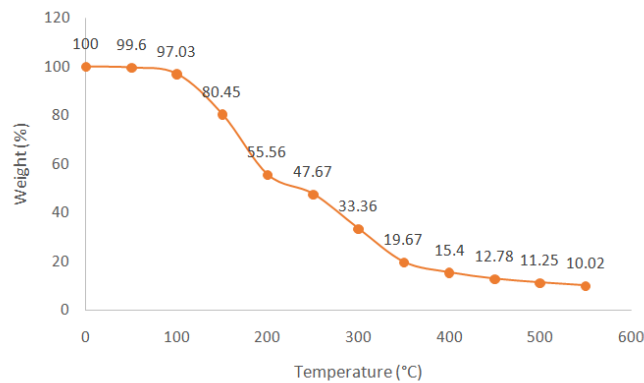


Figure 11: The temperature v/s percentage weight thermo gram of commercial lubricant





RESEARCH ARTICLE

***In vitro* and *In silico* Evaluation of the Biological Potency of 3,5,7,3',4',5'-Hexahydroxyflavone Isolated from *Euphorbia milii* Des Moul. Leaves**

A.Ch.Pradyutha^{1*}, Sabitha Yadam² and P.Sakuntala³

¹Assistant Professor, Department of Microbiology, RBVRR Womens College (Autonomous), Narayanguda, (Affiliated to Osmania University), Hyderabad, Telangana, India.

²Research Head, Department of Ciencia Labs, Ciencia Labs LLP, Hyderabad, Telangana, India.

³Associate Professor, Department of Physics, Geethanjali College of Engineering and Technology, (Affiliated to Jawaharlal Nehru Technological University), Hyderabad, Telangana, India.

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***Address for Correspondence**

A.Ch.Pradyutha

Assistant Professor,

Department of Microbiology,

RBVRR Womens College (Autonomous), Narayanguda,

(Affiliated to Osmania University),

Hyderabad, Telangana, India.

E.Mail: pradyutha.g@gmail.com



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ABSTRACT

This study investigates the *in vitro* Antioxidant, Antidiabetic activities, and Molecular simulation studies of 3,5,7,3',4',5'-Hexahydroxyflavone (myricetin), a compound isolated from the ethyl acetate extract of *Euphorbia milii* leaves. The antioxidant potential of myricetin was assessed using the 2,2-diphenyl-1-picrylhydrazyl (DPPH) assay, and its activity was compared with the standard antioxidant, ascorbic acid. Results revealed that myricetin displayed prominent antioxidant activity, emphasizing its efficacy as a potent antioxidant. The antidiabetic potential was evaluated through *in vitro* inhibition assays targeting key carbohydrate hydrolyzing enzymes— α -amylase and α -glucosidase. Myricetin demonstrated significant inhibitory activity against both enzymes compared to the reference drug, acarbose, suggesting its promising antidiabetic potential. The Protein binding studies with Bovine Serum Albumin (BSA) was investigated by using absorption, and emission spectroscopic methods. These results emphasize the potential of myricetin as a promising candidate for further development in antioxidant and antidiabetic therapies. In addition, molecular docking studies were performed to explore the interactions between myricetin and two critical targets: α -D-glucosidase (PDB ID: 3A4A) and protein tyrosine phosphatase 1B (PTP1B, PDB ID: 1T49). The docking results provided valuable insights, supporting the biological activities observed *in vitro*.

Keywords: Antioxidant, Antidiabetic, protein binding, Docking studies, Molecular simulations



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INTRODUCTION

In latest periods, scientific concern in medicinal plants has rushed as researchers hunt for natural substitutions to synthetic drugs, which often come with undesirable side effects and drug resistance issues. The global shift towards the conventional plant-based therapies, reflects an increasing recognition of the effectiveness and safety of medicinal plants. [Shahrajabian *et al.*, 2023] Many contemporary medicines have origins in traditional plant remedies, with compounds like aspirin (derived from *Salix* species) and metformin (initially from *Galega officinalis*) serving as key examples. [Alamgir *et al.*, 2017] With the increasing incidence of chronic diseases and the restrictions associated with contemporary treatments, medicinal plants present a promising way for discovering novel therapeutic agents. [Pan *et al.*, 2013]. *Euphorbia milii*, a member of the Euphorbiaceae family, is notorious for its rich phytochemical profile, which embraces flavonoids, alkaloids, and terpenoids with significant medicinal properties. However, the bioactive potential of compounds derived from this plant remains underexplored, particularly concerning metabolic diseases like diabetes [Pradyutha *et al.*, 2024]. An imbalance between the body's antioxidant defenses and the generation of reactive oxygen species (ROS) is known as oxidative stress. A major factor in the progression of many chronic illnesses, such as diabetes, cancer, neurodegenerative diseases, and cardiovascular disorders, is oxidative stress. ROS, including hydrogen peroxide, superoxide anions, and hydroxyl radicals, cause oxidative damage to proteins, lipids, and DNA, which ultimately results in cell dysfunction and tissue damage. Because of their inherent antioxidant qualities, plant-derived compounds have recently drawn more attention as a means of combating oxidative stress [Gallia *et al.*, 2024]. Diabetes is the most common disease and has become an epidemic on a global scale. Long-term problems affecting the kidneys, nervous system, cardiovascular system, and eyes are linked to the disease. Insulin therapy and oral hypoglycemic medications are the mainstays of recent diabetes treatments, which aim to control blood glucose levels. Plant-based compounds have received a lot of attention recently as potential treatments for diabetes because of their safety, effectiveness, and capacity to target several disease-related pathways. By a variety of mechanisms, including boosting glucose absorption, inhibiting enzymes that hydrolyze carbohydrates, improving insulin sensitivity, and regulating oxidative stress, phytochemicals like flavonoids, alkaloids, terpenoids, and phenolic acids have demonstrated strong antidiabetic activity [Wang *et al.*, 2023]. Through this investigation, we target to establish myricetin's therapeutic potential in managing oxidative stress and diabetes, providing a foundation for future drug development based on natural products.

Experimental

Antioxidant activity

The antioxidant efficiency of myricetin was assessed using the DPPH (2,2-diphenyl-1-picrylhydrazyl) free radical scavenging assay. The isolate was made in DMSO at different concentrations, from 100 µg/ml to 500 µg/ml. DPPH was dissolved in methanol to create a 0.004% (w/v) DPPH solution. For the assay, 1 ml of each concentration of the isolate was combined with 4 ml of the DPPH solution. The mixture was then incubated in the dark for 30 minutes. Ascorbic acid, a known antioxidant, served as a positive control for comparison against the antioxidant activity of the bioactive compound isolated from leaf extract of *E. milii*. After incubation, the absorbance of the samples was measured at a wavelength of 517 nm. [Pradyutha *et al.*, 2022]

The percentage of DPPH scavenging activity was calculated using the following formula

$$\% \text{ of DPPH scavenging activity} = [(A_o - A_s) / A_o] \times 100$$

A_o-absorbance of the control (mixture without the plant sample)

A_s- absorbance of the plant sample

In vitro-Antidiabetic screening

By enhancing the breakdown of carbohydrates into glucose, the digestive enzymes α -amylase and α -glucosidase play vital roles in controlling blood glucose levels in diabetes mellitus. Their activity raises the concentration of glucose, which causes hyperglycemia in diabetics. Thus, blocking these enzymes has emerged as a crucial therapeutic approach for efficiently controlling blood glucose levels. Using enzyme inhibition assays, we screened the tested compound's inhibitory effects on α -amylase and α -glucosidase in order to assess its antidiabetic potential.

[Gong *et al.*, 2020]



**Pradyutha et al.,****Inhibition of α -amylase Enzyme**

The experiment consisted of mixing α -amylase (0.5 mg/ml) with the sample at varying concentrations from 100 μ g/ml to 500 μ g/ml. A 1% starch solution and 100 μ l of 0.2 mM phosphate buffer (pH 6.9) were then added to this mixture. The reaction was conducted at 37°C for 5 minutes, after which it was stopped by adding of 2 ml of 3,5-dinitrosalicylic acid reagent. The resultant mixture was heated at 100°C for 15 minutes and then diluted with 10 ml of distilled water in an ice bath. Finally, the activity of α -amylase was evaluated by measuring the absorbance at 540 nm using a spectrophotometer, reflecting the intensity of the colour produced. [keharom *et al.*, 2016]

Inhibition of α -glucosidase Enzyme

The experiment involved adding different sample concentrations, ranging from 100 mg/ml to 500 mg/ml, to a mixture that included 1 ml of a 2% w/v maltose starch solution and 0.2 M tris buffer (pH 8). This reaction mixture was incubated at 37°C for 10 minutes. Following this, 1 ml of α -glucosidase enzyme (1 U/ml) was introduced to initiate the reaction, which was allowed to proceed at 35°C for an additional 40 minutes. To stop the reaction, 2 ml of 6 N hydrochloric acid was added. The inhibitory effect was evaluated by measuring the colour intensity of the resulting solution at 540 nm using a spectrophotometer. [Podsdek *et al.*, 2014]

Protein Binding Studies**UV-VIS Spectroscopy**

Absorption spectra were recorded on Shimadzu 1800 UV-visible spectrophotometer using 1 cm quartz micro cuvettes. Absorption titrations were recorded from 200-400nm by keeping the concentration of the BSA constant (10 μ M) and by varying the concentration of myricetin from 10 to 100 μ M. For the myricetin, the binding constants (Kb) have been determined from the spectroscopic titration data.

Fluorescence Spectroscopy

The protein-binding studies have been performed by tryptophan fluorescence quenching experiments using bovine serum albumin in buffer (containing 5 mM Tris HCl and 50 mM NaCl at pH 7.0). The quenching of emission intensity of the tryptophan residues of BSA at 343 nm was examined in the presence of increasing concentrations of myricetin as quenchers. The quencher was added in equal increments with concentration increasing from 5 μ M to 25 μ M to a fixed concentration of BSA. Fluorescence spectra were documented from 300 to 500 nm at an excitation wavelength of 296 nm by using the Shimadzu RF 5301 PC Spectrofluorimeter.

Molecular Docking

The target proteins, alpha-glucosidase (PDB ID: 3A4A) [Kitada *et al.*, 2023] and PTP1B (protein tyrosine phosphatase 1B, PDB ID: 1T49) [Wiesmann *et al.*, 2004], were retrieved from the RCSB Protein Data Bank (<https://www.rcsb.org>). The compounds of interest were sourced from PubChem (<https://pubchem.ncbi.nlm.nih.gov>) [Kim *et al.*, 2023]. Molecular interactions between the proteins and compounds were evaluated using AutoDock Vina [Eberhardt *et al.*, 2021]. Both proteins and ligands underwent preparation prior to docking. The active site of alpha-glucosidase was identified, and a grid was generated with dimensions of 19 Å × 19 Å × 19 Å, centred at coordinates X = 21.0165, Y = -7.4, and Z = 24.2. Similarly, for PTP1B, a grid of 25 Å × 25 Å × 25 Å was generated with coordinates X = 53.82, Y = 25.1, and Z = 22.02. Initial geometric optimization was performed, followed by the application of the General Amber Force Field (GAFF). Default docking parameters were used throughout the study. To validate the docking protocol, native ligands of alpha-glucosidase and PTP1B were re-docked into their respective active sites under the specified conditions. The root-mean-square deviation (RMSD) of the re-docking results was less than 1 Å, confirming the accuracy and reliability of the docking setup [Trott *et al.*, 2010]. The results were visualized and evaluated for post-docking analysis using Chimera [Pettersen *et al.*, 2004] and Discovery Studio [Studio 2008]. This workflow established a robust and trustworthy protocol for conducting molecular docking studies.



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RESULTS AND DISCUSSION

Antioxidant Activity

The findings reveal that myricetin exhibits higher free radical inhibition activity than the common antioxidant ascorbic acid. This study supports Huang's (2024) research, which showed myricetin's protective properties against oxidative stress. The bioactivity of myricetin exhibits a pronounced dose-dependent response, with a notable increase in activity as concentration increases. Interestingly, myricetin displays higher DPPH free radical scavenging potential than ascorbic acid at 300 µg/ml, 400 µg/ml, and 500 µg/ml. A steady increase in myricetin's activity is identified, with a remarkable 48% activity at 100 µg/ml, escalating to 98% at 500 µg/ml (Figure-1). This suggests that while the scavenging activity may be less pronounced at lower concentrations, the compound's capacity to neutralize radicals becomes more significant as the concentration increases. The high efficacy of myricetin as antioxidant agent is due to its structure. Myricetin has multiple hydroxyl groups, which accomplished of donating electrons to counteract free radicals. This helps to dismiss the chain reactions of oxidative stress. [Ng *et al.*, 2023]. These conclusions highlight myricetin's significant bioactive properties, likely attributed to its potent free radical scavenging capabilities and antioxidant activity. The results imply that myricetin may be a more effective antioxidant than ascorbic acid at the tested concentrations. The consistent dose-response relationship for both myricetin and ascorbic acid emphasizes the importance of concentration in evaluating the efficacy of bioactive compounds. It was also proved by Arumugam [Arumugam *et al.*, 2019] through his studies. Though the flavonoid myricetin is common and present in fruits and vegetables [Rice-Evans *et al.*, 1996], we can extract this bioactive myricetin from leaves of *Euphorbia milii* plant as it is drought tolerance and low maintenance make it an efficient for large-scale myricetin extraction.

In-vitro Antidiabetic activity

Maintaining blood glucose levels in diabetic patients is essential to prevent the complications commonly linked to the condition. The ability to sustain plasma glucose concentration over the long term, even with changing dietary patterns, is one of the most critical and finely regulated processes in mammals. [Abo-Shady *et al.*, 2023]

α -amylase activity

The data illustrates that myricetin exhibits a strong inhibitory effect on α -amylase enzyme activity, showing a dose-dependent response. At the lowest concentration of 100 µg/ml, myricetin achieved 40% inhibition, which is slightly lower than the 42% inhibition observed with the standard drug acarbose. As the concentration increased to 200 µg/ml, myricetin's inhibitory activity enhanced to 70%, surpassing acarbose, which showed 68% inhibition at the same concentration. At 300 µg/ml, myricetin maintained a higher inhibition (78.1%) compared to acarbose (75%). This trend continued at 400 µg/ml, where myricetin exhibited 99% inhibition, marginally higher than acarbose (97%). At the highest concentration of 500 µg/ml, myricetin showed maximum inhibition at 116%, which is again slightly higher than acarbose inhibition of 112%. (Figure-2). These results suggest that myricetin is a potent inhibitor of α -amylase and, at higher concentrations, may be more effective than acarbose in controlling enzyme activity.

α -glucosidase inhibition

The data demonstrates that myricetin effectively inhibits α -glucosidase enzyme activity in a dose-dependent manner. At a concentration of 100 µg/ml, myricetin exhibited 38% inhibition, which is lower compared to acarbose 42% inhibition. As the concentration increased to 200 µg/ml, myricetin's inhibition rose to 45%, still lower than acarbose, which showed 56% inhibition. However, at 300 µg/ml, myricetin's inhibition equaled that of acarbose at 76%. At higher concentrations, myricetin surpassed acarbose, showing 98% inhibition at 400 µg/ml compared to acarbose's 89%. Finally, at 500 µg/ml, myricetin exhibited 109% inhibition, slightly higher than acarbose, which showed 105% (Figure-3). According to these results, myricetin may be a powerful α -glucosidase inhibitor because it exhibits less inhibitory activity at lower concentrations but surpasses acarbose activity at higher doses. The ability of myricetin to inhibit both α -amylase and α -glucosidase suggests that it could serve as a potent natural alternative to synthetic inhibitors like acarbose. Natural enzyme inhibitors are often considered more favourable due to their reduced



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likelihood of causing adverse side effects, such as gastrointestinal discomfort, which is common with acarbose. Furthermore, myricetin's dose-dependent effectiveness shows promise as a treatment, especially for postprandial hyperglycemia. Myricetin may be able to help diabetic patients avoid the sudden spikes in blood sugar that frequently follow meals by slowing down the rate at which carbohydrates are broken down and absorbed. Patients looking for natural or plant-based treatment options may find this to be specifically helpful.

Protein binding studies

UV Spectra

The UV-Vis spectrum of BSA protein gives two λ max, one at 220 nm due to the α -helix and another at 280 nm due to the aromatic amino acid residues [Qashqoosh *et al.*, 2019]. Marked changes are observed in BSA λ max at 277 nm with increasing concentration of the flavonoid. Hyperchromism with a blue shift of 1-12 nm indicates formation of a new species resulting from the interaction of the flavonoid rings and the aromatic amino acids of protein [Zsila *et al.*, 2003]. Fluorescence studies also corroborate these observations. A graph plotted for $1 / A - A_0$ Vs [complex] gives the K_b value as $0.36 \times 10^{-2} \text{ M}^{-1}$ (Figure-4).

Fluorescence Spectra

BSA solutions exhibit a strong fluorescence emission with a peak at 343 nm, due to the tryptophan residues, when excited at 296 nm. Fluorescence quenching studies is a decrease in fluorescence intensity and a small red shift occurs regularly with increasing amounts of compound as shown in Figure-5. The values of the Stern-Volmer quenching constants of the compound interacting with BSA is calculated by Stern-Volmer quenching eq. [Hu *et al.*, 2005]. With the increase in myricetin concentration, BSA emission λ max exhibits hypochromism with a blue shift of 3-6nm. This is indicative of an alteration in the local dielectric environment around the tryptophan moiety of the globular protein. Hence, a strong hydrophobic interaction may be occurring between the flavonoid and the tryptophan moiety of the protein. The fluorescence quenching can be described by the Stern-Volmer equation [Gehlen 2020]. The centenary of the Stern-Volmer equation of fluorescence quenching: From the single line plot to the SV quenching map.

$I_0 / I = 1 + K_{sv} [Q]$. Where, I_0 and I are fluorescence intensities of BSA, in absence and presence of myricetin, respectively. K_{sv} is the Stern-Volmer quenching constant, $[Q]$ is Myricetin concentration.

A plot of I_0 / I vs $[Q]$ was drawn and the slope was calculated as $0.21 \times 10^{-5} \text{ M}^{-1}$.

The slope gives the K_{sv} value, which is a measure of binding strength.

Docking studies

The ligand-enzyme complex α -glucosidase and 3,5,7,3',4',5'-hexahydroxyflavone was successfully docked using AutoDock Vina. 3,5,7,3',4',5'-hexahydroxyflavone exhibited a binding affinity of -8.9 kcal/mol, surpassing the standard ligand, Alpha-D-glucopyranose, which had a binding affinity of -7.1 kcal/mol. The molecular interactions of 3,5,7,3',4',5'-hexahydroxyflavone with α -glucosidase were extensive. It formed four hydrogen bonds with key residues in the catalytic site: Tyr158, Arg442, Asp352, and Asp307. These interactions are critical for stabilizing the ligand within the active site and likely contribute to its strong inhibitory activity. Additionally, the compound established van der Waals interactions with a range of residues, including Phe314, Glu411, Phe159, Phe178, Glu277, Gln279, Phe303, and His280. These interactions further stabilize the ligand-enzyme complex, reinforcing its potential to effectively inhibit α -glucosidase activity. (Figure-6) To explore the anti-diabetic potential of 3,5,7,3',4',5'-hexahydroxyflavone, the compound was also docked with PTP1B, a key protein implicated in insulin signalling and glucose metabolism. The binding energy for 3,5,7,3',4',5'-hexahydroxyflavone with PTP1B was calculated as -7.6 kcal/mol, which, while slightly lower than the binding energy of the standard PTP1B inhibitor (-8.8 kcal/mol), still represents significant interaction potential. The compound's hydroxyl groups played a vital role in forming four hydrogen bonds with the residues Glu276 and Lys197 within the active site of PTP1B. These hydrogen bonds suggest a strong and specific interaction with the protein. The binding mode of 3,5,7,3',4',5'-hexahydroxyflavone to PTP1B seems to stabilize the enzyme in its open conformation, which is connected with enhanced binding at the active site. Although its binding energy was lower than the standard inhibitor, the ability to form multiple hydrogen bonds and interact with key residues indicates that the compound may serve as a promising scaffold for designing potent PTP1B inhibitors with potential anti-diabetic effects. (Figure-7) Former research has shown that flavonoids with



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hydroxyl groups display robust inhibitory activity against α -glucosidase due to their capacity to form multiple hydrogen bonds and interact with hydrophobic regions of the enzyme [Zhang *et al.*, 2017]. These findings align with the detected interactions in this study, suggesting that 3,5,7,3',4',5'-hexahydroxyflavone could efficiently decrease postprandial hyperglycemia by inhibiting carbohydrate digestion. Previous literature supports the role of PTP1B inhibitors in improving insulin receptor and suggesting them possible constituents for type 2 diabetes treatment. While 3,5,7,3',4',5'-hexahydroxyflavone showed slightly lower binding energy, its strong hydrogen bonding and structural compatibility with the active site indicate its potential as a lead compound for further optimization. The dual inhibitory action of 3,5,7,3',4',5'-hexahydroxyflavone against α -glucosidase and PTP1B highlights its multifaceted role in managing diabetes. By inhibiting α -glucosidase, the compound could reduce glucose absorption from dietary carbohydrates, thereby mitigating postprandial hyperglycemia. Simultaneously, its interaction with PTP1B suggests a role in improving insulin sensitivity, addressing a key aspect of type 2 diabetes pathophysiology. While the docking studies provide valuable insights into the binding interactions, in vitro and in vivo studies are necessary to confirm the biological activity and pharmacokinetics of 3,5,7,3',4',5'-hexahydroxyflavone.

CONCLUSION

The results of this research validate that myricetin isolated from the ethyl acetate extract of *E. milii* leaves, displays noteworthy antioxidant and antidiabetic activities. The compound displayed prominent efficiency in the DPPH assay, similar to ascorbic acid, demonstrating its high antioxidant potential. Furthermore, myricetin exhibited substantial inhibitory effect against α -amylase and α -glucosidase enzymes, surpassing the effectiveness of the reference drug, acarbose, thereby underscoring its potential as an antidiabetic agent. Protein binding studies with Bovine Serum Albumin (BSA) further supported these biological activities. Moreover, molecular docking studies providing valuable insights into the interactions between myricetin and critical targets such as α -D-glucosidase and protein tyrosine phosphatase 1B (PTP1B), reinforcing the in vitro results. Together, these findings highlight the potential of myricetin as a promising candidate for future development in antioxidant and antidiabetic therapies. Myricetin, a broadly distributed flavonoid, and it has significant attention due to its biological efficacy. Considering its potential for commercial applications, the leaves of *E. milii* plant is a good source for myricetin extraction as it is drought resistance plant and requires minimal maintenance and its abundant availability.

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ETHICAL STATEMENTS

This article does not contain any studies with human participants performed by any of the authors.

CONFLICT OF INTEREST

The authors declare that they have no conflicts of interest.

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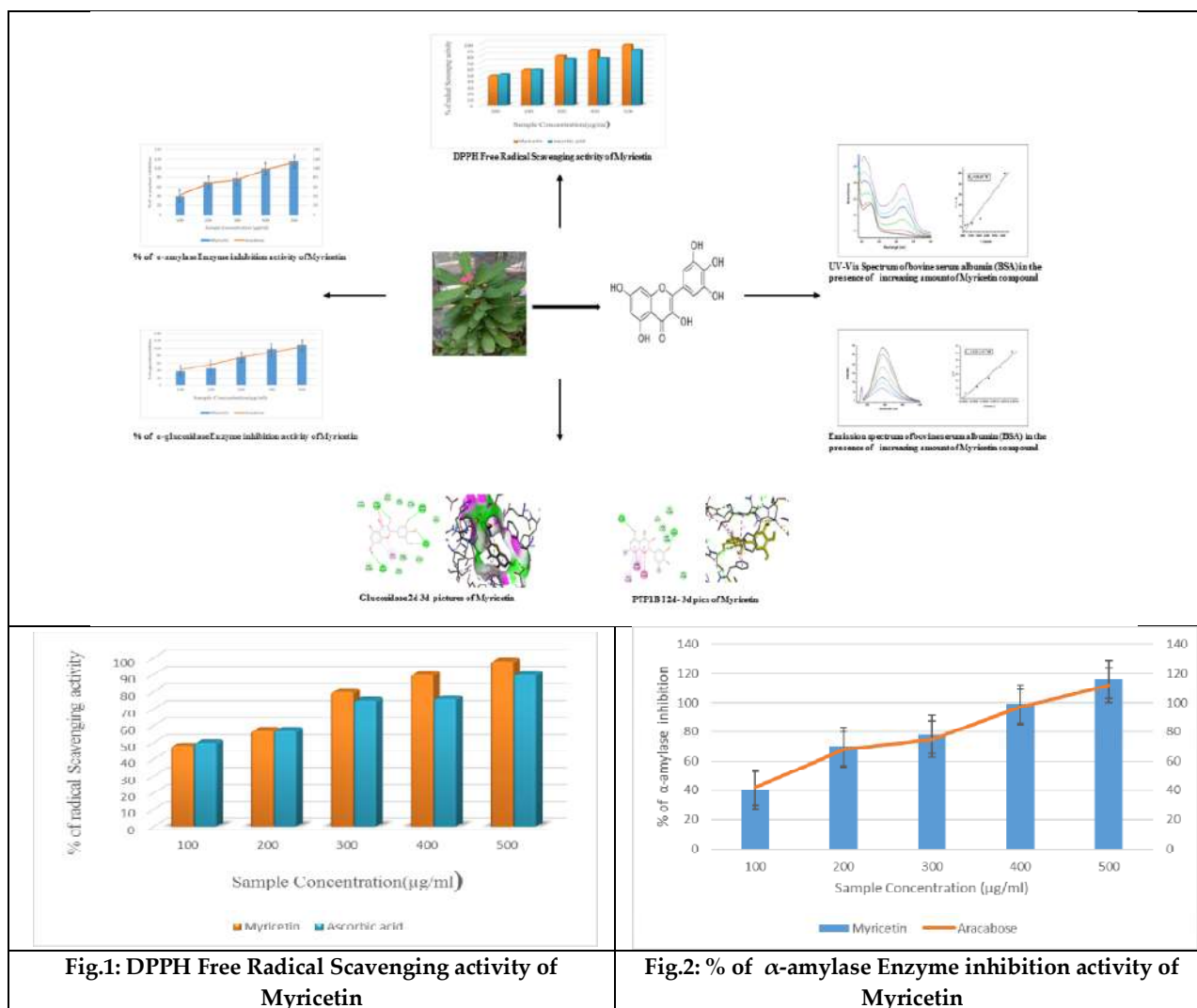
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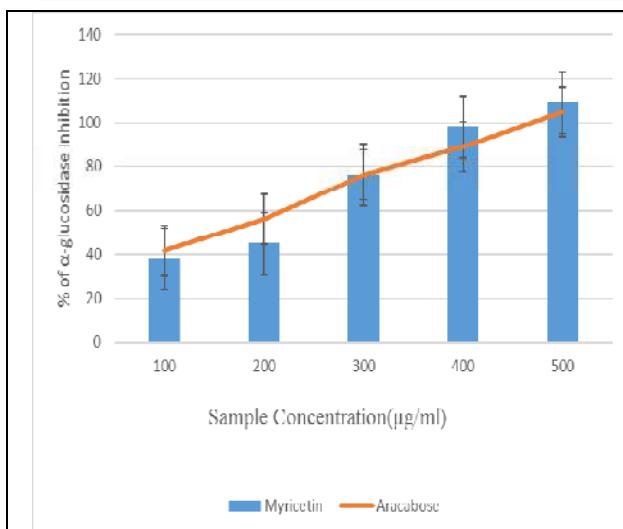


Fig.3: % of α-glucosidase Enzyme inhibition activity of Myricetin

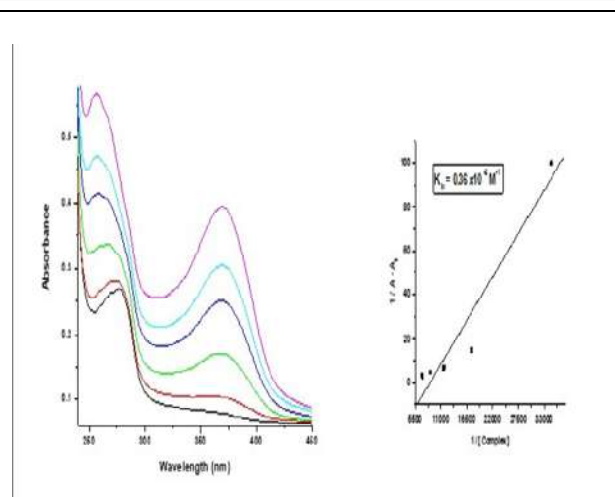


Fig.4: UV-Vis Spectrum of bovine serum albumin (BSA) in the presence of increasing amount of Myricetin compound

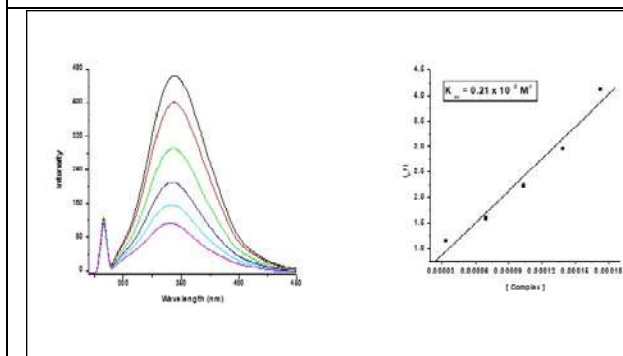


Fig.5: Emission spectrum of bovine serum albumin (BSA) in the presence of increasing amount of Myricetin compound

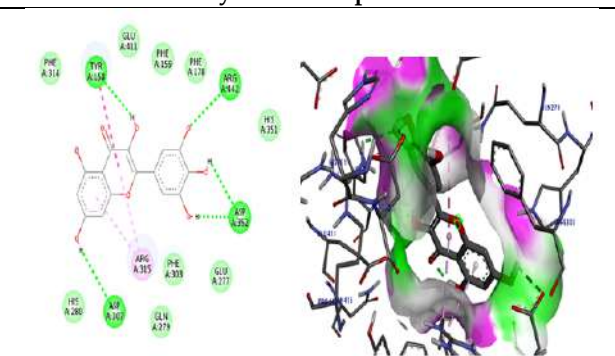


Fig.6: Glucosidase 2d,3d pictures of Myricetin

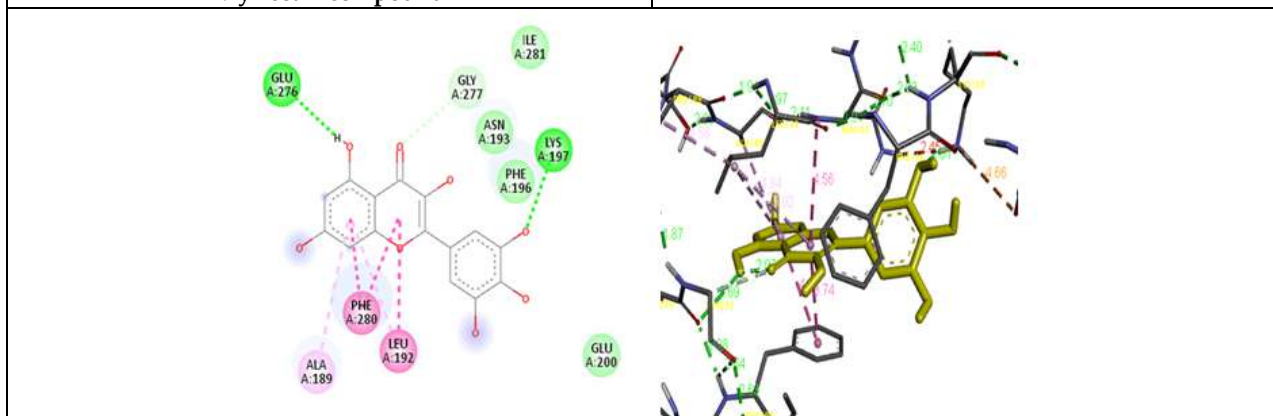


Fig.7: PTP1B I 2d, 3d pictures of Myricetin





REVIEW ARTICLE

The Balance Training in Para Sports : A Rapid Review

Rina Poonia¹, Sekar Sakthivel² and Vijmendra Kumar Grover^{3*}

¹Associate Professor, Department of Libral Arts and Scocial Sciences, Manipal University Jaipur, Rajasthan, India

²Assistant Professor, Department of General and Adapted Physical Education and Yoga (GAPEY), Ramakrishna Mission Vivekananda Educational and Research Institute (Deemed to be University), Coimbatore, Tamil Nadu, India.

³Assistant Professor, Department of Libral Arts and Scocial Sciences, Manipal University Jaipur, Rajasthan, India

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*Address for Correspondence

Vijmendra Kumar Grover

Assistant Professor,

Department of Libral Arts and Scocial Sciences,

Manipal University Jaipur, Rajasthan, India

E.Mail: vkgrover4887@gmail.com



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ABSTRACT

Balance ability is foundational to move efficiently, change the direction quickly, and execute complex movements. In the population of para-athletes this is even more critical because of the presence of physical impairment. Despite the importance, there is lack of comprehensive review synthesizing evidence for understanding the gap and training recommendations. The purpose of this rapid review is to critically appraise and synthesize evidence from the available literature on the understanding and development of the balance ability in para-athletes. A search was performed across PubMed, SPORTDiscus, PEDro and Google Scholar electronic databases by using appropriate keywords collected from expert opinions and previous studies in the field. The review focused on the four categories namely, locomotor disability athletes, visually impaired athletes, hearing-impaired athletes, intellectual disability athletes. The review highlights the lack of studies on large samples. Most of the available evidence are from the children with only few investigations on adults and there was also lack of studies conducted in female population. The findings suggest that it is essential to perform tests for both static and dynamic balance abilities to avoid making inappropriate conclusions about the effectiveness of balance training. The most important factor highlighted in the training related to is the coach and trainer's understanding and knowledge about rehabilitation, skill level, awareness, and athlete's safety.

Keywords: Para-Athletes, Postural Control, Dynamic Balance, Stability, Adaptive Sport



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INTRODUCTION

Balance is a critical component across the lifespan, vital to the performance of activities of daily living and for functional competence. It affects functional mobility and safety in the elderly, the development of postural control, and motor skills in children. Balance is also vital to the performance of fundamental motor skills and therefore essential for the performance of activities relating to sport. Balance, generally, refers to the maintenance of a support base in the presence of varying challenges to posture[1]. Its regulation requires sensory processing of the visual, somatosensory, and vestibular systems. Balance is also an essential skill in sports requiring stability, coordination, and control of body movements[1]. Sport skills are performed effectively with the sufficiently developed body control, and balance and, particularly, dynamic balance of players. When performing athletic activities, the ability to maintain balance is vital for optimal performance and injury prevention[1]. Appropriately developed balance ability enables the athletes to move efficiently, change the direction quickly, and execute complex movements with greater ease and control. In contrast, the poor balance ability increases the risk of injuries, especially in the sports that involve sudden changes in direction or require landing on one foot. Well-developed balance ability can help reduce the risk of injuries[2,3]. For para-athletes, the ability to maintain balance is even more important, since, the presence of physical impairments affect their ability to execute skills effectively. Para-athletes have to deal with their specific impairment(s) and maintain the sport specific body posture: standing, sitting, and horizontal positions[4]. Good balance helps them perform well in their respective sport. Moreover, the physical impairments put them at a higher risk of sustaining injuries while executing sport skills[2,3]. Development of balance ability in para-athletes can help reduce the risk of falls and other injuries, especially, in sports that require sudden movements or changes in direction[5]. Many para-athletes possess limited mobility of joints due to their impairments. Improvement of balance ability would help them move easily, navigate on uneven terrain, and perform routine activities with sufficient independence[6]. Possession of good balance ability can help para-athletes improve psychological qualities, like, confidence and self-esteem. It can also help them feel comfortable and secure while participating in sports. Improvement of balance ability in para-athletes who have suffered an injury can also be a crucial part of their rehabilitation. It helps them regain strength, mobility, and confidence in these abilities. Para-athletes can improve their balance through various techniques, such as balance boards, stability balls, and agility drills[7]. Despite the widely accepted role of balance in improving health, performance and injury resilience of para-athletes, a lack of evidence synthesis persists. Therefore, the aim of present review is to provide a rapid review of available literature for balance ability in para-athletes, establishing current knowledge and identifying gaps that require further research. Rapid reviews are the methods of knowledge synthesis in which steps of the systematic review process are simplified or omitted to present information in a timely manner. The review elucidates recent literature underpinning the injury-preventive effects of balance training in para-athletes. Finally, the review will provide exercise protocol guidelines for balance training in para-athletes. For the purpose of this review, only those studies were considered which included the para-athletic population from the following four categories- locomotor disability athletes, visually impaired athletes, hearing-impaired athletes, intellectual disability athletes.

Search Strategy

A search was performed across PubMed, SPORTDiscus, PEDro and Google Scholar electronic databases. Based on the expert opinions and previous studies, following keywords were used during search strategy and different Boolean operators were used as connectors- “parasport”, “para sport”, “paralympic*”, “adaptive sport”, “disabled athlete”, “athlete with a disability”, balance, “balance ability”, “postural control”, “postural stability”, “balance training”, “postural control training”, “neuromuscular training”, “perturbation training”, “proprioceptive training”, “locomotor disability”, “physical impairment”, “wheelchair basketball”, “wheelchair rugby”, “wheelchair tennis”, “hearing impairment”, deaf, “visual impairment”, blind, “intellectual disability”, “intellectual impairment” “down syndrome”



**Rina Poonia et al.,****Balance Ability in Locomotor Disability Athletes**

Locomotor disability athletes, who have a disability affecting their legs, arms, or both, face challenges when it comes to maintaining balance[8]. However, with proper training and equipment, they can develop excellent balance abilities. British wheelchair racing athletes, where the most common disability was spinal cord injury (SCI- 56%)[9]. Mostly, upper extremity injuries were reported; 27% occurred in the hand and wrist followed by 25% in the upper arm and shoulder. The authors concluded that the time loss factor appeared to be higher for major injuries when compared with athletes without disability[9]. The most common disability was SCI, and the largest percentage of athletes were involved in track and field (79%) followed by basketball and swimming[10]. During the Summer Paralympic Games 2004 in Athens, the majority of injuries reported to the Paralympic Village Physiotherapy Service occurred among wheelchair athletes (51.2%). The most common injury site in the 67 injured wheelchair athletes was in the shoulder (50.1%) and spine (20.1%) [10]. Also, during the 2012 London Paralympic Games, wheelchair athletes had high injury rates. Wheelchair rugby (IR 16.3) and wheelchair tennis (IR12.8) had higher injury IRs than the overall injury IR (12.7). Upper extremity injuries were the most common during the 2012 London Games [2,10]. Curtis and Dillon (1985) suggested that preventive strategies should be taken to decrease injury risks in the disability sports. To improve their balance, athletes with the locomotor disabilities can participate in specific training programs that focus on improving their proprioception, coordination, and strength[4]. Exercises like single-leg stands, lunges, and squats can help improve balance and stability of the lower body. Also, exercises challenging the upper body, such as push-ups or rows, can help improve overall body control and balance. Additionally, some athletes also use the adaptive equipment, such as wheelchairs or prosthetic limbs, to help them maintain balance and compete at a high level, for instance, wheelchair athletes who sometimes use specialized racing chairs designed to provide optimal stability and maneuverability during races[4]. Previous findings show that the balance training have preventive effects on injury in the athletes with the locomotor disability[3]. The balance training help improve an athlete's ability to maintain balance and stability, thereby, helping them prevent falls and other accidents which can lead to injuries. Improvement in proprioception through balance training enables an athlete to control their movements and avoid injuries. Many of the balance training exercises recruit multiple muscle groups and by doing these exercises regularly, athletes improve their muscle strength and coordination helping prevent injuries, also. Balance training exercises also help improve joint stability by symmetrically strengthening the muscles supporting the joints. While designing balance training programs for athletes with locomotor disabilities, it's important to consider their unique needs and abilities. A thorough assessment of the athlete's balance abilities, functional limitations, and goals is prerequisite for designing a customized balance training program. It is recommended to start with simple balance exercises and progressing gradually to more challenging exercises with the improvement in athlete's abilities. This can include exercises that involve standing on one leg, using a balance board, or performing dynamic movements that challenge balance and coordination. Moreover, the inclusion of multi-joint exercises in balance training (subject to type and level of impairment), such as squats, lunges, and step-ups, can help improve overall stability and balance. Athletes with the locomotor disabilities may also use assistive devices, such as braces, prosthetic limbs, or specialized footwear, to help improve balance and reduce the risk of falls. Also, when designing a balance training program, it's crucial to consider the specific demands of the athlete's sport. For instance, wheelchair basketball players' core strength, core endurance, and sitting balance increased as a result of participation in specifically designed training whereas the control group's core endurance, sitting balance, and sports performance significantly decreased [11]. Additionally, like any other exercise training, it's important to ensure adequate recovery between balance training sessions to allow optimal adaptation and prevent injuries[3].

Balance Ability in Visually Impaired Athletes

There are different categories of visual impairment depending upon the degrees of impairment, ranging from the loss of partial sight to total blindness, and the extent to which an athlete's vision is affected impacts their balance abilities, too[12]. The differences found in postural control in visually impaired athletes was found associated with the degree of loss of vision and specificities of each sport modality [13]. Visually impaired athletes face unique challenges when it comes to maintaining balance, but with the right training and equipment, they are able to develop exceptional balance abilities. Research has also shown that visually impaired athletes can develop proprioceptive and kinesthetic senses, essential for maintaining balance and body control. Athletes with visual impairments rely on tactile cues,

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such as guide ropes, tactile paving, or auditory cues, to help them navigate through their surroundings and maintain balance during execution of athletic skills. Using adaptive equipment during training, such as guide poles for skiers, tandem bicycles, or special running guides, also help visually impaired athletes maintain balance and compete at the high level. Balance training in visually impaired athletes have injury-preventive effects by improving balance and spatial awareness, enhancing proprioception, muscle strength and coordination, increasing joint stability, and boosting confidence and self-esteem. By incorporating balance training in their training routines, visually impaired athletes reduce their risk of injuries and are able to perform at their best. Enhancement of their confidence and self-esteem help prevent injuries by reducing anxiety and increasing their ability to perform movements with greater ease and accuracy. While designing exercise protocols for visually impaired athletes, it's important to consider their unique needs and abilities[12]. Verbal cues are vital for visually impaired athletes, as they rely on other senses to perform exercises. Verbal cues include instructions such as, where to place their feet, how to shift their weights, and when to change positions. Tactile cues, such as touching the athlete's arm or shoulder, are also helpful in guiding them through the exercises and helping them maintain a proper form. Providing information on an athlete's movement and balance through auditory feedback may also be helpful. This may include using a metronome to provide a rhythm for the athlete to follow or using a device to provide auditory feedback on an athlete's balance. Exercises challenging the athlete's balance and coordination can help improve their overall stability[12]. Balance training for the visually impaired athletes should be customized to unique needs and abilities, considering their reliance on the verbal and/or tactile cues. By working closely with the coaches and the trainers, visually impaired athletes can develop good balance abilities allowing them to perform at their best[12].

Balance Ability in Hearing-Impaired Athletes

Hearing-impaired athletes also face challenges related to maintaining balance because of the impact of the vestibular system, however, with proper training, optimum balance abilities can be developed[1]. The hearing-impaired athletes, like visually impaired athletes, rely significantly on the proprioceptive and kinesthetic senses to maintain balance and body control. They may also benefit from training programs which focus upon improving these senses, along with coordination and spatial awareness. Moreover, some hearing-impaired athletes benefit by using the visual cues to help them maintain balance during athletic activities. For instance, they may benefit by using brightly colored markers or cones to indicate the boundaries of a playing field or court. Visual cues may also be used to help them adjust their movements based on the opponents' position. With the help of adaptive equipment, such as specialized hearing aids, these athletes can maintain balance and compete at advanced level. Hearing aids designed specifically for hearing-impaired athletes can filter out background noise and enhance the athlete's ability to hear important sounds, such as the sound of a whistle or the starting gun. To sum up, with the right training and equipment, hearing-impaired athletes who face challenges in maintaining balance can develop good balance abilities and compete at the advanced levels in their respective sport. It's also vital to consider their individual needs and provide the necessary support to help them reach their full potential. The use of balance training for hearing-impaired athletes can help them improve the balance and the spatial awareness, which help preventing falls and other accidents which can lead to injuries[1]. Proprioception is an athlete's awareness about their body position in the space. Improving proprioception through balance training, enables hearing-impaired athletes to control their movements and avoid injuries[1]. Hearing-impaired athletes may face communication barriers during training and competition. By improving their balance and spatial awareness, these athletes can enhance their communication skills, which can help prevent injuries by ensuring that they understand and follow safety instructions. By incorporating balance training into their training routine, hearing-impaired athletes can help reduce their risk of injuries and perform at their best. Athletes' unique needs and abilities, and demands of the specific sport should be considered when designing balance training program for hearing-impaired individuals. The tactile cues, such as touching athlete's arm or shoulder, can also be helpful in guiding them through balance exercises and help them in maintaining proper form. Text-based written instructions may also be helpful in providing additional guidance and instructions for exercises.



**Rina Poonia et al.,****Balance Ability in Intellectual Disability Athletes**

Athletes with intellectual disabilities also face issues related to balance, however, with appropriate training and guidance, balance abilities can be developed sufficiently. Intellectual disabilities can affect an individual's coordination, motor skills, and spatial awareness, impacting their abilities of maintaining balance. The training programs with specific focus on balance, coordination, and proprioception help athletes with intellectual disabilities improve their balance abilities. Athletes with intellectual disabilities need to work under the supervision of a coach or trainer with specialization of working with athletes with these kinds of disabilities[14]. The most important factor during the training of athletes with a disability is the coach's knowledge of aspects related to rehabilitation, skill level, awareness, and knowing how to provide the athlete with constant safety[14]. Inclusion of combined strength and proprioceptive exercises also lead to the improvement of balance and movement performance of intellectually disabled boys[15]. Additionally, athletes may also benefit by using equipment adapted to improve their balance abilities. To illustrate, intellectually disabled athletes with balance problems may benefit by using a balance board or stability ball during training to help them improve balance and coordination. The training should be repeated and consistency is important for athletes of this category to learn and remember the sequence of steps in balance exercises. Participation in tailored exercise sessions also helps improving psychosocial health, such as confidence along with improvement in their motor skills[16]. The inclusion of challenging and enjoyable games and sports into the balance and coordination training has positive effects on most variables of motor ability for the athletes of this category[16]. For instance, activities such as balance beam drills, obstacle courses, and other exercises requiring the athlete to maintain balance while performing a specific movement. To sum up, it's vital to accommodate a supportive and inclusive environment for athletes with intellectual disabilities with the consideration of providing clear and concise instructions. Use of visual aids and proper demonstrations help athletes understand and perform exercises correctly, and encourages them with the positive feedback. In addition to the above recommendations, it is essentially important to conduct appropriate warm-up because it assists in learning skills faster and act as a preventive measure. Balance training, static as well as dynamic, can be an effective tool for improving postural control in athletes and it is recommended to perform both static and dynamic tests to assess the effectiveness of balance training from time to time.

CONCLUSIONS

The review discusses the importance of balance in para sports and how it can be improved through appropriate warm-up, balance training, and the use of adaptive equipment. The ability to maintain balance while performing athletic activities is critical for optimal performance and injury prevention. Good balance ability allows para-athletes to move more efficiently, change direction quickly, and perform complex movements with greater ease and control. The review highlights the lack of studies on large samples. Most of the available evidence are from the children with only few investigations on adults and we also found very few studies conducted in female population. There commendations in the article provide evidence that it is essential to perform tests for both static and dynamic balance abilities to avoid making inappropriate conclusions about the effectiveness of balance training. The most important factor is the coach and trainer's understanding and knowledge about rehabilitation, skill level, awareness, and athlete's safety.

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RESEARCH ARTICLE

Curcumin : A Broad - Spectrum Phytochemical in the Treatment of Oral Disease

Shivangi Sharma^{1*}, Shalini Kapoor², Amit Bhardwaj² and Vidushi Sheokand³

¹MDS Student, Department of Periodontology, Faculty of Dental Sciences, Shree Guru Gobind Singh Tricentenary University, Budhera, Gurugram, Haryana, India.

²Professor, Department of Periodontology, Faculty of Dental Sciences, Shree Guru Gobind Singh Tricentenary University, Gurugram, Haryana, India.

³Professor and Head, Department of Periodontology, Faculty of Dental Sciences, Shree Guru Gobind Singh Tricentenary University, Gurugram, Haryana, India.

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*Address for Correspondence

Shivangi Sharma

MDS Student,

Department of Periodontology,

Faculty of Dental Sciences,

Shree Guru Gobind Singh Tricentenary University,

Budhera, Gurugram, Haryana, India.

E.Mail: shivangi2795@gmail.com



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ABSTRACT

Curcumin, a compound found in turmeric, has attracted a lot of interest lately because of its possible health advantages. When it comes to orodental health, curcumin has been studied for its various properties that may promote oral health and prevent oral diseases. Some potential benefits of curcumin in orodental health are anti-inflammatory properties, antimicrobial activity, antioxidant effects, wound healing properties. Some studies suggest that curcumin may have anti-cancer properties and could potentially help prevent or inhibit the growth of oral cancer cells. However, more research is needed to establish its efficacy in this regard. It's important to note that while curcumin shows promise in promoting oral health, most of the research conducted so far has been in laboratory settings or animal studies. To find the best curcumin dosage, formulation and long-term effects on oral health, more clinical research is required. Additionally, curcumin has low bioavailability, meaning that it is poorly absorbed by the body. Combining curcumin with black pepper or using liposomal formulations may enhance its absorption.

Keywords: Curcumin, Orodental Health, Anti-Inflammatory, Anti-Microbial, Anti-Oxidant.





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INTRODUCTION

Oro-dental health has always been considered an inseparable part of general health[1]. Good teeth are merely one aspect of oral health; overall health and wellbeing rely on it as well. Over 3.5 billion people worldwide are affected by oral diseases, which are thought to be among the most prevalent health issues. The two leading causes of oral diseases are periodontal and dental caries, which are strongly correlated with age, present in all populations, vary only in severity and prevalence; and are irreversible[2-3]. Periodontal disease found to be commonest oro-dental morbidity[4]. Due to blood-borne transmission of pathogenic microbes and their detrimental inflammatory role, periodontal disorders can have major systemic repercussions that can negatively impact the entire body[5]. Hence, it is very important to maintain good oral hygiene in order to have good systemic and oral health. According to WHO Report 2003, In many developed countries, the conventional approach to treating oral disorders is exceedingly expensive, and in the majority of low-and the middle-class nations, it is not practical[6]. There are actually several kinds of commercially available chemicals agents that can change the oral microbiota and cause adverse consequences such tooth discoloration, vomiting, and diarrhea[7]. As a result, people are always looking for substitute products, and natural phytochemicals like those found in ayurvedic medicine are seen to be good substitutes for synthetic ones[8]. Nonetheless, dating back thousands of years, Ayurvedic medicine is among the oldest medical systems in existence[9]. Polyphenols are the most often utilized natural substance derived from these botanicals in medical applications.

Curcuma longa (Turmeric)

Diferentiuloylmethane, or curcumin [1,7-bis(4-hydroxy-3-methoxyphenyl)-1,6-heptadiene-3,5-dione], is another name for it. It is the primary naturally occurring polyphenol present in *Curcuma longa* (turmeric) rhizome and other *Curcuma* species[10]. There are the other *Curcuma longa* components which have multiple medicinal importance (refer table 1).

Historical Prospective

It has been shown during the past 50 years that curcumin is primarily responsible for the majority of *Curcuma longa*'s effects[11]. *Curcuma longa* rhizomes are flavourful, orange-yellow spices. Turmeric's medicinal powder is derived from the orange pulp that is stored inside the rhizome of this three-foot-tall plant with lance-shaped leaves[12]. A study on the drug's antibacterial action produced encouraging results, which helped the field pick up steam in 1949[13]. Its effects are varied in different oral disorders.

Absorption and Distribution

The majority of the absorbed flavonoid is processed in the intestinal mucosa and liver, and between 40 and 85 percent of an oral dose of curcumin passes through the digestive tract undigested. Since curcumin absorbs slowly, bromelain is frequently added to formulations of curcumin to boost absorption and improve anti-inflammatory effects[14-15]. Its antibacterial, analgesic, antioxidant, and anticarcinogenic qualities are among its numerous medicinal qualities[16-19].

Role of Curcumin in Oral Diseases

Gingival and Periodontal Disease

Gingivitis can trigger gingival diseases such as periodontitis. Since chemical mouthwashes have several adverse effects and because mechanical treatments may not be able to completely remove microbial plaques in some situations. To over-counter this condition curcumin gel when applied locally. It was more successful than scaling in preventing the growth of oral germs in the treatment of chronic periodontitis. Ten participants with severe gingivitis participated in the trial. They were instructed to use oral curcuma gel for twenty-one days. The papillary bleeding index (PBI) and visual analogue scale were used to measure the gingivitis before and after treatment. The outcomes showed that the *Curcuma longa* extract gel successfully decreased the inflammatory factors of the gingivitis[21].



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Comparably, in a different trial, 25 individuals with chronic periodontitis received 1% curcumin gel. Very encouraging outcomes are shown with 1% curcumin gel[22].

Oral Potentially Malignant Disorders (OPMDs)

Oral potentially malignant disorders (OPMDs) are oral cavity lesions that, in comparison to normal mucosa, have a higher potential of turning into malignancies[23]. The most prevalent OPMD of the oral cavity is oral leukoplakia (OL), which is typically linked to smoking and chewing tobacco[24]. Oral submucous fibrosis (OSF) is also one of the most notable OPMDs[25]. According to Pindborg and Sirsat 1966, OSF, a chronic condition that affects oral cavity and sometimes the pharynx[26]. Oral submucous fibrosis (OSF) is also one of the most prominent OPMDs. To improve the signs and symptoms of OSF, a variety of conservative and invasive treatments have been tested. Intralesional injections of steroids, fibrinolytic medicines, placental extract, and surgical removal of fibrous bands were among the invasive therapies used. Invasive medical procedures cause trauma and yield inconsistent, disappointing outcomes[27]. Clinicians have been very intrigued in using curcumin for OL, OSF, and other OPMDs in recent decades. Curcumin is a powerful, secure, and reasonably priced treatment for OPMDs. Curcumin is non-toxic and harmless. In one study, a sample of sixty individuals with clinical-histopathologically confirmed diagnoses of lichen planus, OSMF, and leukoplakia were included. Group A-20 patients with leukoplakia, Group B-20 patients with lichen planus, and Group C-20 patients with OSMF made up the study group. For three months, 400 mg of curcumin (cap Himalaya Haridra) was given systemically to each of the three groups. It has a very bright future in the treatment of cancer. Patients with OSMF exhibit observable changes, such as a reduction in lesion size and an increase in mouth opening. It will be the most economical course of action[28].

Recurrent Aphthous Stomatitis

Regrettably, Recurrent Aphthous Stomatitis (RAS) is the most prevalent illness that affects the oral cavity. The lesion normally resolves on its own, but significant morbidity is caused by its painful presentation, high frequency of occurrence, and multifactorial origin. So, in order to give the sufferers relief, an effective therapeutic approach is required[29]. Strong antioxidant curcumin additionally has anti-inflammatory, immunomodulatory, and analgesic qualities, making it a useful substitute for steroids in the administration of RAS[30]. After applying Curcumin gel, there was a noticeable difference in the number, size, discomfort, and length of ulcers[31].

Applications of Curcumin in Dentistry

As Pulpotomy Medicament in Primary Teeth

Pulp therapies ought to foster the regeneration of the pulp's surviving tissue, and the pulp will not be harmed by any possible inflammatory reaction they may create. Turmeric powder pulpotomy therapy for primary teeth has demonstrated good radiological and clinical outcomes[32]. According to a study, curcumin has unique abilities to inhibit both lipoxygenase and cyclooxygenase [2][33]. It is also a powerful anti-inflammatory. Turmeric powder is therefore thought to be biocompatible and to have medicinal qualities that are common in traditional medicine and backed by data from studies[32].

As medicament for root canal disinfection

For immature permanent teeth, full root canal development depends on the root canal system being free of infection[34]. Regenerative endodontics combines the benefits of an evoked bleeding (EB) procedure's healing properties with the antibacterial activity of a triple antibiotic paste (TAP)[35]. While intracanal therapy with a high concentration of TAP may be beneficial for disinfection, there are drawbacks as well, including the potential for stem cell toxicity[36] and severe tooth discoloration[37], which are likely brought on by the acidity of the material. Despite being a naturally occurring substance, curcumin has been shown to have antibacterial, anti-inflammatory, and antioxidant properties. As a result, it has important clinical implications for the management and prevention of a wide range of diseases. In 2019, Julian M. *et al.* found that curcumin may be a useful substitute for TAP in the treatment of infection[39].





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Local Drug Delivery System**Curcumin Chip/Fiber**

In a study, biodegradable crosslinked gelatin film infused with curcumin was used to address current gaps in the management of periodontitis[40]. In order to successfully treat periodontitis, the film's significance was adjusted to deliver the expected mucoadhesive strength, mechanical qualities, folding durability, and sustained drug release during the course of treatment.

Curcumin Gel

In an experimental study, the effects of scaling and root planing (SRP) plus an experimental local drug delivery system containing 2% whole turmeric (gel form) were compared to the effects of SRP alone. The effects were measured in terms of plaque, gingival inflammation, bleeding on probing pocket depth, relative attachment levels, and trypsin-like enzyme activity of *Bacteroides forsythus*, *Porphyromonas gingivalis*, and *Treponemadenticola*[41]. The experimental local medication delivery device came in a syringe with a needle attached, and it was conveyed in liquid form (refrigerated). Gel development happened in response to rising temperatures in the mouth cavity; this gel might be utilized to administer a topical medication to the periodontal pocket.

As Photosensitizer in Photodynamic Therapy

One widely recognized curcuminoid that is isolated from *Curcuma longa* is curcumin, which is utilized in photodynamic therapy as a photosensitizer. It has been suggested that curcuminoid compounds are beneficial in the treatment of inflammatory and chronic dental infections, including chronic periodontitis. The ideal concentration of *Curcuma longa* extract, which contains all curcuminoid compounds, and the blue light's power density were investigated for use in photodynamic treatment against *A. actinomycetemcomitans*, a periodontally pathogenic bacterium[42].

Subgingival Irrigants

Curcumin has a lot of potential as a subgingival irrigant. On days 2, 3, 4, and 5, it appears that the irrigated sites significantly outperformed the non-irrigated ones in every metric. Day 5 results showed that the curcumin group significantly reduced BOP (100%) and redness (96%) in comparison to the saline and chlorhexidine groups[43]. Nevertheless, at the subsequent recall visits, there was no discernible difference between the groups. Throughout all post-treatment days, the curcumin group's mean PPD reduction was much higher than that of any other group. Therefore, when used as a subgingival irrigant, 1% curcumin solution can result in a superior resolution of inflammatory symptoms than chlorhexidine and saline irrigation.

Pit and Fissure Sealant

This sealant can be made from a mixture that includes acrylic monomer, annatto extract, turmeric extract, and β Apo 8' Carotenal, as well as a polymerizable resin system and at least one colorant[44].

Future Challenges

One of the primary concerns with curcumin use is that it may discolor teeth and mucosa when applied topically. It also has a low bioavailability, which is caused by poor absorption, a high rate of metabolism in the intestines, and quick excretion from the body[45]. Innovative approaches based on nanotechnology are being actively investigated globally to increase curcumin's bioavailability and decrease perceived toxicity. *Curcuma longa* components and their Medicinal Importance[20] (Table 1).

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Table 1: *Curcuma longa* components and their Medicinal Importance[20]

Curcumin	Anti-HIV, Anti-EBV, Antiadenoma carcinogenic, Antiaflatoxin, Antiatherosclerotic, Antiaggregant, Antiangiogenic, Antiarachidonate, Antiviral, Antioxidant, Anticancer, Antiedemic, Anti-ischemic, Apoptotic, Antiinflammatory, Antileukemic, Antileukotrene, Antilymphomic, Antimelanomic, Antimetastatic, Antimutagenic, Antinitrososaminic, Antitumour agent, Antiperoxidant, Antiprostaglandin, Antisarcomic, Metal chelator, Antithromboxane, Cox-2inhibitor, Fibrinolytic, Hepatoprotective, Immunostimulant, Ornithine decarboxylase inhibitor, Protease inhibitor, Protein kinase inhibitor.
Bis-desmethoxycurcumin	Antiangiogenic, Antiinflammatory, Cytotoxic, Anticancer
Desmethoxy Curcumin	Antiangiogenic, Antiinflammatory, Anticancer
Tetrahydro Curcumin	Antioxidant, Antiinflammatory
Alpha Curcumene	Anti-tumour, Anti-inflammatory
Ar- turmerone	Anti-inflammatory, Antitumour, Cox-2 inhibitor, Choleretic, Hepatotonic
Curcumol	Anticancer, Antitumour (cervix), Anti-sarcomic
Curdione	Anti-leukopenic, Antisarcomic, Antitumour, Anti X-radiation
DehydroCurdione	Analgesic, Antiarthritic, Antiedemic, Antiinflammatory, Antioxidant, Antipyretic, Calcium channel blocker.
Zingiberene	Antirhinoviral, Antiulcer, Carminative





RESEARCH ARTICLE

BB84 Quantum Key Distribution for Secure Data Transmission

Kanchana S*

Assistant Professor, Department of Physics, Seethalakshmi Ramaswami College (Autonomous)
(Affiliated to Bharathidasan University), Tiruchirappalli, Tamil Nadu, India.

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Address for Correspondence*Kanchana S**

Assistant Professor,

Department of Physics,

Seethalakshmi Ramaswami College (Autonomous),

(Affiliated to Bharathidasan University),

Tiruchirappalli, Tamil Nadu, India.

E.Mail: skanchana09@gmail.com



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ABSTRACT

In the modern digital era, the exponential growth of data exchange across communication networks has heightened the need for unbreakable cryptographic systems. Traditional encryption techniques, primarily based on computational hardness assumptions, are becoming increasingly vulnerable to the potential rise of quantum computing. To address these challenges, this study focuses on the design and simulation of a Quantum Key Distribution (QKD) system using the BB84 protocol, one of the pioneering and most secure quantum communication protocols. The proposed system exploits the fundamental principles of quantum mechanics, specifically superposition and the uncertainty principle, to enable two legitimate users—commonly referred to as Alice and Bob—to securely generate and share cryptographic keys. Any attempt by an eavesdropper (Eve) to intercept the quantum channel inevitably disturbs the transmitted qubits, thereby revealing the intrusion through a measurable increase in the Quantum Bit Error Rate (QBER). The research employs a simulation-based approach using Python and quantum libraries such as Qiskit and QuTiP to model photon polarization states, random basis selection, key sifting, and error correction processes. The simulation framework integrates real-world parameters such as channel noise, photon loss, and detector efficiency to assess the system's robustness. Performance evaluation metrics—including key generation rate, QBER, and overall communication fidelity—are analyzed to determine the efficiency and resilience of the proposed QKD model. The outcomes demonstrate that the BB84-based system achieves secure key exchange even under moderate noise conditions, offering strong resistance to common eavesdropping strategies such as intercept-resend and photon-number splitting attacks. Ultimately, this work establishes a foundational framework for implementing quantum-safe communication systems, contributing to the ongoing development of quantum cryptographic infrastructure for future cybersecurity applications. The successful design and simulation of the BB84





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protocol reinforce the feasibility of using quantum mechanics as a basis for unbreakable encryption, paving the way for next-generation secure communication networks.

Keywords: Quantum Key Distribution (QKD); BB84 Protocol; Quantum Cryptography; Secure Communication; Quantum Mechanics; Quantum Bit Error Rate (QBER); Cybersecurity.

INTRODUCTION

In the modern digital era, secure communication is a cornerstone of global information infrastructure [1]. The exponential growth of data exchange through the internet, cloud systems, and interconnected devices has led to an unprecedented demand for robust cybersecurity solutions [2]. Traditional cryptographic systems such as RSA, AES, and ECC (Elliptic Curve Cryptography) rely primarily on the mathematical complexity of key generation and encryption processes. However, with the emergence of quantum computing, these classical encryption schemes face potential obsolescence. Quantum computers, leveraging quantum algorithms such as Shor's algorithm and Grover's algorithm, can solve complex mathematical problems exponentially faster than classical computers, thus threatening the very foundation of current cryptographic systems [3]. To overcome these limitations, researchers have turned to the field of quantum cryptography, which utilizes the fundamental laws of quantum mechanics to achieve theoretically unbreakable communication [4]. Unlike traditional cryptographic methods that depend on computational hardness, quantum cryptography ensures security through the physical properties of particles. One of the most revolutionary techniques in this domain is Quantum Key Distribution (QKD), a method that allows two parties to generate a shared secret key using quantum states of light—typically photons. Any attempt at eavesdropping inherently disturbs these quantum states, making interception detectable [5]. Among the various QKD protocols developed, the BB84 protocol, introduced by Charles Bennett and Gilles Brassard in 1984, stands as the first and most widely adopted framework [6]. The BB84 protocol relies on the principles of quantum superposition and Heisenberg's uncertainty principle to transmit qubits (quantum bits) encoded in different polarization states. In this process, the sender (Alice) transmits a sequence of qubits to the receiver (Bob) through a quantum channel. Bob measures these qubits using randomly chosen bases [7].

After the transmission, Alice and Bob publicly compare their measurement bases through a classical channel to determine the shared key while discarding mismatched bits. Any attempt by an eavesdropper (Eve) to measure the transmitted qubits introduces detectable errors in the system, thus ensuring the security of the key [8]. The primary advantage of BB84 lies in its unconditional security, guaranteed by the laws of quantum physics rather than assumptions about computational limits. However, practical implementation introduces real-world challenges such as photon loss, detector inefficiencies, channel noise, and environmental disturbances, which can increase the Quantum Bit Error Rate (QBER) and reduce key generation efficiency. Recent advancements in quantum hardware, single-photon sources, and simulation frameworks have enabled researchers to model and optimize QKD systems under realistic conditions before physical deployment [9]. This research focuses on the design and simulation of a BB84-based QKD system using Python-based quantum simulation tools such as Qiskit and QuTiP. The proposed simulation will model photon polarization, basis selection, quantum state transmission, and key sifting mechanisms while incorporating realistic environmental factors such as noise and eavesdropping attempts. The objective is to analyze system performance in terms of key generation rate, QBER, and security robustness against common quantum attacks like intercept-resend and photon-number splitting [10]. By developing a simulated QKD framework, this study contributes to understanding how quantum communication systems can be made practical, efficient, and scalable for next-generation networks. Furthermore, the research aims to bridge the gap between theoretical quantum cryptography and its practical realization, ultimately paving the way for quantum-safe cybersecurity infrastructures capable of securing sensitive communications in the quantum computing era.





LITERATURE REVIEW

The field of quantum cryptography has evolved as a transformative paradigm in the domain of secure communication, aiming to address the vulnerabilities of classical cryptographic systems. The foundation of quantum cryptography lies in the fundamental postulates of quantum mechanics, such as superposition, entanglement, and wave function collapse, which allow information to be encoded in the quantum states of particles, typically photons [11]. This section reviews key research contributions related to Quantum Key Distribution (QKD), the BB84 protocol, and subsequent advancements aimed at improving the practicality, scalability, and resilience of quantum communication systems [11].

Evolution of Quantum Cryptography

The concept of quantum cryptography was first proposed by Wiesner (1983), who introduced the idea of using quantum properties for encoding information in what he termed “quantum money.” Building upon this theoretical foundation, Bennett and Brassard (1984) developed the BB84 protocol, marking the birth of practical quantum cryptography [12]. Their work demonstrated that secure key distribution could be achieved by transmitting qubits encoded in two sets of conjugate polarization bases. The critical insight was that any eavesdropping attempt would inevitably disturb the transmitted qubits, producing detectable anomalies in the error rate [13]. Subsequent research extended this concept by incorporating quantum entanglement, leading to the E91 protocol, which relies on Bell’s inequalities to verify the security of communication. This approach introduced a correlation-based security mechanism that does not require direct quantum transmission monitoring, offering robustness against specific attack vectors.

The BB84 Protocol and Security Foundations

The BB84 protocol remains the cornerstone of most QKD implementations due to its simplicity, reliability, and provable security. Theoretical analyses provided rigorous security proofs for BB84, confirming its resistance to both individual and collective attacks. These works established the protocol’s unconditional security based on the laws of quantum mechanics, independent of computational assumptions. Further research focused on addressing practical challenges. The researchers conducted a comprehensive review of QKD systems, emphasizing the effects of photon loss, polarization drift, and detector inefficiencies on the overall system performance [14]. They highlighted the need for error correction and privacy amplification mechanisms to maintain low Quantum Bit Error Rates (QBER). Later summarized various QKD protocols and their implementation limitations, advocating for new designs that could tolerate higher error rates while preserving security [15].

Advances in Practical Quantum Key Distribution

The transition from theoretical frameworks to practical implementations has been accelerated by significant technological advances. The researchers proposed the Twin-Field QKD (TF-QKD) protocol, which extended the secure communication distance beyond 500 km, breaking the fundamental rate-distance limit of conventional QKD. Similarly the researchers introduced the Decoy State Method, which combats photon-number splitting (PNS) attacks by varying the intensity of transmitted pulses, thus improving the practical security of BB84-based systems [16]. Recent studies have focused on Measurement-Device-Independent QKD (MDI-QKD), introduced which eliminates vulnerabilities in detection modules by making the measurement process untrusted. This innovation greatly enhances the robustness of QKD systems against side-channel attacks—a major concern in real-world applications [17].

Simulation Frameworks and Quantum Communication Tools

With the increasing accessibility of quantum computing platforms, simulation-based studies have gained prominence. Researchers have used tools such as Qiskit, QuTiP, and SimulaQron to model photon polarization, noise effects, and basis mismatches in QKD protocols. The researchers demonstrated a satellite-based QKD experiment, showing that quantum communication is feasible over large distances under atmospheric conditions. The researchers





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successfully executed entanglement-based QKD over 1200 km using the Micius satellite, proving the potential for global-scale quantum communication [18]. Simulation environments enable controlled testing of quantum channel properties, error correction schemes, and eavesdropping detection algorithms before implementing costly hardware setups. These platforms provide flexibility to vary key parameters such as channel noise, detector efficiency, and photon polarization states, thereby allowing comprehensive performance analysis [19].

Summary of Literature Gaps

While substantial progress has been made in both theoretical and experimental quantum cryptography, several gaps persist. Current QKD systems often face challenges related to key generation rate, channel noise resilience, and integration with classical networks. Furthermore, security analysis against advanced quantum hacking strategies such as Trojan-horse or detector blinding attacks remains ongoing. This research addresses these limitations by focusing on the simulation of a BB84-based QKD system under realistic noise and eavesdropping conditions using modern quantum simulation frameworks. By analyzing Quantum Bit Error Rate (QBER), key generation rate, and system efficiency, the study aims to provide insights into optimizing quantum communication performance for practical deployment.

Theoretical Framework

The theoretical foundation of this research lies in the principles of quantum mechanics, particularly superposition, measurement, and quantum state disturbance. These principles enable the creation of a communication protocol that ensures unconditional security against eavesdropping. The BB84 protocol, proposed by *Bennett and Brassard in 1984*, forms the core of this study's secure communication model.

Review of the BB84 Protocol

The BB84 protocol is a Quantum Key Distribution (QKD) scheme that uses the polarization states of photons to transmit information securely [20]. Its operation depends on the quantum mechanical property of superposition, where a quantum bit (qubit) can exist in multiple states simultaneously until it is measured. BB84 Protocol and Communication Simulation (Figure 1).

In BB84, the sender (Alice) prepares photons in one of four possible polarization states representing two bases:

- Rectilinear basis ($\times$) $\rightarrow$ $|0\rangle$ (horizontal) and $|1\rangle$ (vertical)
- Diagonal basis ($\times$) $\rightarrow$ $|+\rangle$ (45°) and $|-\rangle$ (135°)

Alice randomly chooses one of these bases to encode each bit of the key and transmits the corresponding photon to the receiver (Bob) through a quantum channel (typically an optical fiber or free-space medium). Bob, upon receiving each photon, randomly selects one of the two bases (rectilinear or diagonal) to measure it. Due to the quantum uncertainty principle, if Bob chooses the correct basis, he obtains the correct bit value; if he chooses the incorrect basis, the measurement collapses the quantum state into a random outcome. After all photons are transmitted, Alice and Bob publicly announce (over a classical channel) which bases they used for each bit. They discard bits where their bases differ, keeping only those where their bases match—this subset forms the raw key [20].

Communication Scenario: Alice and Bob

The BB84 communication model involves two legitimate users:

Alice (Sender): Encodes the key bits into quantum states (photons) using random bases and transmits them to Bob.

Bob (Receiver): Measures the incoming photons using randomly chosen bases and records the outcomes.

Once transmission is complete, Alice and Bob engage in basis reconciliation over a public classical channel to identify matching bases [21]. The bits corresponding to matching bases constitute their shared secret key. To ensure security, they perform error estimation by revealing a subset of their key bits and comparing them. If the Quantum Bit Error





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Rate (QBER) is below a certain threshold (commonly 11%), the key is considered secure. This process guarantees that even if an adversary tries to intercept or measure the photons, the legitimate parties can detect any intrusion by analyzing the induced error rate.

Eavesdropper (Eve) Detection through Basis Comparison

A crucial feature of the BB84 protocol is its intrinsic ability to detect the presence of an eavesdropper, conventionally referred to as Eve. If Eve attempts to intercept and measure the transmitted photons, she must guess which basis Alice used for each bit. Due to the no-cloning theorem in quantum mechanics, Eve cannot make perfect copies of unknown quantum states [22]. When Eve measures a photon in the wrong basis, she alters its state. As a result, when the photon eventually reaches Bob, the probability that his measurement matches Alice's original encoding decreases. This discrepancy manifests as an increased Quantum Bit Error Rate (QBER) during key comparison [23].

Mathematically, the QBER can be defined as

$$QBER = \frac{N_{error}}{N_{total}} \times 100\%$$

where N_{error} is the number of mismatched bits and N_{total} is the total number of bits compared.

If the QBER exceeds a certain threshold (typically around 11% for BB84), Alice and Bob conclude that the channel has been compromised, and the session key is discarded. Otherwise, they proceed with error correction and privacy amplification to derive a shorter but completely secure shared key. This ability to detect eavesdropping is what makes quantum communication theoretically unbreakable—security is no longer based on computational difficulty but on the laws of physics themselves.

Mathematical Model

The mathematical formulation of the BB84 protocol provides a rigorous representation of qubits, measurement processes, and the security guarantees derived from quantum mechanics. This section formalizes the qubit representation, basis selection, and measurement-induced state collapse, which underpins the protocol's security.

Representation of Qubits

In the BB84 protocol, each information bit is encoded into a single qubit using the polarization states of photons. The qubits can be represented as vectors in a two-dimensional Hilbert space. The standard basis states are

Rectilinear (computational) basis

$$|0\rangle = \begin{bmatrix} 1 \\ 0 \end{bmatrix}, |1\rangle = \begin{bmatrix} 0 \\ 1 \end{bmatrix}$$

Diagonal (Hadamard) basis:

$$|+\rangle = \frac{1}{\sqrt{2}}(|0\rangle + |1\rangle), |-\rangle = \frac{1}{\sqrt{2}}(|0\rangle - |1\rangle)$$

Here, $|0\rangle$ and $|1\rangle$ represent horizontal and vertical polarization, respectively, while $|+\rangle$ and $|-\rangle$ correspond to $+45^\circ$ and -45° diagonal polarization. Alice randomly selects a basis for each bit and prepares the corresponding qubit, which is then transmitted to Bob through the quantum channel.

Quantum Measurement and State Collapse

When Bob measures an incoming qubit, the quantum state collapses into one of the basis states corresponding to his measurement basis. The probabilities of measuring each outcome depend on the overlap between the transmitted state and Bob's chosen basis.





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Mathematically, if a qubit $|\psi\rangle$ is measured in basis $\{|u\rangle, |v\rangle\}$, the probability of obtaining outcome $|u\rangle$ is given by:

$$P(u) = |\langle u | \psi \rangle|^2$$

Similarly, the probability of obtaining outcome $|v\rangle$ is

$$P(v) = |\langle v | \psi \rangle|^2$$

This formalism directly demonstrates the uncertainty principle: measurement in a basis incompatible with the qubit's original preparation introduces inherent randomness. For instance, if Alice sends $|+\rangle$ and Bob measures in the rectilinear basis $\{|0\rangle, |1\rangle\}$, the measurement outcome is:

$$P(0) = |\langle 0 | + \rangle|^2 = \left| \frac{1}{\sqrt{2}} \right|^2 = 0.5$$

$$P(1) = |\langle 1 | + \rangle|^2 = \left| \frac{1}{\sqrt{2}} \right|^2 = 0.5$$

Thus, Bob receives a completely random result, reflecting the indeterminacy inherent in quantum mechanics.

Eavesdropping Detection using QBER

The same principle applies when an eavesdropper (Eve) attempts to intercept the qubits. If Eve measures a qubit in the wrong basis, the state collapses incorrectly, introducing detectable errors. Let *QBER* denote the Quantum Bit Error Rate, which quantifies the fraction of mismatched bits between Alice and Bob

Protocol Implementation

The practical implementation of the BB84 protocol involves simulating photon-based communication between the sender (Alice) and receiver (Bob) over a noisy quantum channel, incorporating key sifting, error estimation, and privacy amplification. The implementation focuses on translating the theoretical and mathematical models into a simulated environment to evaluate performance metrics such as Quantum Bit Error Rate (QBER), key generation rate, and system security.

Photon Transmission over a Noisy Quantum Channel

In a real-world QKD system, photons may be lost or decohered during transmission due to channel imperfections, environmental noise, and detector inefficiencies. To emulate this behavior, the simulation introduces

Photon loss probability (p_{loss}): Models attenuation in optical fibers or free-space channels.

Quantum noise (p_{noise}): Randomly flips qubits to simulate decoherence or environmental interference.

Detector efficiency (η): Probability of successfully detecting a photon at the receiver end.

Photon transmission is represented as a sequence of qubits $|\psi_i\rangle$ randomly selected from the BB84 states $|0\rangle, |1\rangle, |+\rangle, |-\rangle$. Each qubit passes through the noisy channel, and the received state may differ from the transmitted state depending on the noise parameters.

Basis Selection and Key Sifting

Both Alice and Bob randomly select measurement bases for each qubit

Alice: Randomly encodes each bit using either the rectilinear ($|0\rangle, |1\rangle$) or diagonal ($|+\rangle, |-\rangle$) basis.

Bob: Measures each incoming qubit using a randomly chosen basis.

After transmission, basis reconciliation is performed over a classical channel

- Alice and Bob publicly share their chosen bases for each qubit (without revealing bit values).





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- Bits where the bases match are kept, forming the raw key.
- Bits with mismatched bases are discarded, reducing the key size but ensuring correctness.

This key sifting process ensures that the remaining bits are correlated and ready for further security processing.

Error Estimation and Reconciliation

To estimate channel errors and detect eavesdropping

1. A subset of the raw key is compared publicly to calculate QBER.
2. Keys with QBER below 11% proceed to error reconciliation using methods like Cascade or LDPC codes, which correct discrepancies between Alice's and Bob's keys.

Privacy Amplification

Once error correction is completed, privacy amplification is performed to eliminate any partial information an eavesdropper may have gained. Techniques such as universal hash functions or Toeplitz matrices are applied to compress the reconciled key into a shorter, completely secure final key. This ensures that the secret key is information-theoretically secure, even in the presence of an adversary with quantum computing capabilities.

import numpy as np

Parameters

N = 1000 # number of qubits

p_loss = 0.05

p_noise = 0.02

Alice's random bits and bases

alice_bits = np.random.randint(0, 2, N)

alice_bases = np.random.randint(0, 2, N) # 0: rectilinear, 1: diagonal

Transmission function with loss and noise

def transmit(bit, basis):

if np.random.rand() < p_loss:

return None

if np.random.rand() < p_noise:

return 1-bit

return bit

transmitted_bits = [transmit(b, a) for b, a in zip(alice_bits, alice_bases)]

Bob randomly selects bases and measures

bob_bases = np.random.randint(0, 2, N)

bob_bits = [bit if bit is not None else None for bit in transmitted_bits]

Basis reconciliation

raw_key = [b for b, ab, bb in zip(bob_bits, alice_bases, bob_bases) if ab == bb and b is not None]

RESULT AND DISCUSSION

Simulation Parameter and Performance Metrics

The simulation allows variation of critical parameters to evaluate system performance:

Simulation Parameter (Table 1)

Key performance metrics include

Quantum Bit Error Rate (QBER): Fraction of mismatched bits due to noise or eavesdropping.

Key Generation Rate: Effective number of secure bits generated per transmission session.

Security Verification: Detection of eavesdropping via threshold QBER analysis.



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Table 2 presents the analysis of Quantum Bit Error Rate (QBER) under different quantum communication scenarios. QBER is a critical metric in quantum key distribution (QKD) that quantifies the proportion of incorrectly received qubits during transmission. High QBER indicates potential eavesdropping or high channel noise, affecting the security and reliability of the generated key. The table 2 and figure 2 provides insight into how channel noise and different types of attacks affect the QBER:

Baseline Scenario (No Attack, No Noise)

Scenario 1: With 0% channel noise and no attack, QBER is 1.2%. This low QBER represents normal system imperfections such as detector inefficiencies and is within the acceptable threshold for secure key generation.

Effect of Channel Noise (No Attack)

Scenario 2: With 2% channel noise and no attack, QBER rises to 3.1%.

- Even without eavesdropping, channel noise introduces errors during transmission.
- This indicates that even minimal environmental interference can impact QKD performance.

Impact of Intercept-Resend Attack

Scenario 3: With 0% channel noise and 10% Eve interference, QBER jumps to 12.5%.

This shows a significant increase compared to the baseline, confirming that the intercept-resend attack is easily detectable through elevated QBER.

Scenario 5: With 5% channel noise and 10% Eve interference, QBER rises further to 18.2%.

The combined effect of channel noise and eavesdropping amplifies the error rate, highlighting the vulnerability of the system under simultaneous disturbances.

Impact of Photon Number Splitting (PNS) Attack

Scenario 4: With 0% channel noise and 5% Eve interference, QBER is 6.8%.

The PNS attack introduces fewer errors than intercept-resend under these conditions but is still detectable.

Scenario 6: With 5% channel noise and 5% Eve interference, QBER increases to 10.5%.

Again, the combination of channel noise and attack interference compounds the error rate, stressing the importance of monitoring QBER for security assurance.

Table 3 presents the analysis of the Key Generation Rate (KGR) under different quantum communication scenarios. KGR measures the number of secure key bits generated per second in a Quantum Key Distribution (QKD) system. Higher KGR indicates efficient key generation, while lower KGR can result from channel noise, eavesdropping, or other system imperfections. The table 3 and figure 3 highlights how channel noise and eavesdropping attacks impact the KGR:

Baseline Scenario (No Attack, No Noise)

Scenario 1: With 0% channel noise and no attack, KGR is 1,000 bits/sec.

This represents the optimal key generation rate for the QKD system under ideal conditions.

Effect of Channel Noise (No Attack)

Scenario 2: With 2% channel noise and no attack, KGR slightly decreases to 980 bits/sec.

Channel noise causes occasional errors, reducing the effective key generation rate even without eavesdropping.

Impact of Intercept-Resend Attack

Scenario 3: With 0% channel noise and 10% Eve interference, KGR drops to 870 bits/sec.

Intercept-resend attacks introduce errors that require discarding certain bits during key sifting and reconciliation, reducing the KGR.

Scenario 5: With 5% channel noise and 10% Eve interference, KGR further decreases to 720 bits/sec.



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Combined effects of noise and eavesdropping significantly reduce secure key throughput.

Impact of Photon Number Splitting (PNS) Attack

Scenario 4: With 0% channel noise and 5% Eve interference, KGR is 910 bits/sec.

PNS attacks are less disruptive than intercept-resend in terms of immediate errors, so KGR reduction is smaller.

Scenario 6: With 5% channel noise and 5% Eve interference, KGR falls to 800 bits/sec.

Even moderate channel noise combined with PNS attacks can noticeably impact the key generation rate.

Table 4 presents the analysis of the Secure Key Fraction (SKF) under different quantum communication scenarios. The Secure Key Fraction measures the proportion of generated key bits that remain secure after error correction and privacy amplification. Higher values indicate better security, while lower values reflect increased vulnerability due to noise or eavesdropping. The table 4 and figure 4 demonstrates how channel noise and eavesdropping affect the fraction of secure key bits:

Baseline Scenario (No Attack, No Noise)

Scenario 1: With 0% channel noise and no attack, SKF is 99%.

Nearly all generated key bits remain secure, indicating an ideal QKD system.

Effect of Channel Noise (No Attack)

Scenario 2: With 2% channel noise and no attack, SKF slightly decreases to 96%.

Channel noise introduces errors that must be corrected, slightly reducing the fraction of secure bits.

Impact of Intercept-Resend Attack

Scenario 3: With 0% channel noise and 10% Eve interference, SKF drops to 85%.

A significant portion of bits must be discarded during privacy amplification due to eavesdropping, lowering the secure fraction.

Scenario 5: With 5% channel noise and 10% Eve interference, SKF reduces further to 70%.

The combination of noise and attack severely impacts the usable secure key.

Impact of Photon Number Splitting (PNS) Attack

Scenario 4: With 0% channel noise and 5% Eve interference, SKF is 90%.

PNS attacks are less disruptive than intercept-resend, so the secure key fraction is higher.

Scenario 6: With 5% channel noise and 5% Eve interference, SKF falls to 80%.

Moderate noise combined with PNS attacks still reduces the fraction of secure bits, but less drastically than intercept-resend.

CONCLUSION

The analysis of the Quantum Key Distribution (QKD) system through the three metrics—Quantum Bit Error Rate (QBER), Key Generation Rate (KGR), and Secure Key Fraction (SKF)—provides a comprehensive understanding of its performance, reliability, and security under various operational scenarios. The study demonstrates how both environmental factors (channel noise) and adversarial interventions (eavesdropping attacks) influence the efficiency and security of the QKD system.

Effect of Channel Noise

- Channel noise, even at modest levels (2–5%), significantly impacts the QKD performance.
- As observed in Scenario 2 of the QBER table, QBER increased from 1.2% to 3.1% due to just 2% channel noise, highlighting the sensitivity of qubit transmission to environmental disturbances.



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- Similarly, the KGR reduced from 1,000 bits/sec to 980 bits/sec, and the SKF decreased from 99% to 96%, showing that noise directly affects both the quantity and the security of the generated key.
- These findings emphasize the necessity of maintaining high-quality quantum channels with minimal environmental interference to sustain optimal QKD performance.

Impact of Eavesdropping Attacks

- The study considered Intercept-Resend and Photon Number Splitting (PNS) attacks, representing common eavesdropping strategies in QKD.
- The Intercept-Resend attack consistently caused the highest QBER, reaching 12.5% without noise and 18.2% with 5% channel noise, confirming that this type of attack introduces substantial errors detectable during error estimation.
- The PNS attack, while less disruptive to QBER (6.8% without noise, 10.5% with 5% noise), still reduced the KGR and SKF, indicating a compromise in secure key generation.
- The comparison shows that Intercept-Resend attacks are more easily detectable due to the sharp increase in QBER, whereas PNS attacks may remain subtler but still degrade key security.

Trade-offs Between QBER, KGR, and SKF

- A critical observation is the inverse relationship between QBER and both KGR and SKF. As errors increase due to noise or attacks, a larger proportion of key bits must be discarded during reconciliation and privacy amplification.
- For instance, Scenario 5 (5% channel noise + 10% Intercept-Resend attack) shows the highest QBER (18.2%), the lowest KGR (720 bits/sec), and the lowest SKF (70%), demonstrating that high error rates drastically reduce both the throughput and the security of the QKD system.
- This highlights the inherent trade-off in QKD: maintaining low QBER is essential not only for security but also to ensure efficient key generation.

System Robustness and Security Implications

- The baseline scenarios without noise or attacks consistently exhibit optimal performance, with QBER ~1.2%, KGR = 1,000 bits/sec, and SKF = 99%, indicating the inherent robustness of the system under ideal conditions.
- However, real-world deployment must account for channel imperfections and adversarial threats. The results show that even moderate noise and interference significantly degrade performance, stressing the need for dynamic monitoring, error correction, and attack detection mechanisms.
- Furthermore, the study validates that QBER serves as a reliable indicator for detecting eavesdropping, enabling timely interventions such as discarding compromised keys or initiating enhanced privacy amplification.

Practical Implications for Quantum Communication

- For secure and efficient QKD implementation, system designers must minimize channel noise through advanced optical fiber technology, low-loss transmission, or error-resilient encoding.
- Mitigation strategies against attacks, such as decoy-state protocols and photon-number monitoring, can reduce the impact of PNS attacks while maintaining high SKF and KGR.
- Overall, the results underscore the delicate balance in QKD between security, throughput, and error management, which is essential for reliable quantum communications in practical networks.

In conclusion, the study confirms that QKD performance is highly sensitive to both environmental noise and eavesdropping attacks. Maintaining low QBER is crucial for achieving high key generation rates and ensuring the secure key fraction remains substantial. Intercept-Resend attacks are more disruptive but detectable, while PNS attacks pose subtler threats. Therefore, robust channel management, vigilant monitoring, and adaptive security protocols are imperative for practical deployment of secure quantum communication systems.





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Table 1: Simulation Parameter

Parameter	Range / Value	Description
Number of Qubits (N)	500 – 10,000	Total transmitted qubits per session
Photon Loss Probability (p_loss)	0 – 0.1	Simulates channel attenuation
Noise Probability (p_noise)	0 – 0.05	Simulates decoherence and environmental effects
Detector Efficiency (η)	0.7 – 0.99	Probability of photon detection

Table 2: Quantum Bit Error Rate (QBER) Analysis

Scenario	Channel Noise (%)	Attack Type	Eve's Interference (%)	QBER (%)
1	0	None	0	1.2
2	2	None	0	3.1
3	0	Intercept-Resend	10	12.5
4	0	PNS	5	6.8
5	5	Intercept-Resend	10	18.2
6	5	PNS	5	10.5

Table 3: Key Generation Rate (KGR) Analysis

Scenario	Channel Noise (%)	Attack Type	Eve's Interference (%)	Key Generation Rate (bits/sec)
1	0	None	0	1,000
2	2	None	0	980
3	0	Intercept-Resend	10	870
4	0	PNS	5	910
5	5	Intercept-Resend	10	720
6	5	PNS	5	800

Table 4: Secure Key Fraction Analysis

Scenario	Channel Noise (%)	Attack Type	Eve's Interference (%)	Secure Key Fraction (%)
1	0	None	0	99
2	2	None	0	96
3	0	Intercept-Resend	10	85
4	0	PNS	5	90
5	5	Intercept-Resend	10	70
6	5	PNS	5	80





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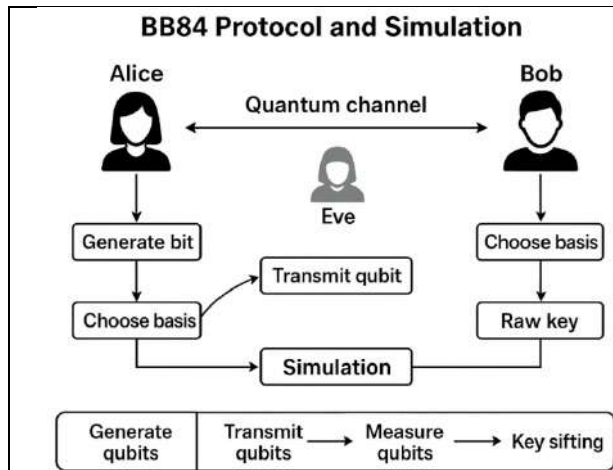


Figure 1: BB84 Protocol and Communication Simulation

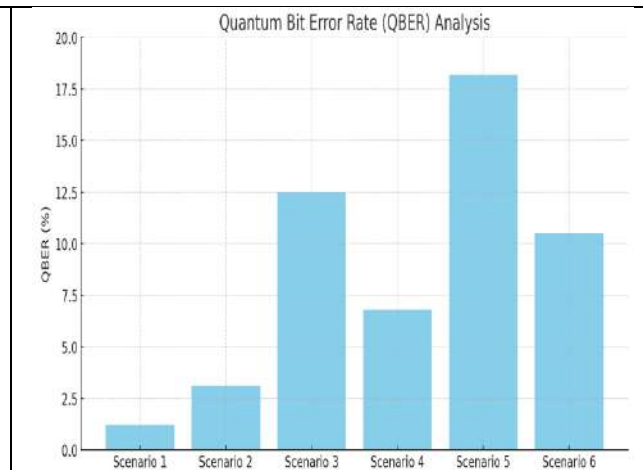


Figure 2: Graphical representation of the Quantum Bit Error Rate (QBER) Analysis

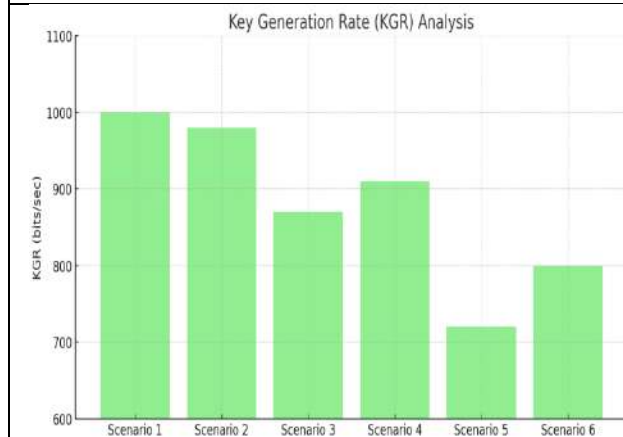


Figure 3: Graphical representation of the Key Generation Rate (KGR) Analysis

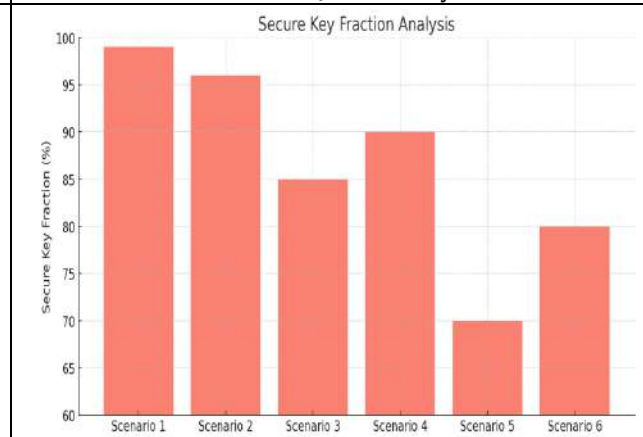


Figure 4: Graphical representation of the Secure Key Fraction Analysis





RESEARCH ARTICLE

A Pharmacological study of Kokilaksha Extract capsule: A Herbal Ayurvedic Drug

Ankita Baria¹ and Dipeeka Surwase^{2*}

¹Third Year Student, Department of Kayachikitsa, Parul Institute of Ayurved, Parul University, Limda, Waghodia, Vadodara, Gujarat, India.

²Associate Professor, Department of Kayachikitsa, Parul Institute of Ayurved, Parul University, Limda, Waghodia, Vadodara, Gujarat, India.

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*Address for Correspondence

Dipeeka Surwase

Associate Professor,

Department of Kayachikitsa,

Parul Institute of Ayurved,

Parul University,

Limda, Waghodia, Vadodara, Gujarat, India.

E.Mail: dipeeka.surwase21816@paruluniversity.ac.in



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ABSTRACT

Kokilaksha (*Asteracantha longifolia*) is a medicinal plant renowned for its therapeutic properties. Determining the active components in its extract capsules is essential for quality control and efficacy assessment. High-Performance Thin-Layer Chromatography (HPTLC) offers a reliable method for this purpose. Kokilaksha extract capsules were subjected to HPTLC analysis. The extract was prepared and applied to HPTLC plates. Chromatographic separation was achieved using a specific solvent system, and detection was performed under UV light at 254 nm and 366 nm. R_f values and peak areas were recorded and analyzed. Distinct chromatographic profiles were obtained for the Kokilaksha extract. At 254 nm, several peaks were observed, with R_f values ranging from 0.040 to 0.968. At 366 nm, additional peaks appeared, indicating the presence of various active constituents. The percentage area of each peak was calculated, providing insights into the composition of the extract. The HPTLC analysis of kokilaksha extract capsules showed a complex mixture of active compounds, including isoflavone, lupeol, lysine, glycoside, alkaloids, histidine, stigmasterol and terpene, which may explain its medicinal properties. HPTLC is an effective technique for identifying and quantifying active components in Kokilaksha extract capsules. The analysis provides valuable information for quality control and supports the therapeutic potential of Kokilaksha.

Keywords: Kokilaksha, *Asteracantha longifolia*, HPTLC, active components, extract capsules, quality control.



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INTRODUCTION

Medicine analysis is required to ensure that the ingredients, process, and final product are all standardized. Herbal formulations have several challenges in terms of quality analysis and standardization. Herbal formulations undergo a variety of quality-related obstacles resulting from the characteristics of the herbal ingredients and the numerous secondary metabolites they possess. In addition, growing, harvesting, storing, and drying procedures are examples of the internal and extrinsic factors that contribute to alterations in the chemical composition of herbs. Good manufacturing processes in the production units are ensured by a physiochemically standardized product. To make sure that the formulations include active marker compounds, a variety of chromatographic methods are employed. Thin layer chromatography (TLC) is the foundation of high-performance thin-layer chromatography (HPTLC), an analytical method that has been improved to enable quantitative analysis of the chemicals and improve the resolution of the compounds to be separated. Better resolution is made possible by several improvements, such as the use of better TLC plates in the stationary phase with smaller sizes of particles. HPTLC is employed in the identification and quantification of active compounds as well as the identification and detection of contaminants. The goal of the current study was to analyse *Ethanollic extract of kokilaksha* based on physiochemical parameters – weight variation, moisture content, total ash value, alcohol-soluble extractive value, water-soluble extractive value, Ph value, and total ash value as per the norms of Ayurvedic Pharmacopoeia of India (API) and Indian Pharmacopoeia (IP). The study also focused on identifying the phytochemicals in *kokilaksha capsules* using HPTLC and evaluating the therapeutic potential of *Ethanollic extract of kokilaksha*.

AIMS AND OBJECTIVES

To Evaluate the organoleptic characters of the *Ethanollic extract of kokilaksha*.

To assess the physicochemical, Phytochemical and HPTLC Parameters of *Ethanollic extract of kokilaksha*.

MATERIALS AND METHODS

Collection of Plant material: *Ethanollic extract of kokilaksha* was purchased from authenticated resources of Aamsar pvt, M.P.

Identification and Authentification of Raw Drug: Identification and Authentification of raw drugs was done by the GMP certified pharmacy Aamsar pvt. ltd.M.P.

Methods of Evaluation of Ethanollic Extract of Kokilaksha: *Ethanollic extract of kokilaksha* was analysed by using the entire standard qualitative and Quantitative parameters conducted at GMP certified pharmacy Aamsar pvt.ltd.

Physico-chemical Analysis

Physico chemical analysis of *Ethanollic extract of kokilaksha* includes parameters like colour, taste, pH, loss on drying, total ash value, alcohol soluble extract and water soluble extract.

Chromatograph profiling by HPTLC

Preparation of Test solution: Weight 5 gm of the sample in a beaker and add 100ml of methanol to it. sonicate for 16 hours and filter with the help of simple filter paper. filtrate is used as test solution thus obtained for HPTLC fingerprinting. Table No: 2 Chromatographic conditions for HPTLC of Kokilaksha Capsules

Identification of Compounds: For HPTLC interpretation, the unknown component's R_f Value, Relative R_f Value and % area at 254nm and 366nm was compared to the R_f Value, Relative R_f Value of known components listed in the Phytochemical fingerprint and chemometrics online database^[8] and IMPPAT 2.0.



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RESULTS AND DISCUSSION

The Organoleptic characteristics of kokilaksha capsule is mentioned in Table 3. The Physico-chemical parameters result along with its normal range and limit as per the norms of Ayurvedic Pharmacopoeia of India (API) ^[5] and Indian Pharmacopoeia (IP)^[6]. is mentioned in table 4. The HPTLC Chromatograph of kokilaksha capsules developed at wavelength of 254nm with volume of 5.0.0 μ L, 10.0 μ L, 15.0 μ L is depicted in figure 1,2,3 respectively. Chromatograph developed at wavelength of 366nm with volume 15.0 μ L is depicted in figure 4, showing the R_f Values, Chromatograph fingerprint, peak height and percentage area. By comparing the results (Fig 1-4) at Phytochemical fingerprint and chemometrics online data base^[8] and IMPPAT 2.0^[9] chemical substances were then identified is mentioned in Table 5-8 along with their Bioactivity [Source: PubChem, Google Scholar].

DISCUSSION

HPTLC (High-Performance Thin-Layer Chromatography) and physicochemical testing are crucial in Ayurveda medicine because they ensure quality control by confirming the authenticity, purity, and potency of herbal components. Additionally, they aid in the detection of adulteration by spotting contamination or the substitution of harmful or subpar ingredients. Additionally, HPTLC also helps clinical trials by providing standardized products for research, ensuring consistent findings. Such studies contribute to patient care by ensuring therapeutic efficacy with consistent, high-quality products, which leads to better treatment outcomes while additionally minimizing adverse effects by eliminating the likelihood of contamination and adulteration. It also contributes to the advancement of Ayurvedic research by providing consistent information to facilitate the development of evidence-based medicines. Here, the high-performance liquid chromatography (HPTLC) of the methanolic extract of Kokilaksha capsule showed the presence of multiple phytoconstituents in various concentrations. The chromatogram scanned at 254 nm and 366 nm shows a variety of peaks and their obtained R_f Values. The R_f Value, Relative R_f, and peak area % were then compared to standard references to estimate the compound name, which is the primary derivative of the phytochemicals. According to high-performance thin-layer chromatography, the phytochemicals extracted from kokilaksha capsule have anti-inflammatory and antioxidant properties. It additionally includes active components that function as analgesics, Cardioprotective, promotes healthy tissue function, growth ,healing and improves the immune system, protect against cancer cells, improve endothelial function. The chromatogram also reveals compounds that act as Hypoglycemic agents, anti-lipidemic agents, vasodilators (potassium channel blockers) all of which can act as Cardioprotective agents and manage peripheral vascular disorders. The HPTLC chromatogram also displays many chemicals that demonstrate the following actions: anti oxidant, Anti inflammatory, anti-tumour, anti-bacterial, anti-viral, and anti-neoplastic. In light of the discussion that followed, we can conclude that the primary derivatives or metabolites of phytochemical elements detected by HPTLC analysis of kokilaksha capsule could be useful in the treatment of iron deficiency Anemia, in cancer patients by increasing hemoglobin levels and reducing the need for blood transfusion, useful in Cardiac disease, Neurological conditions and inflammatory conditions.

Limitations and Future Scope of the Study

The phytochemicals found in kokilaksha capsules using HPTLC with R_f Value are only primary derivatives of phytochemical components, which limits the knowledge of the drug's pharmacological effect and therapeutic potential. Analytical methods like GCMS (gas chromatography-mass spectrometry) and LCMS (liquid chromatography-mass spectrometry) can be used to determine bioactive phytochemical components in kokilaksha capsule.

CONCLUSION

This study discusses the preparation and quality of kokilaksha capsules using physicochemical evaluation as mentioned in API (Ayurvedic Pharmacopoeia of India) followed by high-performance liquid chromatography (HPTLC). The Chromatogram reveals the presence of phytochemicals capable of improve endothelial function,





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Cardioprotective, promotes healthy tissue function, growth, healing and improves the immune system, anti cancer as well as preventing the progression of inflammatory disorders at various stages. The current study will also serve as a reference standard for medicine manufacturing, quality analysis, and assessing kokilaksha capsules therapeutic potential through GC-MS pharmaceutical analysis and further pre-clinical research.

ACKNOWLEDGEMENT

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CONFLICT OF INTEREST

There is no conflict of interest, according to the authors.

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Table No: 1 Chromatographic conditions for HPTLC of Kokilaksha Capsules

Chromatographic Conditions	
Application Mode	CAMAG Linomat 5 (S/N: 280008) Applicator
Filtering System	Simple filter
Stationary Phase	MERCK - HPTLC Silica gel 60 F ₂₅₄ on Aluminium sheets
Application (Y axis) Start Position	15 mm
Development End Position	80 mm from the plate base
Sample Application Volume	15 µL
Distance Between Tracks	13.4 mm
Development Mode	CAMAG TLC Twin Trough Chamber
Chamber Saturation Time	20 minutes
Mobile Phase (MP)	Tolueneethylacetate methanol(7.5:1.5:0.75:v/v/v)





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Visualization	@ 254 nm and @366 nm
Drying Mode, Temp. and Time	Room Temperature for 5 minutes.

Table No 2: Organoleptic characteristics of kokilaksha capsule

Colour	Brown
Odour	Sweet
Taste	Salty and Bitter
Consistency	Solid(powder form)
Touch	Sticky

Table No 3: Physio-Chemical Parameters of kokilaksha capsule

Sr.no	Parameters	Result	Normal Limit ^[5,6]
1.	Loss on Drying at 110 c (%w/w)	2.2	≤ 15%
2.	Total Ash Value (%w/w)	6.63	≤ 10%
3.	Acid insoluble Ash (%w/w)	2.45	(Variable)
4.	Water soluble extractive value (%w/w)	23.70	15-30%
5.	Alcohol soluble extractive value (%w/w)	11.40	-
6.	P ^H Value (10% Aqueous)	7.5	5.5-7.5
7.	Tablet Avg. Weight Variation (Mg)	720	-

Table No 4: Substance name and their Bioactivity based on R_f Value@254 nm and 5.0 µL volume

Peak No.	R _f Value	% Area	Substance Name	Bioactivity (Source: PubChem, Google Scholar)
1.	0.221	20.04	Isoflavone	Antioxidant, chemo preventive, Cardio protective, Improve Endothelial Function, Lowering cholesterol
2.	0.360	50.27	Lupeol	Anti cancer and anti inflammatory, anti protozoal, Anti microbial, Anti tumor and Chemopreventive
3.	0.468	21.34	Glycoside	Analgesics, Anti-inflammatory
4.	0.957	8.34	Lysine	Anti mucositic activity, Promotes healthy tissue function, growth and healing and improves the immune system.

Table No 5: Substance name and their Bioactivity based on R_f Value@254 nm and 10.0 µL volume

Peak No.	R _f Value	% Area	Substance Name	Bioactivity (Source: PubChem, Google Scholar)
1.	0.222	20.69	Isoflavone	Antioxidant, chemo preventive, Cardio protective, Improve Endothelial Function, Lowering cholesterol
2.	0.285	12.96	Stigmasterol	Antioxidant, Anti-inflammatory, Cardioprotective
3.	0.365	36.37	Lupeol	Anti cancer and anti inflammatory, anti protozoal, Anti microbial, Anti tumor and Chemopreventive
4.	0.464	24.39	Glycoside	Analgesics, Anti-inflammatory
5.	0.968	5.59	Lysine	Anti mucositic activity, Promotes healthy tissue function, growth and healing and improves the immune system.

Table No 6: Substance name and their Bioactivity based on R_f Value@254 nm and 15.0 µL volume

Peak No.	R _f Value	% Area	Substance Name	Bioactivity (Source: PubChem, Google Scholar)
1.	0.040	6.79	Lupeol	Anti cancer and anti inflammatory, anti-protozoal, Anti microbial, Anti





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				tumor and Chemopreventive, Anti Diabetic, Neuroprotective
2.	0.228	23.93	Alkaloid	Anticancer, Analgesic, Anti malarial, Antihyperglycemic, Vasodilatory
3.	0.292	17.00	Emodin	Antineoplastic, Laxative, Antiinflammatory, Antibiotic, Muscle building and Anti angiogenic
4.	0.382	25.55	Histidine	Immunomodulatory, Antioxidant, Antiinflammatory, Antisecretory
5.	0.474	26.73	Glycoside	Analgesics, Anti-inflammatory

Table No 7: Substance name and their Bioactivity based on R_f Value@366 nm and 15.0 µL volume

Peak No.	R _f Value	% Area	Substance Name	Bioactivity (Source: PubChem, Google Scholar)
1	0.046	60.82	Isoflavone	Antioxidant, chemo preventive, Cardioprotective, Improve Endothelial Function, Lowering cholesterol
2	0.146	2.06	Terpene	Cell growth modulation
3	0.303	12.36	Lupeol	Anti cancer and anti inflammatory, Anti protozoal, Anti microbial, Anti tumor and Chemopreventive, Anti Diabetic, Neuroprotective
4	0.372	4.04	Apigenin	Antiproliferative, Antiinflammatory, Antioxidant, Antibacterial, Anti viral, Anti hypertensive
5	0.464	4.73	Glycoside	Analgesics, Anti-inflammatory
6	0.546	3.19	Histidine	Immunomodulatory, Antioxidant, Antiinflammatory, Antisecretory
7	0.710	3.10	Stigmasterol	Antioxidant, Anti-inflammatory, Cardioprotective
8	0.813	3.69	Glucocinene	-
9	0.936	6.01	Lysine	Anti mucositis activity, Promotes healthy tissue function, growth and healing and improves the immune system.

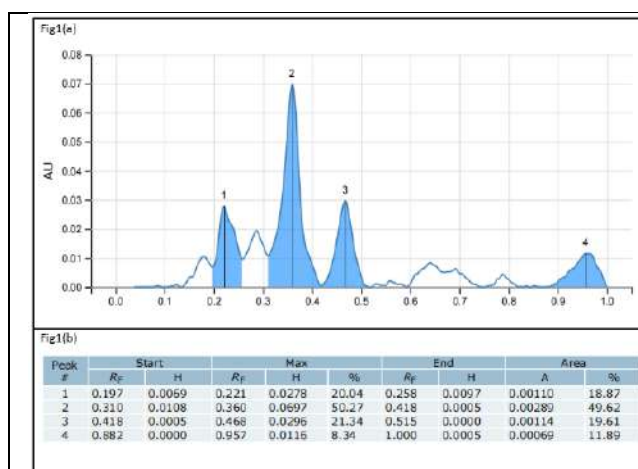


Figure 1: HPTLC Chromatogram of kokilaksha capsule@254 nm and 5.0 µL volume
(A=Fingerprint, B= Peak height, C= R_f Value and Area percentage)

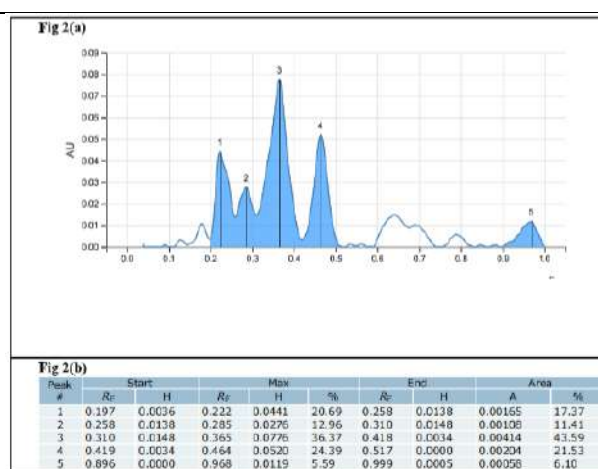
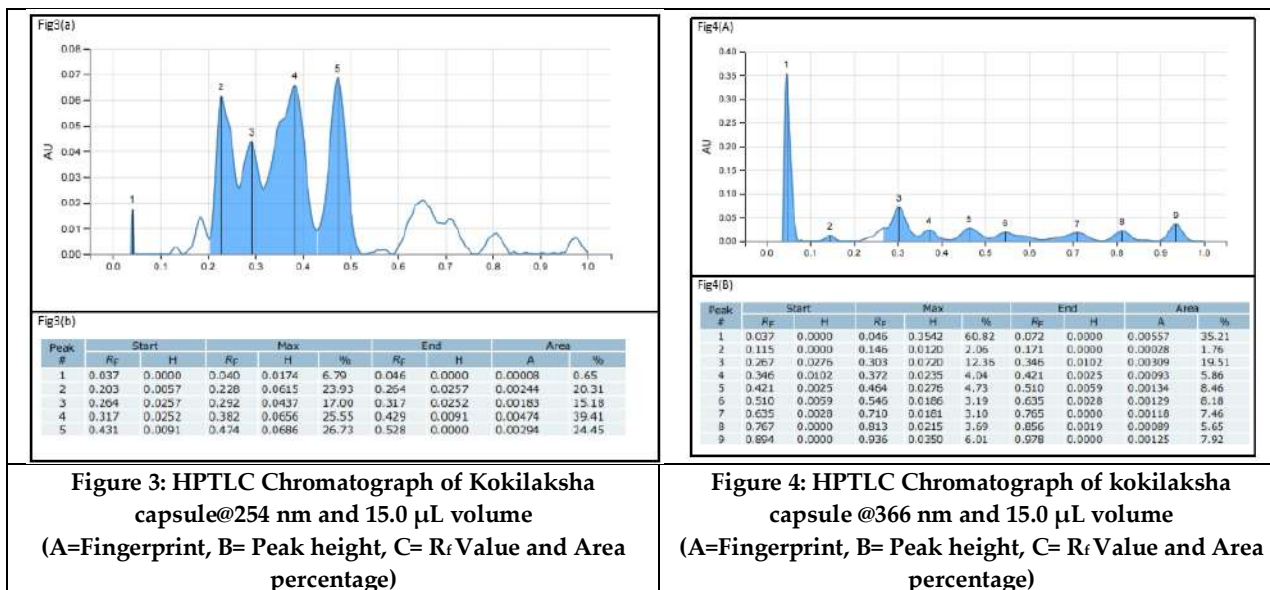


Figure 2: HPTLC Chromatogram of kokilaksha capsule@254 nm and 10.0 µL volume
(A=Fingerprint, B= Peak height, C= R_f Value and Area percentage)





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RESEARCH ARTICLE

Influence of GA₃ and NAA Foliar Sprays on Flowering and Pod Development in Broad Bean (*Vicia faba* L.) cv. BaklaKomal under the Agro-Climatic Conditions of Lower Uttarakhand Hills

Suneeta Singh¹, Sandeep Chauhan^{2*} and Abhay Kumar²

¹Associate Professor and Head, Department of Horticulture, Shri Guru Ram Rai University, Dehradun, Uttarakhand, India.

²Research Scholar, Department of Horticulture, Shri Guru Ram Rai University, Dehradun, Uttarakhand, India.

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*Address for Correspondence

Sandeep Chauhan

Research Scholar,

Department of Horticulture,

Shri Guru Ram Rai University,

Dehradun, Uttarakhand, India.

E.Mail: csandeep@gmail.com



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ABSTRACT

Present field experiment was conducted during the year 2023-24 at the Horticulture Research Block, Department of Horticulture, School of Agricultural Sciences, Shri Guru Ram Rai University, Dehradun, Uttarakhand, India, to evaluate the "Influence of GA₃ and NAA Foliar Sprays on Flowering and Pod Development in Broad Bean (*Vicia faba* L.) under the Agro-Climatic Conditions of Lower Uttarakhand Hills." The experiment was laid out in a Randomized Block Design with three replications and ten treatments, comprising different concentrations of plant growth regulators: T0 (Control), T1 (GA₃ @ 50 ppm), T2 (GA₃ @ 75 ppm), T3 (GA₃ @ 100 ppm), T4 (NAA @ 50 ppm), T5 (NAA @ 75 ppm), T6 (NAA @ 100 ppm), T7 (GA₃ @ 50 ppm + NAA @ 50 ppm), T8 (GA₃ @ 75 ppm + NAA @ 75 ppm) and T9 (GA₃ @ 100 ppm + NAA @ 100 ppm). The broad bean variety 'BaklaKomal' was sown on 4th November 2023. Regular assessments were carried out to record various flowering and pod attributes using standard measurement procedures. Among all treatments, T9 (GA₃ @ 100 ppm + NAA @ 100 ppm) proved to be the most effective in terms of recording the highest number of florets per plant (43.27), fresh weight of pod (14.03 g), dry weight of pod (9.30g) and number of pods per plant (30.00). However, the maximum number of inflorescences per plant (25.27), days to pod emergence (72.67 DAS) and pod length (7.90 cm) were recorded under T3 (GA₃ @ 100 ppm) while the maximum pod diameter (16.13 mm) was recorded under T6 (NAA @ 100 ppm). The study highlights the beneficial effects of combined applications of GA₃ and NAA, particularly at higher concentrations.

Keywords: Broad bean, NAA, GA₃, Fresh weight of pod, Dry weight of pod, Length of pod, Diameter of pod



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INTRODUCTION

Broad bean (*Vicia faba* L.), a member of the Fabaceae family with a diploid chromosome number of $2n=12$, is a leguminous crop primarily cultivated for its edible seeds or beans consumed by humans. In India, broad bean cultivation remains limited and hence, it is considered an underutilized vegetable crop. The tender pods are consumed as vegetables, while the dried seeds are commonly used as pulses (Rathore *et al.*, 2022). Broad beans can also be intercropped with cereals and are known for their ability to fix atmospheric nitrogen up to 300 kg N/ha thereby enhancing soil fertility and overall crop yield. Historically, Korber-Grohne (1987) noted that broad bean cultivation dates back to the late Neolithic era. According to Cubero, its primary centre of origin is believed to be the Near East, specifically Iraq and Iran, with secondary centres in Afghanistan and Ethiopia. There are also suggestions that *Vicia faba* may have originated in West or Central Asia. Today, the crop is widely grown across the Mediterranean region, China, Africa, Europe, the Middle East and Asia, serving as a staple for both human and livestock diets. Broad beans are cold-tolerant and can withstand temperatures as low as 4°C. However, the optimal temperature range for pod development lies between 15-20°C. High temperatures during the rainy season can cause flower and pod drop, while in colder agro-climatic zones, sowing is often delayed until late winter or early spring to prevent frost damage (Sallam *et al.*, 2015). The crop thrives in regions receiving 650-1000 mm of annual rainfall, ideally well-distributed. In tropical and subtropical areas, it can be cultivated at altitudes ranging from 1200 m to 2500 m above sea level. Although generally considered day-neutral, some cultivars may require long-day conditions for flowering. Waterlogging during flowering adversely affects growth and yield (Pampana *et al.*, 2016). Broad beans prefer fine-textured soils but are adaptable to various soil types, with an optimal pH of around 7.

They are resilient to brief periods of waterlogging (Tekalign *et al.*, 2016). Broad bean seeds are nutritionally rich, containing bioactive compounds such as polyphenols and carotenoids. However, their chemical composition varies with cultivar, environmental conditions, and agronomic practices (Witten *et al.*, 2015). Despite their nutritional value including high levels of dietary fibre, essential minerals, vitamins, lipids, γ -aminobutyric acid and phenolic compounds the crop remains underutilized. These components are known to support human health by enhancing antioxidant activity and metabolic functions (Mahdi *et al.*, 2021). However, broad beans also contain anti-nutritional factors like saponins, tannins, phytic acid, lectins, oxalates, trypsin inhibitors and particularly vicine and convicine, which can induce favism in glucose-6-phosphate dehydrogenase deficient individuals (Rizzello *et al.*, 2016; Luzzatto and Arese, 2018; Khazaei *et al.*, 2019; Labba *et al.*, 2021). Favism involves the formation of superoxide radicals, leading to rapid oxidation of glutathione in red blood cells. Techniques such as food processing, sprouting, breeding, germination and fermentation have proven effective in reducing these anti-nutritional factors (Coda *et al.*, 2015; Rizzello *et al.*, 2016 and Shi *et al.*, 2016). As of the latest available data, global production of dry broad beans and horse beans is led by China, with an annual output of approximately 1.7 million tonnes. Ethiopia follows with around 1.15 million tonnes and the United Kingdom produces about 685,000 tonnes. Other significant producers include Australia and France, contributing 635,000 tonnes and 216,000 tonnes, respectively.

Collectively, these countries account for a substantial portion of the world's broad bean supply. In India, crop is primarily grown in specific regions such as Bihar, Madhya Pradesh, parts of Uttar Pradesh and Uttarakhand. Despite its potential for high yields and nutritional benefits, broad bean production in India has not expanded significantly, resulting in a reliance on imports to meet domestic demand. India imports broad beans from over 77 countries, with Uganda, China, and India itself being the leading suppliers, accounting for 67% of India's total broad bean imports. Among the numerous agronomic techniques to improve crop yield and quality, the use of plant growth regulators has gained significant attention. Gibberellic acid, in particular, is known to enhance fruit size, yield and quality by promoting cell division and elongation and regulating crop load and plant development (Devrari *et al.*, 2017; Neelam *et al.*, 2023). GA_3 influences a wide array of developmental processes, including internode elongation, increased flower and pod numbers, early flowering, seed dormancy breaking, accelerated maturity and reduced fruit cracking in horticultural crops. Another widely used PGR is naphthalene acetic acid, an auxin with the molecular formula $C_{10}H_7CH_2CO_2H$. NAA acts as a rooting agent, enhances cellulose fibre formation, prevents premature fruit drop and



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stem thinning, and boosts yield and quality through improved cell division and elongation (Park *et al.*, 2017). The current initiative to investigate the influences of GA₃ and NAA on broad bean cultivation in the low hill regions of Uttarakhand stems from a significant research gap. Few studies have explored the influence of these specific PGRs on broad bean crops in this unique agro-climatic zone. This study aims to address that gap by evaluating the role of GA₃ and NAA in improving the flowering and pod parameters of broad bean under low hill conditions, thereby contributing to enhanced productivity and sustainability for local farming communities.

MATERIALS AND METHODS

The experimental phase took place during the rabi season of 2023-24 at Horticulture Research Block, School of Agricultural Sciences, Shri Guru Ram Rai University, PathriBagh, Dehradun, Uttarakhand, India. Geographically, it is located in between 29°58' and 31°2'30" North latitude and 77° 34'45" and 78°18'30" East longitudes. Broad bean cultivar "BaklaKomal" were used for present experimental trial. For the purpose of the experimentation, a randomized block design was implemented, which comprised ten treatments. A complete overview of the treatments and their associated symbols used in the experiment can be found in Table 1. The treatments are T₀ (Control), T₁ (GA₃ @50ppm), T₂ (GA₃ @75ppm), T₃ (GA₃ @100ppm), T₄ (NAA @50ppm), T₅ (NAA @75ppm), T₆ (NAA @100ppm), T₇ (GA₃ @50ppm + NAA @50ppm), T₈ (GA₃ @75ppm + NAA @75ppm), T₉ (GA₃ @100ppm + NAA @100ppm). Treatments were allocated to the experimental units through a random process, employing the Fisher and Yates random table method (Panse and Sukhatme, 1985) and this was repeated three times to bolster statistical accuracy.

RESULT AND DISCUSSION

The research demonstrated that varying doses of GA₃ and NAA had a significant effect on flowering and pod characteristics in comparison to the control. Tables 2 and 3 illustrate that notable enhancements were achieved with different combinations of Plant growth regulators versus the control.

The results of this study have been carefully noted and will be discussed in detail below

Number of inflorescence per plant

The data presented in Table 2 and Fig 1 indicates that there was significant variation in number of inflorescences per plant among different plant growth regulators. At 60 DAS, the maximum number of inflorescence per plant (18.10) was recorded in T₃ with GA₃ @100ppm and the minimum number of inflorescence per plant (10.17) was recorded in T₄ with NAA @50ppm. Whereas, T₅ (13.13) and T₆ (13.80) were at par with each other. The treatment T₁ (14.67) and T₇ (14.43) were also at par with each other and the treatment T₂ (16.50) and T₉ (16.10) were also at par with each other. However, the significant difference was found in T₀ (12.07) and T₈ (15.70). At 90 DAS, the maximum number of inflorescence per plant (25.27) was recorded in T₃ with GA₃ @100ppm and the minimum number of inflorescence per plant (15.50) was recorded in T₄ with NAA @50ppm which is at par with T₀ (15.87) with control. Whereas, T₆ (18.17), T₇ (19.10) and T₈ (19.80) were at par with each other. The treatment T₁ (21.43) and T₉ (21.80) were also at par with each other. However, the significant difference was found in T₂ (21.43) and T₆ (18.17). The vigorous flowering of auxiliary buds may be attributed to the action of gibberellic acid at optimal levels. Similar observations were made by Kumar *et al.*, (2021) in their study on gladiolus.

Number of florets per plant

The data presented in Table 2 and Fig 2 indicates that there was significant variation in number of florets per plant among different plant growth regulators. At 60 DAS, the maximum number of florets per plant (59.23) was recorded in T₉ with GA₃ @100ppm + NAA @100ppm which is at par with T₈ (57.33) and the minimum number of florets per plant (44.00) was recorded in T₄ with NAA @50ppm. Whereas, T₁ (49.10), T₂ (51.97) and T₆ (49.73) were at par with each other. The treatment T₃ (56.50), T₇ (55.67) and T₈ (57.33) were also at par with each other. However, the significant difference was found in T₅ (47.43). At 90 DAS, the maximum number of florets per plant (43.27) was recorded in T₉ with GA₃ @100ppm + NAA @100ppm which were at par with T₈ (42.23) and the minimum number of



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florets per plant (28.33) was recorded in T₄ at NAA @50ppm which is at par with T₀ (29.13). Whereas, T₂ (37.13) and T₃ (38.73) were at par with each other. The treatment T₇ (41.53) and T₈ (42.23) were also at par with each other. However, the significant difference was found in T₆ (33.67). It might be due to the activity of gibberellic acid that optimum level promoted the auxiliary buds to grow vigorously and their flowering. Kumar *et al.*, (2021) noted similar findings in gladiolus.

Days of pod emergence (DAS)

The data presented in Table 2 and Fig 3 indicates that there was significant variation in Days of pod emergence among different plant growth regulators. The maximum Days to pod emergence (72.67 DAS) was recorded in T₃ with GA₃ @100ppm and the minimum Days to pod emergence (60.00 DAS) was recorded in T₀ at Control. Whereas, T₅ (64.67 DAS), T₆ (64.33 DAS) and T₇ (64.67 DAS) were at par with each other. The treatment T₂ (67.33 DAS), T₉ (67.00 DAS) and T₄ (65.00 DAS), T₈ (65.33 DAS) were also at par with each other. However, there was non-significant effect on Days to pod emergence among the treatment.

Length of pod (cm)

The data presented in Table 2 and Fig 4 indicates that there was significant variation in Length of pod among different plant growth regulators. At 90 DAS, the maximum Length of pod (6.10 cm) was recorded in T₃ with GA₃ @100ppm and the minimum Length of pod (3.57 cm) was recorded in T₀ at Control. Whereas, T₉ (4.30 cm) and T₅ (4.30 cm) were at par with each other. The treatment T₄ (4.43 cm) and T₆ (4.57 cm) were also at par with each other. However, the significant difference was found in T₁ (5.27 cm) and T₂ (5.93 cm). At Final harvest, the maximum Length of pod (7.90 cm) was recorded in T₃ with GA₃ @100ppm and the minimum Length of pod (4.23 cm) was recorded in T₀ at Control which were at par with T₇ (4.47 cm). Whereas, T₄ (5.20), T₆ (4.56 cm), T₈ (5.03 cm) and T₉ (5.00 cm) were at par with each other. The treatment T₁ (7.00 cm) and T₂ (7.20 cm) were also at par with each other. However, the significant difference was found in T₅ (5.53 cm). This extra dry matter creates more spots for storing nutrients, ultimately increasing pod length. This effect was also noted by Tasnim *et al.*, (2019) in mung beans and by Fadhil and Almasoody (2019) in broad beans.

Diameter of pod (cm)

The data presented in Table 3 and Fig 5 indicates that there was significant variation in Diameter of pod among different plant growth regulators. At 90 DAS, the maximum Diameter of pod (9.70 mm) was recorded in T₆ with GA₃ @100ppm + NAA @100ppm and the minimum Diameter of pod (6.50 mm) was recorded in T₀ at Control which is at par with T₂ (6.33 mm). Whereas, T₁ (6.83 mm) and T₃ (6.93 mm) were at par with each other. The treatment T₈ (7.60 mm) and T₉ (7.57 mm) were also at par with each other and T₄ (9.07 mm) and T₅ (9.33 mm) were also at par with each other. However, the significant difference was found in T₇ (7.17 mm). At Final harvest, the maximum Diameter of pod (16.13 mm) was recorded in T₆ with GA₃ @100ppm + NAA @100ppm which is at par with T₆ (15.10 mm) and the minimum Diameter of pod (9.50 mm) was recorded in T₀ at Control. Whereas, T₇ (13.13 mm) and T₈ (13.50 mm) were at par with each other and T₁ (11.10 mm) and T₂ (11.57 mm) also at par with each other. The treatment T₉ (14.53 mm) and T₄ (14.57 mm) were also at par with each other. However, the significant difference was found in T₃ (12.40 mm). This might be due to NAA spray may enhance the movement of sugars from the plant's leaves to the developing pods, results in significantly increasing their width. According to Siddik *et al.*, (2015) sesame plants treated with 50 ppm NAA also showed a rise in pod width.

Fresh weight of pod (g)

The data presented in Table 3 and Fig 6 indicates that there was significant variation in Fresh weight of pod among different plant growth regulators. At 90 DAS, the maximum Fresh weight of pod (7.67 g) was recorded in T₉ with GA₃ @100ppm + NAA @100ppm which were at par with T₈ (7.50 g) and the minimum Fresh weight of pod (4.50 g) was recorded in T₀ at Control which were at par with T₁ (4.87 g). Whereas, T₂ (5.10 g) and T₃ (5.33 g) were at par with each other. The treatment T₆ (6.97 g), T₇ (7.20 g) and T₈ (7.50 g) were also at par with each other. However, the significant difference was found in T₄ (5.80 g). At Final harvest, the maximum Fresh weight of pod (14.03 g) was recorded in T₉ with GA₃ @100ppm and the minimum Fresh weight of pod (9.00 g) was recorded in T₀ at Control. Whereas, T₁ (9.13 g)



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and T₂ (9.63 g) were at par with each other and T₃ (11.53 g) and T₅ (11.50 g) also at par with each other. Also, the treatment T₄ (10.50 g), T₇ (10.57 g) were also at par with each other. However, the significant difference was found in T₆ (12.63 g) and T₈ (12.20 g). This might happen because the photosynthetic machinery has expanded, increasing both the leaf area and the leaf area index, which led to a higher assimilation rate and ultimately heavier pods. Similar results have also been reported by Bairva *et al.*, (2014) in fenugreek.

Dry weight of pod (g)

The data presented in Table 3 and Fig 7 indicates that there was significant variation in Dry weight of pod among different plant growth regulators. At 90 DAS, the maximum Dry weight of pod (2.10 g) was recorded in T₉ with GA₃ @100ppm + NAA @100ppm which were at par with T₈ (3.80 g) and the minimum Dry weight of pod (1.30 g) was recorded in T₀ at Control which were at par with T₁ (1.57 g). Whereas, T₂ (1.93 g) and T₃ (2.17 g) were at par with each other. However, the significant difference was found in T₄ (1.23 g), T₅ (2.90 g) and T₆ (1.50 g). At Final harvest, the maximum Dry weight of pod (9.30 g) was recorded in T₉ with (GA₃ @100ppm + NAA @100ppm) and the minimum Dry weight of pod (0.60 g) was recorded in T₀ at Control which were at par with T₁ (0.87 g). Whereas, T₂ (1.00 g) and T₃ (1.10 g) were at par with each other and T₅ (1.37 g), T₆ (1.50 g) and T₇ (1.37 g) also at par with each other. However, the significant difference was found in T₄ (1.23 g) and T₈ (7.40 g). The reduced weight of fresh pods from GA₃ application on the vegetative parts might result in higher fruit drop rates, either directly or by enhancing the plant's growth and taking away energy from the pods. Similar results have also been reported by Bairva *et al.*, (2014) in fenugreek.

Number of pods per plant

The data presented in Table 3 and Fig 8 indicates that there was significant variation in number of pods per plant among different plant growth regulators. At 90 DAS, the maximum number of pods per plant (47.67) was recorded in T₉ with GA₃ @100ppm + NAA @100ppm which were at par with T₈ (47.67) and the minimum number of Pods per plant (31.00) was recorded in T₀ at Control. Whereas, T₂ (40.67) and T₄ (41.00) were at par with each other. However, the significant difference was found in T₃ (37.00), T₅ (42.33) and T₆ (45.33). At Final harvest, the maximum number of pods per plant (30.00) was recorded in T₉ with GA₃ @100ppm which were at par with T₇ (29.33) and the minimum number of pods per plant (21.00) was recorded in T₀ at Control which were at par with T₁ (22.67). Whereas, T₃ (26.33) and T₄ (26.67) were at par with each other and T₂ (29.00), T₆ (47.33) and T₇ (29.33) also at par with each other. However, there was non-significant effect on number of pods per plant among the treatment at 90 DAS. The use of NAA effectively helps in maintaining buds, flowers, and pods, and it accelerates the movement of nutrients to growing regions, which may increase the pod count for each plant. Conversely, GA₃ can cause a reduction in pod numbers as it diverts nutrients from reproductive structures to promote vegetative growth. These findings are consistent with the studies by Parmar *et al.*, (2011) in green gram.

Conclusion

On the basis of present experimental research on “Influence of GA₃ and NAA Foliar Sprays on Flowering and Pod Development in Broad Bean (*Vicia faba* L.) under the Agro-Climatic Conditions of Lower Uttarakhand Hills” in cultivar BaklaKomal, it can be concluded that among different treatments, the combination of GA₃ @100ppm + NAA @100ppm i.e., T₉ was found to be most effective for increasing number of florets per plant, fresh weight of pod (g), dry weight of pod (g) and number of pods per plant. However, number of inflorescence per plant, days to pod emergence (DAS) and length of pod (cm) was found maximum in T₃ GA₃@ 100ppm and diameter of pod (mm) was recorded maximum in T₆(NAA@100ppm).

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Suneeta Singh *et al.*,**Table1: Treatment combinations with their concentrations**

Treatments	Treatment Combinations	Concentration
T ₀	Control (Water)	100%
T ₁	Gibberellic acid	50 ppm
T ₂	Gibberellic acid	75 ppm
T ₃	Gibberellic acid	100 ppm
T ₄	Naphthalene acetic acid	50 ppm
T ₅	Naphthalene acetic acid	75 ppm
T ₆	Naphthalene acetic acid	100 ppm
T ₇	Gibberellic acid + Naphthalene acetic acid	50 + 50 ppm
T ₈	Gibberellic acid + Naphthalene acetic acid	75 + 75 ppm
T ₉	Gibberellic acid + Naphthalene acetic acid	100 + 100 ppm

Table 2: Effect of GA₃ and NAA on number of inflorescence per plant, number of florets per plant, Days of pod emergence (DAS) of broad bean

Treatment	Number of inflorescence per plant		Number of florets per plant		Days of pod emergence	Length of pod (cm)	
	60 DAS	90 DAS	60 DAS	90 DAS	DAS	90 DAS	At Final harvest
T ₀	12.07	15.87	45.50	29.13	60.00	3.57	4.23
T ₁	14.67	21.43	49.10	35.67	70.67	5.27	7.00
T ₂	16.50	23.83	51.97	37.13	67.33	5.93	7.20
T ₃	18.10	25.27	56.50	38.73	72.67	6.10	7.90
T ₄	10.17	15.50	44.00	28.33	65.00	4.43	5.20
T ₅	13.13	16.50	47.43	31.57	64.67	4.30	5.53
T ₆	13.80	18.17	49.73	33.67	63.33	4.57	6.00
T ₇	14.43	19.10	55.67	41.53	64.67	3.73	4.47
T ₈	15.70	19.80	57.33	42.23	65.33	4.13	5.03
T ₉	16.10	21.80	59.23	43.27	67.00	4.30	5.00
C.D (0.05%)	2.36	3.43	9.08	10.30	NS	0.67	0.43
SE(m) ±	0.79	1.16	3.03	3.44	3.48	0.22	0.14
SE(d) ±	1.12	1.62	4.29	4.87	4.92	0.32	0.20
C.V.	9.46	10.06	10.17	16.50	9.12	8.43	4.37

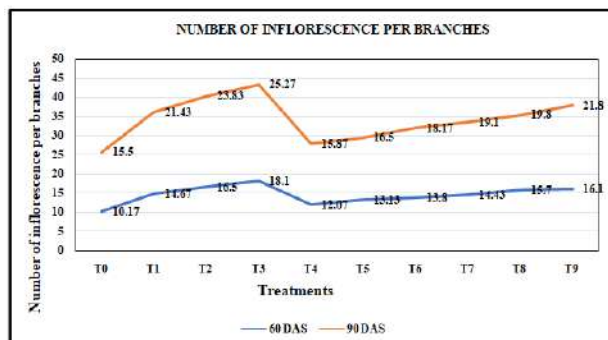
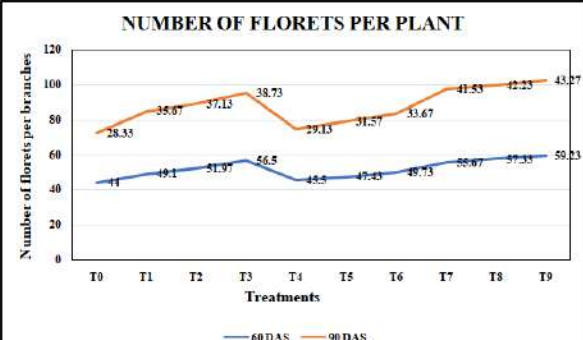
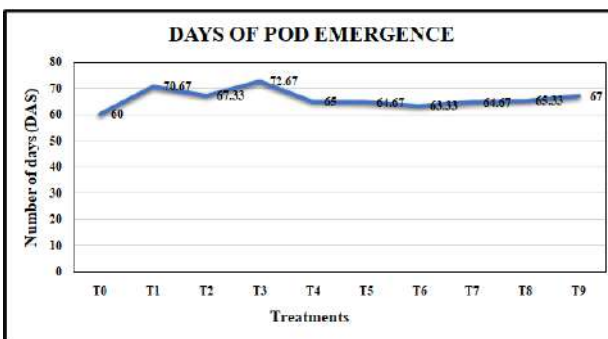
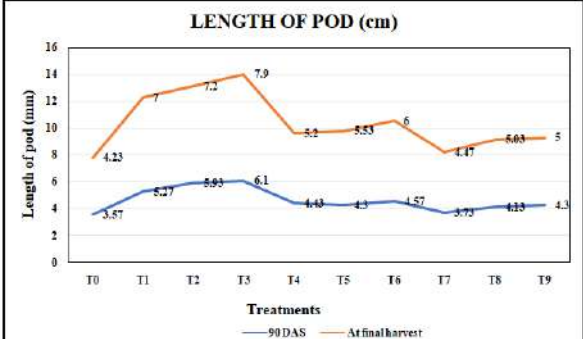
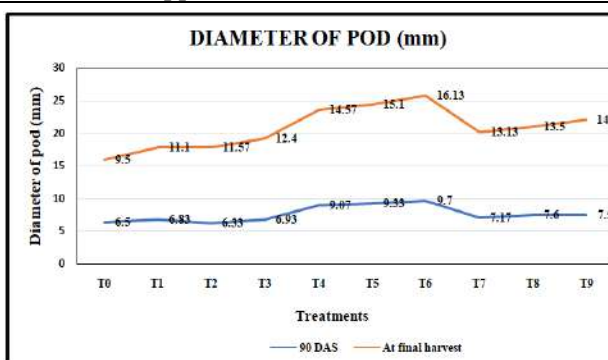
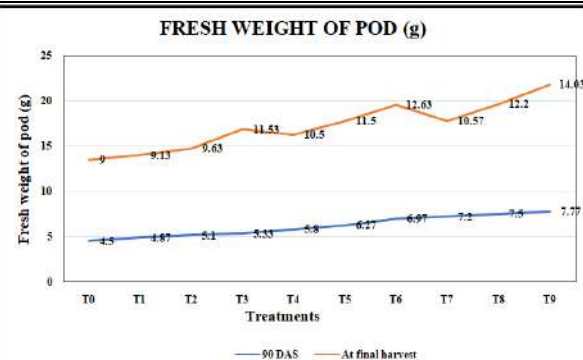
Table 3: Effect of GA₃ and NAA on Diameter of pod (mm), Fresh weight of pod (g), Dry weight of pod (g), number of pods per plant of broad bean

Treatment	Diameter of pod (mm)		Fresh weight of pod (g)		Dry weight of pod (g)		Number of pods per plant	
	90 DAS	At Final harvest	90 DAS	At Final harvest	90 DAS	At Final harvest	90 DAS	At Final harvest
T ₀	6.50	9.50	4.50	9.00	0.60	4.03	31.00	21.00
T ₁	6.83	11.10	4.87	9.13	0.87	4.33	35.00	22.67
T ₂	6.33	11.57	5.10	9.63	1.00	4.70	40.67	24.00
T ₃	6.93	12.40	5.33	11.53	1.10	5.83	37.00	26.33
T ₄	9.07	14.57	5.80	10.50	1.23	5.40	41.00	26.67
T ₅	9.33	15.10	6.27	11.50	1.37	6.37	42.33	28.33
T ₆	9.70	16.13	6.97	12.63	1.50	7.63	45.33	29.67
T ₇	7.17	13.13	7.20	10.57	1.63	6.37	43.67	29.33



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T ₈	7.60	13.50	7.50	12.20	1.90	7.40	47.67	29.00
T ₉	7.57	14.53	7.77	14.03	2.10	9.30	47.67	30.00
C.D (0.05%)	1.29	1.46	0.25	0.74	0.13	0.66	NS	4.19
SE(m) ±	0.43	0.49	0.08	0.28	0.04	0.22	4.053	1.40
SE(d) ±	0.61	0.69	0.12	0.35	0.06	0.31	5.732	1.98
C.V.	9.71	6.44	2.40	3.88	5.84	6.23	17.067	9.08

Fig. 1: Number of inflorescences influenced by application of GA₃ and NAAFig. 2: Number of florets per plant influenced by application of GA₃ and NAAFig. 3: Days of pod emergence (DAS) as influenced by application of GA₃ and NAAFig. 4: Length of pod (cm) as influenced by application of GA₃ and NAAFig. 5: Diameter of pod (mm) as influenced by application of GA₃ and NAAFig. 6: Fresh weight of pod (g) as influenced by application of GA₃ and NAA



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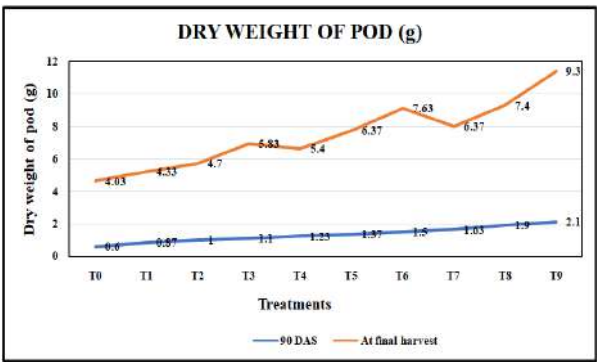


Fig.7: Dry weight of pod (g) as influenced by application of GA₃ and NAA

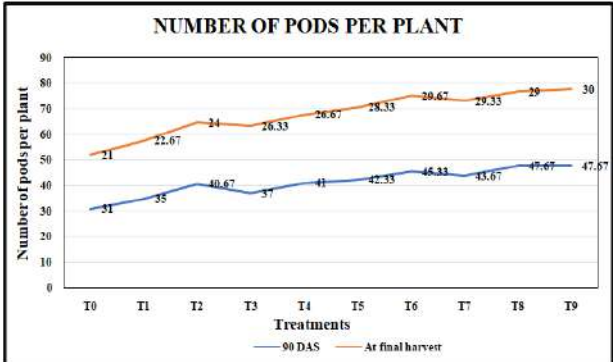


Fig.8: Number of pods per plant as influenced by application of GA₃ and NAA





RESEARCH ARTICLE

Pythagorean Neutrosophic Cubic Set Operations and Aggregate model of MADM

Berna Joyce .L^{1*} and Elvina Mary .L²

¹Research Scholar, Department of Mathematics, Nirmala College for Women (Affiliated to Bharathiar University), Coimbatore, Tamil Nadu, India.

²Assistant Professor, Department of Mathematics, Nirmala College for Women (Affiliated to Bharathiar University), Coimbatore, Tamil Nadu, India.

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*Address for Correspondence

Berna Joyce .L

¹Research Scholar,
Department of Mathematics,
Nirmala College for Women
(Affiliated to Bharathiar University),
Coimbatore, Tamil Nadu, India.
E.Mail: bernajoyceslr@gmail.com



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ABSTRACT

The instances of a Pythagorean Neutrosophic Set and a Pythagorean Neutrosophic Interval Valued Set together constitute a Pythagorean Neutrosophic Cubic Set (PNCS). Because of this, PNCSs are perfect for simultaneously communicating blended information from the Pythagorean Neutrosophic Set (connected to the known component) and the Pythagorean Neutrosophic Interval Valued Set (associated to the unknown half of the information).

Keywords : Pythagorean Neutrosophic Cubic Set weighted arithmetic averaging operator, Pythagorean Neutrosophic Cubic Set weighted geometric averaging operator, Multiple attribute decision making.

INTRODUCTION

Zadeh[11] laid the groundwork for uncertain math in 1965 by developing the theory of fuzzy sets. A short time later, in 1975, Zadeh[12] addressed a fuzzy set reconfiguration with interval valued function membership. Neutrosophic Sets were initially defined in 1995 by FlorentinSmarandache[7]. This enables ambiguity and uncertainty to be handled more thoroughly. In the year 2012, Jun et al[4] defined cubic set. In 2017, Chang Su Kim, FlorentinSmarandache, and Young BaeJun[10] presented the an idea of Neutrosophic Cubic Sets. Yagar[9] first presented the Pythagorean Fuzzy set's evolution in 2013. R. Jhansi & K. Mohana[3] proposed the Neutrosophic Pythagorean Sets. A combination of Pythagorean Neutrosophic Sets and Pythagorean Neutrosophic Interval Valued





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Sets, Berna Joyce [1] introduced a novel idea for PNCS, including IPNCS and EPNCS and then demonstrated several properties of primary and refined orders of PNCS[2]. In 2018, Jun Ye [10] pointed out the MADM approach for neutrosophic cubic numbers. This paper depicts the 'score', 'accuracy' & 'certainty' functions of PNCS, as well as the ranking techniques as well as particular fundamental interactions of the PNCS. Apart from that, two additional methodologies were brought forward: PNCWGA and PNCWAA. Both the MADM based on the PNCWAA and PNCWGA operators and the ranking mechanism of PNCS in a PNC context have been discussed.

PRELIMINARIES

Definition 2.1[8] Pythagorean Neutrosophic set (PNS), $\hat{I} \neq \phi$ is $\hat{\mathbb{D}}_{PNS} = \{(\hat{i}, \mathcal{T}_{\hat{\mathbb{D}}}(\hat{i}), \mathcal{I}_{\hat{\mathbb{D}}}(\hat{i}), \mathcal{F}_{\hat{\mathbb{D}}}(\hat{i})) : \hat{i} \in \hat{I}\}$ where $\mathcal{T}_{\hat{\mathbb{D}}}, \mathcal{I}_{\hat{\mathbb{D}}}, \mathcal{F}_{\hat{\mathbb{D}}} : \hat{I} \rightarrow [0, 1]$ and $0 \leq (\mathcal{T}_{\hat{\mathbb{D}}}(\hat{i}))^2 + (\mathcal{I}_{\hat{\mathbb{D}}}(\hat{i}))^2 + (\mathcal{F}_{\hat{\mathbb{D}}}(\hat{i}))^2 \leq 2$ where $\mathcal{T}_{\hat{\mathbb{D}}}(\hat{i})$ denotes the 'degree of membership', $\mathcal{I}_{\hat{\mathbb{D}}}(\hat{i})$ denotes the 'degree of indeterminacy' and $\mathcal{F}_{\hat{\mathbb{D}}}(\hat{i})$ denotes the 'degree of non-membership'.

Definition 2.2[7] A Pythagorean Neutrosophic Interval Valued Set (PNIVS) in $\hat{I} \neq \phi$ is of the form

$\hat{\mathbb{D}}_{PNIVS} = \{(\hat{i}, [\mathcal{D}_{\hat{\mathbb{T}}}^-(\hat{i}), \mathcal{D}_{\hat{\mathbb{T}}}^+(\hat{i})], [\mathcal{D}_{\hat{\mathbb{I}}}^-(\hat{i}), \mathcal{D}_{\hat{\mathbb{I}}}^+(\hat{i})], [\mathcal{D}_{\hat{\mathbb{F}}}^-(\hat{i}), \mathcal{D}_{\hat{\mathbb{F}}}^+(\hat{i})]) : \hat{i} \in \hat{I}\}$ where $\mathcal{D}_{\hat{\mathbb{T}}}(\hat{i}), \mathcal{D}_{\hat{\mathbb{I}}}(\hat{i}), \mathcal{D}_{\hat{\mathbb{F}}}(\hat{i}) : \hat{I} \rightarrow [0, 1]$ and $0 \leq (\mathcal{D}_{\hat{\mathbb{T}}}(\hat{i}))^2 + (\mathcal{D}_{\hat{\mathbb{I}}}(\hat{i}))^2 + (\mathcal{D}_{\hat{\mathbb{F}}}(\hat{i}))^2 \leq 2$ where $\mathcal{D}(\hat{i})$ denotes the degree of membership, $\mathcal{D}_{\hat{\mathbb{I}}}(\hat{i})$ denotes the degree of indeterminacy and $\mathcal{D}_{\hat{\mathbb{F}}}(\hat{i})$ denotes the degree of non-membership.

Definition 2.3[10] Let $\hat{I} \neq \phi$, a Pythagorean Neutrosophic Cubic Set (PNCS), having a form,

$\hat{\mathbb{D}}_{PNCS} = \{(\hat{i}, \hat{\mathbb{D}}_{PNIVS}(\hat{i}), \varpi_{PNS}(\hat{i})) : \hat{i} \in \hat{I}\}$ where $\hat{\mathbb{D}}_{PNIVS}(\hat{i})$ represent the Pythagorean Neutrosophic Interval valued set in $\hat{I}$. $\varpi_{PNS}(\hat{i})$ represent the Pythagorean Neutrosophic Set. PNCS can be denoted as a pair $\hat{\mathbb{D}}_{PNCS} = (\hat{\mathbb{D}}, \varpi)$.

Definition 2.4[10] Let $\hat{I} \neq \phi$. A PNCS $\hat{\mathbb{D}}_{PNCS} = (\hat{\mathbb{D}}_{PNIVS}, \varpi_{PNS})$ in $\hat{I}$ is said to be Internal Pythagorean Neutrosophic Cubi set (IPNCS) if $\hat{\mathbb{D}}_{PNIVS}^-(\hat{i}) \leq \varpi_{PNS}(\hat{i}) \leq \hat{\mathbb{D}}_{PNIVS}^+(\hat{i}) \forall \hat{i} \in \hat{I}$

Definition 2.5[10] Let $\hat{I} \neq \phi$. APNCS $\hat{\mathbb{D}}_{PNCS} = (\hat{\mathbb{D}}_{PNIVS}, \varpi_{PNS})$ in $\hat{I}$ is said to be External Pythagorean Neutrosophic Cubi set (EPNCS) if $\varpi_{PNS}(\hat{i}) \notin (\hat{\mathbb{D}}_{PNIVS}^-(\hat{i}), \hat{\mathbb{D}}_{PNIVS}^+(\hat{i})) \forall \hat{i} \in \hat{I}$

PNCS approach on Operations & Ranking technique

Definition 3.1 If $\hat{\mathbb{R}}_{PNCS} = (\hat{\mathcal{R}}_{PNIVS}, \varpi_{PNS})$ and $\hat{\mathbb{S}}_{PNCS} = (\hat{\mathcal{S}}_{PNIVS}, \varrho_{PNS})$ be two PNCSs. Then there are the following operations.

- 1) The complement of PNCS $\hat{\mathbb{S}}_{PNCS} = (\hat{\mathcal{S}}, \varpi)$ is $\hat{\mathbb{S}}_{PNCS}^c = (\hat{\mathcal{S}}^c, \varpi^c)$. $\hat{\mathcal{S}}^c = \{(\hat{\mathcal{S}}_{PNCS}, [\mathbb{F}_{\hat{\mathcal{S}}}^-(\hat{\mathcal{S}}_{PNCS}), \mathbb{F}_{\hat{\mathcal{S}}}^+(\hat{\mathcal{S}}_{PNCS})], [1 - \mathbb{I}_{\hat{\mathcal{S}}}^-(\hat{\mathcal{S}}_{PNCS}), 1 - \mathbb{I}_{\hat{\mathcal{S}}}^+(\hat{\mathcal{S}}_{PNCS})], [\mathbb{T}_{\hat{\mathcal{S}}}^-(\hat{\mathcal{S}}_{PNCS}), \mathbb{T}_{\hat{\mathcal{S}}}^+(\hat{\mathcal{S}}_{PNCS})]) : \hat{\mathcal{S}}_{PNCS} \in \hat{\mathcal{D}}\}$
- 2) P-order of PNCS $\hat{\mathbb{R}}_{PNCS} \subseteq_{\hat{\mathcal{P}}} \hat{\mathbb{S}}_{PNCS} \Leftrightarrow \hat{\mathcal{R}}_{PNCS} \subseteq \hat{\mathcal{S}}_{PNCS}$ and $\varpi(\hat{\mathcal{R}}_{PNCS}) \leq \varrho(\hat{\mathcal{S}}_{PNCS})$
- 3) Equality of PNCS $\hat{\mathbb{R}}_{PNCS} = \hat{\mathbb{S}}_{PNCS} \Leftrightarrow \hat{\mathcal{R}}_{PNCS} = \hat{\mathcal{S}}_{PNCS}$ and $\varpi(\hat{\mathcal{R}}_{PNCS}) = \varrho(\hat{\mathcal{S}}_{PNCS})$
- 4) The Union of PNCS

$$\hat{\mathbb{R}}_{PNCS} \cup \hat{\mathbb{S}}_{PNCS} = \left\{ \left(\hat{\mathcal{S}}_{PNCS}, \left(\max(\mathbb{T}_{\hat{\mathcal{R}}}(\hat{\mathcal{S}}_{PNCS}), \mathbb{T}_{\hat{\mathcal{S}}}(\hat{\mathcal{S}}_{PNCS})), \min(\mathbb{I}_{\hat{\mathcal{R}}}(\hat{\mathcal{S}}_{PNCS}), \mathbb{I}_{\hat{\mathcal{S}}}(\hat{\mathcal{S}}_{PNCS})), \min(\mathbb{F}_{\hat{\mathcal{R}}}(\hat{\mathcal{S}}_{PNCS}), \mathbb{F}_{\hat{\mathcal{S}}}(\hat{\mathcal{S}}_{PNCS}))) \right), \left(\max(\varpi_{\hat{\mathcal{R}}_{\mathbb{T}}}(\hat{\mathcal{S}}_{PNCS}), \varpi_{\hat{\mathcal{S}}_{\mathbb{T}}}(\hat{\mathcal{S}}_{PNCS})), \min(\varpi_{\hat{\mathcal{R}}_{\mathbb{I}}}(\hat{\mathcal{S}}_{PNCS}), \varpi_{\hat{\mathcal{S}}_{\mathbb{I}}}(\hat{\mathcal{S}}_{PNCS})), \min(\varpi_{\hat{\mathcal{R}}_{\mathbb{F}}}(\hat{\mathcal{S}}_{PNCS}), \varpi_{\hat{\mathcal{S}}_{\mathbb{F}}}(\hat{\mathcal{S}}_{PNCS}))) \right) : \hat{\mathcal{S}}_{PNCS} \in \hat{\mathcal{D}} \right\}$$

- 5) The intersection of PNCS

$$\hat{\mathbb{R}}_{PNCS} \cap \hat{\mathbb{S}}_{PNCS} = \left\{ \left(\hat{\mathcal{S}}_{PNCS}, \left(\min(\mathbb{T}_{\hat{\mathcal{R}}}(\hat{\mathcal{S}}_{PNCS}), \mathbb{T}_{\hat{\mathcal{S}}}(\hat{\mathcal{S}}_{PNCS})), \max(\mathbb{I}_{\hat{\mathcal{R}}}(\hat{\mathcal{S}}_{PNCS}), \mathbb{I}_{\hat{\mathcal{S}}}(\hat{\mathcal{S}}_{PNCS})), \max(\mathbb{F}_{\hat{\mathcal{R}}}(\hat{\mathcal{S}}_{PNCS}), \mathbb{F}_{\hat{\mathcal{S}}}(\hat{\mathcal{S}}_{PNCS}))) \right), \left(\min(\varpi_{\hat{\mathcal{R}}_{\mathbb{T}}}(\hat{\mathcal{S}}_{PNCS}), \varpi_{\hat{\mathcal{S}}_{\mathbb{T}}}(\hat{\mathcal{S}}_{PNCS})), \max(\varpi_{\hat{\mathcal{R}}_{\mathbb{I}}}(\hat{\mathcal{S}}_{PNCS}), \varpi_{\hat{\mathcal{S}}_{\mathbb{I}}}(\hat{\mathcal{S}}_{PNCS})), \max(\varpi_{\hat{\mathcal{R}}_{\mathbb{F}}}(\hat{\mathcal{S}}_{PNCS}), \varpi_{\hat{\mathcal{S}}_{\mathbb{F}}}(\hat{\mathcal{S}}_{PNCS}))) \right) : \hat{\mathcal{S}}_{PNCS} \in \hat{\mathcal{D}} \right\}$$

- 6) The addition of PNCS





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$$\hat{\mathbb{R}}_{PNCS} \oplus \hat{\mathbb{S}}_{PNCS} = \left(\langle \hat{\delta}_{PNCS}, \left(\begin{aligned} &[T_{\mathbb{R}}^-(\hat{\delta}_{PNCS}) + T_{\mathbb{S}}^-(\hat{\delta}_{PNCS}) - T_{\mathbb{R}}^-(\hat{\delta}_{PNCS})T_{\mathbb{S}}^-(\hat{\delta}_{PNCS}), T_{\mathbb{R}}^+(\hat{\delta}_{PNCS}) + T_{\mathbb{S}}^+(\hat{\delta}_{PNCS}) - T_{\mathbb{R}}^+(\hat{\delta}_{PNCS})T_{\mathbb{S}}^+(\hat{\delta}_{PNCS})], \\ &[I_{\mathbb{R}}^-(\hat{\delta}_{PNCS})I_{\mathbb{S}}^-(\hat{\delta}_{PNCS}), I_{\mathbb{R}}^+(\hat{\delta}_{PNCS})I_{\mathbb{S}}^+(\hat{\delta}_{PNCS})], [F_{\mathbb{R}}^-(\hat{\delta}_{PNCS})F_{\mathbb{S}}^-(\hat{\delta}_{PNCS}), F_{\mathbb{R}}^+(\hat{\delta}_{PNCS})F_{\mathbb{S}}^+(\hat{\delta}_{PNCS})] \end{aligned} \right) \right. \\ \left. (\omega_{\mathbb{R}_T}(\hat{\delta}_{PNCS}) + \omega_{\mathbb{S}_T}(\hat{\delta}_{PNCS}) - \omega_{\mathbb{R}_T}(\hat{\delta}_{PNCS})\omega_{\mathbb{S}_T}(\hat{\delta}_{PNCS}), \omega_{\mathbb{R}_I}(\hat{\delta}_{PNCS})\omega_{\mathbb{S}_I}(\hat{\delta}_{PNCS}), \omega_{\mathbb{R}_F}(\hat{\delta}_{PNCS})\omega_{\mathbb{S}_F}(\hat{\delta}_{PNCS})) : \hat{\delta}_{PNCS} \in \hat{\mathcal{D}} \right)$$

7) The multiplication of PNCS

$$\hat{\mathbb{R}}_{PNCS} \otimes \hat{\mathbb{S}}_{PNCS} = \left(\langle \hat{\delta}_{PNCS}, \left(\begin{aligned} &[T_{\mathbb{R}}^-(\hat{\delta}_{PNCS})T_{\mathbb{S}}^-(\hat{\delta}_{PNCS}), T_{\mathbb{R}}^+(\hat{\delta}_{PNCS})T_{\mathbb{S}}^+(\hat{\delta}_{PNCS})], \\ &[I_{\mathbb{R}_{PNCS}}^-(\hat{\delta}_{PNCS}) + I_{\mathbb{S}_{PNCS}}^-(\hat{\delta}_{PNCS}) - I_{\mathbb{R}_{PNCS}}^-(\hat{\delta}_{PNCS})I_{\mathbb{S}_{PNCS}}^-(\hat{\delta}_{PNCS}), I_{\mathbb{R}_{PNCS}}^+(\hat{\delta}_{PNCS}) + I_{\mathbb{S}_{PNCS}}^+(\hat{\delta}_{PNCS}) - I_{\mathbb{R}_{PNCS}}^+(\hat{\delta}_{PNCS})I_{\mathbb{S}_{PNCS}}^+(\hat{\delta}_{PNCS})], \\ &[F_{\mathbb{R}_{PNCS}}^-(\hat{\delta}_{PNCS}) + F_{\mathbb{S}_{PNCS}}^-(\hat{\delta}_{PNCS}) - F_{\mathbb{R}_{PNCS}}^-(\hat{\delta}_{PNCS})F_{\mathbb{S}_{PNCS}}^-(\hat{\delta}_{PNCS}), F_{\mathbb{R}_{PNCS}}^+(\hat{\delta}_{PNCS}) + F_{\mathbb{S}_{PNCS}}^+(\hat{\delta}_{PNCS}) - F_{\mathbb{R}_{PNCS}}^+(\hat{\delta}_{PNCS})F_{\mathbb{S}_{PNCS}}^+(\hat{\delta}_{PNCS})] \end{aligned} \right) \right. \\ \left. \left(\begin{aligned} &(\omega_{\mathbb{R}_T}(\hat{\delta}_{PNCS})\omega_{\mathbb{S}_T}(\hat{\delta}_{PNCS}), \omega_{\mathbb{R}_I}(\hat{\delta}_{PNCS}) + \omega_{\mathbb{S}_I}(\hat{\delta}_{PNCS}) - \omega_{\mathbb{R}_I}(\hat{\delta}_{PNCS})\omega_{\mathbb{S}_I}(\hat{\delta}_{PNCS}), \\ &\omega_{\mathbb{R}_F}(\hat{\delta}_{PNCS}) + \omega_{\mathbb{S}_F}(\hat{\delta}_{PNCS}) - \omega_{\mathbb{R}_F}(\hat{\delta}_{PNCS})\omega_{\mathbb{S}_F}(\hat{\delta}_{PNCS})) \end{aligned} \right) : \hat{\delta}_{PNCS} \in \hat{\mathcal{D}} \right)$$

8) The scalar multiplication of PNCS

$$\varrho \hat{\mathbb{R}}_{PNCS} = \varrho(\mathcal{R}, \omega) = \left(\langle \hat{\delta}_{PNCS}, [1 - (1 - T_{\mathbb{R}}^-(\hat{\delta}_{PNCS}))^{\varrho}, 1 - (1 - T_{\mathbb{R}}^+(\hat{\delta}_{PNCS}))^{\varrho}], [(I_{\mathbb{R}}^-(\hat{\delta}_{PNCS}))^{\varrho}, (I_{\mathbb{R}}^+(\hat{\delta}_{PNCS}))^{\varrho}], [(F_{\mathbb{R}}^-(\hat{\delta}_{PNCS}))^{\varrho}, (F_{\mathbb{R}}^+(\hat{\delta}_{PNCS}))^{\varrho}], \right. \\ \left. (1 - (1 - \omega_{\mathbb{R}_T}(\hat{\delta}_{PNCS}))^{\varrho}, (\omega_{\mathbb{R}_I}(\hat{\delta}_{PNCS}))^{\varrho}, (\omega_{\mathbb{R}_F}(\hat{\delta}_{PNCS}))^{\varrho}) : \hat{\delta}_{PNCS} \in \hat{\mathcal{D}} \right)$$

9) The power operation of PNCS

$$(\hat{\mathbb{R}}_{PNCS})^{\varrho} = (\mathcal{R}, \omega)^{\varrho} = \left(\langle \hat{\delta}_{PNCS}, [(T_{\mathbb{R}}^-(\hat{\delta}_{PNCS}))^{\varrho}, (T_{\mathbb{R}}^+(\hat{\delta}_{PNCS}))^{\varrho}], [1 - (1 - I_{\mathbb{R}}^-(\hat{\delta}_{PNCS}))^{\varrho}, 1 - (1 - I_{\mathbb{R}}^+(\hat{\delta}_{PNCS}))^{\varrho}], [1 - (1 - F_{\mathbb{R}}^-(\hat{\delta}_{PNCS}))^{\varrho}, 1 - (1 - F_{\mathbb{R}}^+(\hat{\delta}_{PNCS}))^{\varrho}], \right. \\ \left. ((\omega_{\mathbb{R}_T}(\hat{\delta}_{PNCS}))^{\varrho}, 1 - (1 - \omega_{\mathbb{R}_I}(\hat{\delta}_{PNCS}))^{\varrho}, 1 - (1 - \omega_{\mathbb{R}_F}(\hat{\delta}_{PNCS}))^{\varrho}) : \hat{\delta}_{PNCS} \in \hat{\mathcal{D}} \right)$$

Definition 3.2

Let $\hat{\mathbb{R}}_{PNCS} = (\hat{\mathcal{R}}_{PNCS}, \omega_{PNCS})$ be PNCS, then

$$S_{PNCS_r}(\hat{\mathbb{R}}_{PNCS}) = \frac{\left(\frac{T_{\mathbb{R}}^-(\hat{\delta}_{PNCS}) + (1 - I_{\mathbb{R}}^+(\hat{\delta}_{PNCS})) + (1 - F_{\mathbb{R}}^+(\hat{\delta}_{PNCS})) + T_{\mathbb{R}}^+(\hat{\delta}_{PNCS}) + (1 - I_{\mathbb{R}}^-(\hat{\delta}_{PNCS})) + (1 - F_{\mathbb{R}}^-(\hat{\delta}_{PNCS}))}{2} \right)}{\frac{\omega_{\mathbb{R}_T}^2(\hat{\delta}_{PNCS}) - \omega_{\mathbb{R}_I}^2(\hat{\delta}_{PNCS}) - \omega_{\mathbb{R}_F}^2(\hat{\delta}_{PNCS})}{3}} \rightarrow (1)$$

$$Q_{PNCS}(\hat{\mathbb{R}}_{PNCS}) = \frac{\left(\frac{(\min(T_{\mathbb{R}}^-(\hat{\delta}_{PNCS}) - F_{\mathbb{R}}^-(\hat{\delta}_{PNCS}), T_{\mathbb{R}}^+(\hat{\delta}_{PNCS}) - F_{\mathbb{R}}^+(\hat{\delta}_{PNCS})) + \max(T_{\mathbb{R}}^-(\hat{\delta}_{PNCS}) - F_{\mathbb{R}}^-(\hat{\delta}_{PNCS}), T_{\mathbb{R}}^+(\hat{\delta}_{PNCS}) - F_{\mathbb{R}}^+(\hat{\delta}_{PNCS})))}{2} \right)}{\omega_{\mathbb{R}_T}^2(\hat{\delta}_{PNCS}) - \omega_{\mathbb{R}_F}^2(\hat{\delta}_{PNCS})} \rightarrow (2)$$

$$C_{PNCS}(\hat{\mathbb{R}}_{PNCS}) = \frac{\left(\frac{T_{\mathbb{R}}^-(\hat{\delta}_{PNCS}) + T_{\mathbb{R}}^+(\hat{\delta}_{PNCS})}{2} + \omega_{\mathbb{R}_T}^2(\hat{\delta}_{PNCS}) \right)}{2} \rightarrow (3)$$

Equation (1), (2), (3) is called “score”, “accuracy” & “certainty” functions of PNCS

Definition 3.3

If $\mathbb{A}_{PNCS} = (\hat{\mathcal{A}}, \omega)$, $\mathbb{B}_{PNCS} = (\hat{\mathcal{B}}, \psi)$ are PNCS. Then the ranking method

1. if $S_{PNCS_r}(\mathbb{A}_{PNCS}) > S_{PNCS_r}(\mathbb{B}_{PNCS})$, then $\mathbb{A}_{PNCS} > \mathbb{B}_{PNCS}$;
2. if $S_{PNCS_r}(\mathbb{A}_{PNCS}) = S_{PNCS_r}(\mathbb{B}_{PNCS})$ and $Q_{PNCS}(\mathbb{A}_{PNCS}) > Q_{PNCS}(\mathbb{B}_{PNCS})$ then $\mathbb{B}_{PNCS} > \mathbb{A}_{PNCS}$;
3. if $S_{PNCS_r}(\mathbb{A}_{PNCS}) = S_{PNCS_r}(\mathbb{B}_{PNCS})$, $Q_{PNCS}(\mathbb{A}_{PNCS}) = Q_{PNCS}(\mathbb{B}_{PNCS})$ and $C_{PNCS}(\mathbb{B}_{PNCS}) > C_{PNCS}(\mathbb{A}_{PNCS})$ then $\mathbb{B}_{PNCS} > \mathbb{A}_{PNCS}$;
4. if $S_{PNCS_r}(\mathbb{A}_{PNCS}) = S_{PNCS_r}(\mathbb{B}_{PNCS})$, $Q_{PNCS}(\mathbb{B}_{PNCS}) = Q_{PNCS}(\mathbb{A}_{PNCS})$ and $C_{PNCS}(\mathbb{A}_{PNCS}) = C_{PNCS}(\mathbb{B}_{PNCS})$ then $\mathbb{A}_{PNCS} = \mathbb{B}_{PNCS}$.

PNCS Weighted aggregation operators

PNCS “Weighted Arithmetic Averaging Operator” (PNCWAA)



**Definition 4.11**

Let $S_{PNCS_i} = (\mathcal{S}_i, \varpi_i) = (\delta_{PNCS_i}, \langle \mathcal{S}_{TPNCS_i}, \mathcal{S}_{IPNCS_i}, \mathcal{S}_{FPNCS_i} \rangle, \langle \varpi_{TPNCS_i}, \varpi_{IPNCS_i}, \varpi_{FPNCS_i} \rangle)$ for $i = 1, 2, \dots, n$ be PNCS, PNCWAA: $\Omega^n \rightarrow \Omega$. A PNCWAA operator, $PNCWAA(s_1, s_2, \dots, s_n) = \sum_{i=1}^n w_{PNCS_i} s_{PNCS_i}$, $\rightarrow$ (4) where $w_{PNCS_d} (d = 1, 2, \dots, n) \& w_{PNCS_d} \in [0, 1]$ and $\sum_{d=1}^n w_{PNCS_d} = 1$.

Theorem 4.12

Let $S_{PNCS_i} = (\mathcal{S}_i, \varpi_i) = (\delta_{PNCS_i}, \langle \mathcal{S}_{TPNCS_i}, \mathcal{S}_{IPNCS_i}, \mathcal{S}_{FPNCS_i} \rangle, \langle \varpi_{TPNCS_i}, \varpi_{IPNCS_i}, \varpi_{FPNCS_i} \rangle)$ for $i = 1, \dots, n$ be PNCS and the value of PNCWAA operator is

$$PNCWAA(S_{PNCS_1}, S_{PNCS_2}, \dots, S_{PNCS_n}) = \left\{ \begin{aligned} & \left[1 - \prod_{d=1}^n (1 - \mathcal{S}_{TPNCS_i}^-(\delta_{PNCS_i}))^{w_d}, 1 - \prod_{d=1}^n (1 - \mathcal{S}_{TPNCS_i}^+(\delta_{PNCS_i}))^{w_d} \right], \\ & \left[\prod_{d=1}^n (\mathcal{S}_{IPNCS_i}^-(\delta_{PNCS_i}))^{w_d}, \prod_{d=1}^n (\mathcal{S}_{IPNCS_i}^+(\delta_{PNCS_i}))^{w_d} \right], \left[\prod_{d=1}^n (\mathcal{S}_{FPNCS_i}^-(\delta_{PNCS_i}))^{w_d}, \prod_{d=1}^n (\mathcal{S}_{FPNCS_i}^+(\delta_{PNCS_i}))^{w_d} \right] \} \rightarrow \\ & (1 - \prod_{d=1}^n (1 - \varpi_{TPNCS_i}(\delta_{PNCS_i}))^{w_d}, \prod_{d=1}^n (\varpi_{IPNCS_i}(\delta_{PNCS_i}))^{w_d}, \prod_{d=1}^n (\varpi_{FPNCS_i}(\delta_{PNCS_i}))^{w_d}) \end{aligned} \right\} \rightarrow$$

(5)

where w_{PNCS_i} is the weight of S_{PNCS_d}

Proof

Equation (5) can be shown using the inductive method.

1) The following outcome can be obtained using the operations of definition 3.1 when $n=2$.

$$PNCWAA(S_{PNCS_1}, S_{PNCS_2}) = w_1 S_{PNCS_1} \oplus_{PNCS} w_2 S_{PNCS_2}$$

$$= \left\{ \begin{aligned} & \left[1 - \prod_{d=1}^2 (1 - \mathcal{S}_{TPNCS_i}^-(\delta_{PNCS_i}))^{w_{PNCS_i}}, 1 - \prod_{d=1}^2 (1 - \mathcal{S}_{TPNCS_i}^+(\delta_{PNCS_i}))^{w_{PNCS_i}} \right], \\ & \left[\prod_{d=1}^2 (\mathcal{S}_{IPNCS_i}^-(\delta_{PNCS_i}))^{w_{PNCS_i}}, \prod_{d=1}^2 (\mathcal{S}_{IPNCS_i}^+(\delta_{PNCS_i}))^{w_{PNCS_i}} \right], \left[\prod_{d=1}^2 (\mathcal{S}_{FPNCS_i}^-(\delta_{PNCS_i}))^{w_{PNCS_i}}, \prod_{d=1}^2 (\mathcal{S}_{FPNCS_i}^+(\delta_{PNCS_i}))^{w_{PNCS_i}} \right] \} \rightarrow \\ & (1 - \prod_{d=1}^2 (1 - \varpi_{TPNCS_i}(\delta_{PNCS_i}))^{w_{PNCS_i}}, \prod_{d=1}^2 (\varpi_{IPNCS_i}(\delta_{PNCS_i}))^{w_{PNCS_i}}, \prod_{d=1}^2 (\varpi_{FPNCS_i}(\delta_{PNCS_i}))^{w_{PNCS_i}}) \end{aligned} \right\} \rightarrow$$

(6)

2) Equation (5) states that the following formula holds when $n=\hat{c}$:

$$PNCWAA(S_{PNCS_1}, S_{PNCS_2}, \dots, S_{PNCS_{\hat{c}}}) =$$

$$\left\{ \begin{aligned} & \left[1 - \prod_{d=\hat{1}}^{\hat{c}} (1 - \mathcal{S}_{TPNCS_i}^-(\delta_{PNCS_i}))^{w_i}, 1 - \prod_{d=\hat{1}}^{\hat{c}} (1 - \mathcal{S}_{TPNCS_i}^+(\delta_{PNCS_i}))^{w_i} \right], \\ & \left[\prod_{d=\hat{1}}^{\hat{c}} (\mathcal{S}_{IPNCS_i}^-(\delta_{PNCS_i}))^{w_i}, \prod_{d=\hat{1}}^{\hat{c}} (\mathcal{S}_{IPNCS_i}^+(\delta_{PNCS_i}))^{w_i} \right], \left[\prod_{d=\hat{1}}^{\hat{c}} (\mathcal{S}_{FPNCS_i}^-(\delta_{PNCS_i}))^{w_i}, \prod_{d=\hat{1}}^{\hat{c}} (\mathcal{S}_{FPNCS_i}^+(\delta_{PNCS_i}))^{w_i} \right] \} \rightarrow (7) \\ & (1 - \prod_{d=\hat{1}}^{\hat{c}} (1 - \varpi_{TPNCS_i}(\delta_{PNCS_i}))^{w_i}, \prod_{d=\hat{1}}^{\hat{c}} (\varpi_{IPNCS_i}(\delta_{PNCS_i}))^{w_i}, \prod_{d=\hat{1}}^{\hat{c}} (\varpi_{FPNCS_i}(\delta_{PNCS_i}))^{w_i}) \end{aligned} \right\}$$

(3) From the Def (3.1) and the Equation. (6) and (7), the outcome when $n=\hat{c}+1$ is given by:

$$PNCWAA(S_{PNCS_1}, S_{PNCS_2}, \dots, S_{PNCS_{\hat{c}}}, S_{PNCS_{\hat{c}+1}})$$

$$= \left\{ \begin{aligned} & \left[1 - \prod_{d=\hat{1}}^{\hat{c}} (1 - \mathcal{S}_{TPNCS_i}^-(\delta_{PNCS_i}))^{w_i}, 1 - \prod_{d=\hat{1}}^{\hat{c}} (1 - \mathcal{S}_{TPNCS_i}^+(\delta_{PNCS_i}))^{w_i} \right], \\ & \left[\prod_{d=\hat{1}}^{\hat{c}} (\mathcal{S}_{IPNCS_i}^-(\delta_{PNCS_i}))^{w_i}, \prod_{d=\hat{1}}^{\hat{c}} (\mathcal{S}_{IPNCS_i}^+(\delta_{PNCS_i}))^{w_i} \right], \left[\prod_{d=\hat{1}}^{\hat{c}} (\mathcal{S}_{FPNCS_i}^-(\delta_{PNCS_i}))^{w_i}, \prod_{d=\hat{1}}^{\hat{c}} (\mathcal{S}_{FPNCS_i}^+(\delta_{PNCS_i}))^{w_i} \right] \} \rightarrow \\ & (1 - \prod_{d=\hat{1}}^{\hat{c}} (1 - \varpi_{TPNCS_i}(\delta_{PNCS_i}))^{w_i}, \prod_{d=\hat{1}}^{\hat{c}} (\varpi_{IPNCS_i}(\delta_{PNCS_i}))^{w_i}, \prod_{d=\hat{1}}^{\hat{c}} (\varpi_{FPNCS_i}(\delta_{PNCS_i}))^{w_i}) \end{aligned} \right\}$$

$$\oplus_{PNCS_{\hat{c}+1}} S_{PNCS_{\hat{c}+1}}$$





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$$= \left\{ \left\langle \left[1 - \prod_{d=1}^{\ell+1} \left(1 - \mathcal{S}_{TPNCS_i}^-(\delta_{PNCS}) \right)^{w_i}, 1 - \prod_{d=1}^{\ell+1} \left(1 - \mathcal{S}_{TPNCS_i}^+(\delta_{PNCS}) \right)^{w_i} \right], \right. \right. \\ \left. \left[\prod_{d=1}^{\ell+1} \left(\mathcal{S}_{IPNCS_i}^-(\delta_{PNCS}) \right)^{w_i}, \prod_{d=1}^{\ell+1} \left(\mathcal{S}_{IPNCS_i}^+(\delta_{PNCS}) \right)^{w_i} \right], \left[\prod_{d=1}^{\ell+1} \left(\mathcal{S}_{FPNCS_i}^-(\delta_{PNCS}) \right)^{w_i}, \prod_{d=1}^{\ell+1} \left(\mathcal{S}_{FPNCS_i}^+(\delta_{PNCS}) \right)^{w_i} \right] \right\rangle \\ \left. \left\langle \left(1 - \prod_{d=1}^{\ell+1} \left(1 - \mathcal{W}_{TPNCS_i}(\delta_{PNCS}) \right)^{w_i}, \prod_{d=1}^{\ell+1} \left(\mathcal{W}_{IPNCS_i}(\delta_{PNCS}) \right)^{w_i}, \prod_{d=1}^{\ell+1} \left(\mathcal{W}_{FPNCS_i}(\delta_{PNCS}) \right)^{w_i} \right\rangle \right\}$$

Undoubtedly, the PNCWAA operator encompasses the following essential attributes:

1) Idempotency:

If $\mathcal{S}_{PNCS_i} = (\mathcal{S}_i, \mathcal{W}_i) = (\mathcal{X}, \langle \mathcal{S}_{TPNCS_i}, \mathcal{S}_{IPNCS_i}, \mathcal{S}_{FPNCS_i} \rangle, \langle \mathcal{W}_{TPNCS_i}, \mathcal{W}_{IPNCS_i}, \mathcal{W}_{FPNCS_i} \rangle) \forall i = 1, \dots, n$ be PNCS. If $\mathcal{S}_{PNCS_i}$ is equal, i.e., $\mathcal{S}_{PNCS_i} = \mathcal{S}_{PNCS} = (\mathcal{X}, \langle \mathcal{S}_{PNCS_T}, \mathcal{S}_{PNCS_I}, \mathcal{S}_{PNCS_F} \rangle, \langle \mathcal{W}_{PNCS_T}, \mathcal{W}_{PNCS_I}, \mathcal{W}_{PNCS_F} \rangle)$ for $j = 1, 2, \dots, n$, then $\text{PNCWAA}(\mathcal{S}_{PNCS_1}, \mathcal{S}_{PNCS_2}, \dots, \mathcal{S}_{PNCS_n}) = \mathcal{S}_{PNCS}$.

2) Boundedness:

Let $\mathcal{S}_{PNCS_i} = (\mathcal{S}_i, \mathcal{W}_i) = (\mathcal{X}, \langle \mathcal{S}_{TPNCS_i}, \mathcal{S}_{IPNCS_i}, \mathcal{S}_{FPNCS_i} \rangle, \langle \mathcal{W}_{TPNCS_i}, \mathcal{W}_{IPNCS_i}, \mathcal{W}_{FPNCS_i} \rangle)$ for $i = 1, \dots, n$ PNCS,

$$\begin{aligned} & \mathcal{S}_{PNCS_{\min}} \\ &= \left\langle \left[\min_{i_{PNCS}} \mathcal{S}_{PNCS_{T_i}}^-(\delta_{PNCS}), \min_{i_{PNCS}} \mathcal{S}_{PNCS_{T_i}}^+(\delta_{PNCS}) \right], \left[\max_{i_{PNCS}} \mathcal{S}_{PNCS_{I_i}}^-(\delta_{PNCS}), \max_{i_{PNCS}} \mathcal{S}_{PNCS_{I_i}}^+(\delta_{PNCS}) \right], \right. \\ & \quad \left. \left[\max_{i_{PNCS}} \mathcal{S}_{PNCS_{F_i}}^-(\delta_{PNCS}), \max_{i_{PNCS}} \mathcal{S}_{PNCS_{F_i}}^+(\delta_{PNCS}) \right] \right\rangle \\ & \quad \left\langle \min_{i_{PNCS}} \mathcal{W}_{PNCS_{T_i}}, \max_{i_{PNCS}} \mathcal{W}_{PNCS_{I_i}}, \max_{i_{PNCS}} \mathcal{W}_{PNCS_{F_i}} \right\rangle \\ & \mathcal{S}_{PNCS_{\max}} \\ &= \left\langle \left[\max_{i_{PNCS}} \mathcal{S}_{PNCS_{T_i}}^-(\delta_{PNCS}), \max_{i_{PNCS}} \mathcal{S}_{PNCS_{T_i}}^+(\delta_{PNCS}) \right], \left[\min_{i_{PNCS}} \mathcal{S}_{PNCS_{I_i}}^-(\delta_{PNCS}), \min_{i_{PNCS}} \mathcal{S}_{PNCS_{I_i}}^+(\delta_{PNCS}) \right], \right. \\ & \quad \left[\min_{i_{PNCS}} \mathcal{S}_{PNCS_{F_i}}^-(\delta_{PNCS}), \min_{i_{PNCS}} \mathcal{S}_{PNCS_{F_i}}^+(\delta_{PNCS}) \right] \right\rangle \\ & \quad \left\langle \max_{i_{PNCS}} \mathcal{W}_{PNCS_{T_i}}, \min_{i_{PNCS}} \mathcal{W}_{PNCS_{I_i}}, \min_{i_{PNCS}} \mathcal{W}_{PNCS_{F_i}} \right\rangle \end{aligned}$$

Then, there exists $\mathcal{S}_{PNCS_{\min}} \leq \text{PNCWAA}(\mathcal{S}_{PNCS_1}, \mathcal{S}_{PNCS_2}, \dots, \mathcal{S}_{PNCS_n}) \leq \mathcal{S}_{PNCS_{\max}}$.

3) Monotonicity:

Let $\mathcal{S}_{PNCS_i} = (\mathcal{S}_i, \mathcal{W}_i) = (\delta_{PNCS}, \langle \mathcal{S}_{TPNCS_i}, \mathcal{S}_{IPNCS_i}, \mathcal{S}_{FPNCS_i} \rangle, \langle \mathcal{W}_{TPNCS_i}, \mathcal{W}_{IPNCS_i}, \mathcal{W}_{FPNCS_i} \rangle)$ and $\mathcal{S}_{PNCS_i}^* = (\mathcal{S}_i^*, \mathcal{W}_i^*) = (\delta_{PNCS}, \langle \mathcal{S}_{TPNCS_i}^*, \mathcal{S}_{IPNCS_i}^*, \mathcal{S}_{FPNCS_i}^* \rangle, \langle \mathcal{W}_{TPNCS_i}^*, \mathcal{W}_{IPNCS_i}^*, \mathcal{W}_{FPNCS_i}^* \rangle)$ for $i = 1, \dots, n$ be two collection of PNCS. If $\mathcal{S}_{PNCS_i} \leq \mathcal{S}_{PNCS_i}^*$, then $\text{PNCWAA}(\mathcal{S}_{PNCS_1}, \mathcal{S}_{PNCS_2}, \dots, \mathcal{S}_{PNCS_n}) \leq \text{PNCWAA}(\mathcal{S}_{PNCS_1}^*, \mathcal{S}_{PNCS_2}^*, \dots, \mathcal{S}_{PNCS_n}^*)$.

Proof (1) Since $\mathcal{S}_{PNCS_i} = \mathcal{S}_{PNCS}$ for $i = 1, 2, \dots, n$, we have the following result:

$$\text{PNCWAA}(\mathcal{S}_{PNCS_1}, \mathcal{S}_{PNCS_2}, \dots, \mathcal{S}_{PNCS_n}) = \sum_{i=1}^n w_i \mathcal{S}_{PNCS_i}$$

$$= \left\{ \left\langle \left[1 - \prod_{d=1}^n \left(1 - \mathcal{S}_{TPNCS_i}^-(\delta_{PNCS}) \right)^{w_d}, 1 - \prod_{d=1}^n \left(1 - \mathcal{S}_{TPNCS_i}^+(\delta_{PNCS}) \right)^{w_d} \right], \right. \right. \\ \left. \left[\prod_{d=1}^n \left(\mathcal{S}_{IPNCS_i}^-(\delta_{PNCS}) \right)^{w_d}, \prod_{d=1}^n \left(\mathcal{S}_{IPNCS_i}^+(\delta_{PNCS}) \right)^{w_d} \right], \left[\prod_{d=1}^n \left(\mathcal{S}_{FPNCS_i}^-(\delta_{PNCS}) \right)^{w_d}, \prod_{d=1}^n \left(\mathcal{S}_{FPNCS_i}^+(\delta_{PNCS}) \right)^{w_d} \right] \right\rangle \\ \left. \left\langle \left(1 - \prod_{d=1}^n \left(1 - \mathcal{W}_{TPNCS_i}(\delta_{PNCS}) \right)^{w_d}, \prod_{d=1}^n \left(\mathcal{W}_{IPNCS_i}(\delta_{PNCS}) \right)^{w_d}, \prod_{d=1}^n \left(\mathcal{W}_{FPNCS_i}(\delta_{PNCS}) \right)^{w_d} \right\rangle \right\}$$

$$= (\mathcal{X}, \langle \mathcal{S}_{TPNCS}, \mathcal{S}_{IPNCS}, \mathcal{S}_{FPNCS} \rangle, \langle \mathcal{W}_{TPNCS}, \mathcal{W}_{IPNCS}, \mathcal{W}_{FPNCS} \rangle) = \mathcal{S}_{PNCS}$$

2) Since $\mathcal{S}_{PNCS_{\min}}$ is the minimum PNCS and $\mathcal{S}_{PNCS_{\max}}$ is the maximum PNCS, there is $\mathcal{S}_{PNCS_{\min}} \leq \mathcal{S}_{PNCS_i} \leq \mathcal{S}_{PNCS_{\max}}$. Thus, there exists $\sum_{i=1}^n w_i \mathcal{S}_{PNCS_{\min}} \leq \sum_{i=1}^n w_i \mathcal{S}_{PNCS_i} \leq \sum_{i=1}^n w_i \mathcal{S}_{PNCS_{\max}}$. $\mathcal{S}_{PNCS_{\min}} \leq \sum_{i=1}^n w_i \mathcal{S}_{PNCS_i} \leq \mathcal{S}_{PNCS_{\max}}$. Therefore $\mathcal{S}_{PNCS_{\min}} \leq \text{PNCWAA}(\mathcal{S}_{PNCS_1}, \mathcal{S}_{PNCS_2}, \dots, \mathcal{S}_{PNCS_n}) \leq \mathcal{S}_{PNCS_{\max}}$.

3) If $\mathcal{S}_{PNCS_i} \leq \mathcal{S}_{PNCS_i}^*$, there is $\sum_{i=1}^n w_i \mathcal{S}_{PNCS_i} \leq \sum_{i=1}^n w_i \mathcal{S}_{PNCS_i}^*$, therefore, $\text{PNCWAA}(\mathcal{S}_{PNCS_1}, \mathcal{S}_{PNCS_2}, \dots, \mathcal{S}_{PNCS_n}) \leq \text{PNCWAA}(\mathcal{S}_{PNCS_1}^*, \mathcal{S}_{PNCS_2}^*, \dots, \mathcal{S}_{PNCS_n}^*)$.

PNCS "Weighted Geometric Averaging Operator" (PNCWGA)





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Definition 4.21

If $S_{PNCs_i} = (S_i, \varpi_i) = (\delta_{PNCs_i}, \langle \mathcal{S}_{TPNCs_i}, \mathcal{S}_{IPNCs_i}, \mathcal{S}_{FPNCs_i} \rangle, \langle \varpi_{TPNCs_i}, \varpi_{IPNCs_i}, \varpi_{FPNCs_i} \rangle) \forall i = 1, 2, \dots, n$ be PNCs and PNCWGA: $\Omega_{PNCs}^n \rightarrow \Omega_{PNCs}$. A PNCWGA operator is defined as $PNCWGA(S_{PNCs_1}, S_{PNCs_2}, \dots, S_{PNCs_n}) = \sum_{i=1}^n \mathcal{S}_{PNCs_i}^{w_{PNCs_i}}, \rightarrow (8)$ where $w_i (i = 1, 2, \dots, n)$ is the weight with $w_{PNCs_i} \in [0, 1]$ and $\sum_{i=1}^n w_{PNCs_i} = 1$.

Theorem 4.22

Let $S_{PNCs_i} = (S_i, \varpi_i) = (\delta_{PNCs_i}, \langle \mathcal{S}_{TPNCs_i}, \mathcal{S}_{IPNCs_i}, \mathcal{S}_{FPNCs_i} \rangle, \langle \varpi_{TPNCs_i}, \varpi_{IPNCs_i}, \varpi_{FPNCs_i} \rangle)$ for $i = 1, \dots, n$ be PNCs, the value of PNCWGA is a PNCs,

$$PNCWGA(S_1, S_2, \dots, S_n) = \prod_{i=1}^n S_i^{w_i}$$

$$= \left\{ \begin{aligned} & \left[\prod_{d=1}^n \left(\mathcal{S}_{TPNCs_i}^-(\delta_{PNCs_i}) \right)^{w_d}, \prod_{d=1}^n \left(\mathcal{S}_{TPNCs_i}^+(\delta_{PNCs_i}) \right)^{w_d} \right], \\ & \left[1 - \prod_{d=1}^n \left(1 - \mathcal{S}_{IPNCs_i}^-(\delta_{PNCs_i}) \right)^{w_d}, 1 - \prod_{d=1}^n \left(1 - \mathcal{S}_{IPNCs_i}^+(\delta_{PNCs_i}) \right)^{w_d} \right], \left[1 - \prod_{d=1}^n \left(1 - \mathcal{S}_{FPNCs_i}^-(\delta_{PNCs_i}) \right)^{w_d}, 1 - \prod_{d=1}^n \left(1 - \mathcal{S}_{FPNCs_i}^+(\delta_{PNCs_i}) \right)^{w_d} \right], \\ & \left[\prod_{d=1}^n \left(\varpi_{TPNCs_i}(\delta_{PNCs_i}) \right)^{w_d}, 1 - \prod_{d=1}^n \left(1 - \varpi_{IPNCs_i}(\delta_{PNCs_i}) \right)^{w_d}, 1 - \prod_{d=1}^n \left(1 - \varpi_{FPNCs_i}(\delta_{PNCs_i}) \right)^{w_d} \right] \end{aligned} \right\}$$

$\rightarrow (9)$ where $w_d (d = 1, 2, \dots, n)$ is the weight of $s_d (d = 1, 2, \dots, n)$ with $w_d \in [0, 1]$ and $\sum_{d=1}^n w_d = 1$.

Proof

1) If $n = 2$, then by definition 3.1,

$$PNCWGA(S_1, S_2) = S_1^{w_1} \otimes S_2^{w_2}$$

$$= \left\{ \begin{aligned} & \left[\prod_{d=1}^2 \left(\mathcal{S}_{TPNCs_i}^-(\delta_{PNCs_i}) \right)^{w_i}, \prod_{d=1}^2 \left(\mathcal{S}_{TPNCs_i}^+(\delta_{PNCs_i}) \right)^{w_i} \right], \\ & \left[1 - \prod_{d=1}^2 \left(1 - \mathcal{S}_{IPNCs_i}^-(\delta_{PNCs_i}) \right)^{w_i}, 1 - \prod_{d=1}^2 \left(1 - \mathcal{S}_{IPNCs_i}^+(\delta_{PNCs_i}) \right)^{w_i} \right], \left[1 - \prod_{d=1}^2 \left(1 - \mathcal{S}_{FPNCs_i}^-(\delta_{PNCs_i}) \right)^{w_i}, 1 - \prod_{d=1}^2 \left(1 - \mathcal{S}_{FPNCs_i}^+(\delta_{PNCs_i}) \right)^{w_i} \right], \\ & \left[\prod_{d=1}^2 \left(\varpi_{TPNCs_i}(\delta_{PNCs_i}) \right)^{w_i}, 1 - \prod_{d=1}^2 \left(1 - \varpi_{IPNCs_i}(\delta_{PNCs_i}) \right)^{w_i}, 1 - \prod_{d=1}^2 \left(1 - \varpi_{FPNCs_i}(\delta_{PNCs_i}) \right)^{w_i} \right] \end{aligned} \right\}$$

$\rightarrow (10)$ 2) Equation (5) states that the following formula holds when $n = \hat{c}$:

$$PNCWGA(S_1, S_2, \dots, S_k) = \prod_{d=1}^{\hat{c}} S_d^{w_d}$$

$$= \left\{ \begin{aligned} & \left[\prod_{d=1}^{\hat{c}} \left(\mathcal{S}_{TPNCs_i}^-(\delta_{PNCs_i}) \right)^{w_i}, \prod_{d=1}^{\hat{c}} \left(\mathcal{S}_{TPNCs_i}^+(\delta_{PNCs_i}) \right)^{w_i} \right], \\ & \left[1 - \prod_{d=1}^{\hat{c}} \left(1 - \mathcal{S}_{IPNCs_i}^-(\delta_{PNCs_i}) \right)^{w_i}, 1 - \prod_{d=1}^{\hat{c}} \left(1 - \mathcal{S}_{IPNCs_i}^+(\delta_{PNCs_i}) \right)^{w_i} \right], \left[1 - \prod_{d=1}^{\hat{c}} \left(1 - \mathcal{S}_{FPNCs_i}^-(\delta_{PNCs_i}) \right)^{w_i}, 1 - \prod_{d=1}^{\hat{c}} \left(1 - \mathcal{S}_{FPNCs_i}^+(\delta_{PNCs_i}) \right)^{w_i} \right], \\ & \left[\prod_{d=1}^{\hat{c}} \left(\varpi_{TPNCs_i}(\delta_{PNCs_i}) \right)^{w_i}, 1 - \prod_{d=1}^{\hat{c}} \left(1 - \varpi_{IPNCs_i}(\delta_{PNCs_i}) \right)^{w_i}, 1 - \prod_{d=1}^{\hat{c}} \left(1 - \varpi_{FPNCs_i}(\delta_{PNCs_i}) \right)^{w_i} \right] \end{aligned} \right\}$$

$\rightarrow (11)$ (3) From the Def (3.1) and the Equation. (6) and (7), the outcome when $n = \hat{c} + 1$ is given by:

$$PNCWGA(S_1, S, \dots, S_k, S_{k+1})$$





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$$= \left\{ \begin{aligned} & \left[\prod_{d=1}^{\ell+1} \left(\mathcal{S}_{TPNCS_i}^- (\delta_{PNCS}) \right)^{w_i}, \prod_{d=1}^{\ell+1} \left(\mathcal{S}_{TPNCS_i}^+ (\delta_{PNCS}) \right)^{w_i} \right], \\ & \left[1 - \prod_{d=1}^{\ell+1} \left(1 - \mathcal{S}_{IPNCS_i}^- (\delta_{PNCS}) \right)^{w_i}, 1 - \prod_{d=1}^{\ell+1} \left(1 - \mathcal{S}_{IPNCS_i}^+ (\delta_{PNCS}) \right)^{w_i} \right] \\ & , \left[1 - \prod_{d=1}^{\ell+1} \left(1 - \mathcal{S}_{FPNCS_i}^- (\delta_{PNCS}) \right)^{w_i}, 1 - \prod_{d=1}^{\ell+1} \left(1 - \mathcal{S}_{FPNCS_i}^+ (\delta_{PNCS}) \right)^{w_i} \right] \\ & \left(\prod_{d=1}^{\ell+1} \left(\omega_{TPNCS_i} (\delta_{PNCS}) \right)^{w_i}, 1 - \prod_{d=1}^{\ell+1} \left(1 - \omega_{IPNCS_i} (\delta_{PNCS}) \right)^{w_i}, 1 - \prod_{d=1}^{\ell+1} \left(1 - \omega_{FPNCS_i} (\delta_{PNCS}) \right)^{w_i} \right) \end{aligned} \right\}$$

1) Idempotency:

Let $\mathcal{S}_{PNCS_i} = (\mathcal{S}_i, \omega_i) = (\delta_{PNCS}, \langle \mathcal{S}_{TPNCS_i}, \mathcal{S}_{IPNCS_i}, \mathcal{S}_{FPNCS_i} \rangle, \langle \omega_{TPNCS_i}, \omega_{IPNCS_i}, \omega_{FPNCS_i} \rangle)$ for $i = 1, \dots, n$ be a collection of PNCS. If $\mathcal{S}_{PNCS_i}$ is equal, i.e., $\mathcal{S}_{PNCS_i} = \mathcal{S}_{PNCS} = (x, \langle \mathcal{S}_T, \mathcal{S}_I, \mathcal{S}_F \rangle, \langle \omega_T, \omega_I, \omega_F \rangle)$ for $j = 1, 2, \dots, n$, then $PNCWGA(\mathcal{S}_{PNCS_1}, \mathcal{S}_{PNCS_2}, \dots, \mathcal{S}_{PNCS_n}) = \mathcal{S}_{PNCS}$.

2) Boundedness:

Let $\mathcal{S}_{PNCS_i} = (\mathcal{S}_i, \omega_i) = (x, \langle \mathcal{S}_{TPNCS_i}, \mathcal{S}_{IPNCS_i}, \mathcal{S}_{FPNCS_i} \rangle, \langle \omega_{TPNCS_i}, \omega_{IPNCS_i}, \omega_{FPNCS_i} \rangle)$ for $i = 1, \dots, n$ be PNCS,

$$\mathcal{S}_{PNCS_{min}} = \left\{ \begin{aligned} & \left(\delta_{PNCS}, \left[\min_d \mathcal{S}_{PNCS_{T_i}}^- (\delta_{PNCS}), \min_d \mathcal{S}_{PNCS_{T_i}}^+ (\delta_{PNCS}) \right], \left[\max_d \mathcal{S}_{PNCS_{I_d}}^- (\delta_{PNCS}), \max_d \mathcal{S}_{PNCS_{I_d}}^+ (\delta_{PNCS}) \right], \right. \\ & \left. \left[\max_d \mathcal{S}_{PNCS_{F_d}}^- (\delta_{PNCS}), \max_d \mathcal{S}_{PNCS_{F_d}}^+ (\delta_{PNCS}) \right] \right. \\ & \left. \langle \min_d \omega_{PNCS_{T_d}}, \max_d \omega_{PNCS_{I_d}}, \max_d \omega_{PNCS_{F_d}} \rangle \right) \end{aligned} \right\}$$

$$\mathcal{S}_{PNCS_{max}} = \left\{ \begin{aligned} & \left(\delta_{PNCS}, \left[\max_{i_{PNCS}} \mathcal{S}_{PNCS_{T_i}}^- (\delta_{PNCS}), \max_{i_{PNCS}} \mathcal{S}_{PNCS_{T_i}}^+ (\delta_{PNCS}) \right], \left[\min_{i_{PNCS}} \mathcal{S}_{PNCS_{I_i}}^- (\delta_{PNCS}), \min_{i_{PNCS}} \mathcal{S}_{PNCS_{I_i}}^+ (\delta_{PNCS}) \right], \right. \\ & \left. \left[\min_{i_{PNCS}} \mathcal{S}_{PNCS_{F_i}}^- (\delta_{PNCS}), \min_{i_{PNCS}} \mathcal{S}_{PNCS_{F_i}}^+ (\delta_{PNCS}) \right] \right. \\ & \left. \langle \max_{i_{PNCS}} \omega_{PNCS_{T_i}}, \min_{i_{PNCS}} \omega_{PNCS_{I_i}}, \min_{i_{PNCS}} \omega_{PNCS_{F_i}} \rangle \right) \end{aligned} \right\}$$

Then, there exists $\mathcal{S}_{PNCS_{min}} \leq PNCWGA(\mathcal{S}_{PNCS_1}, \mathcal{S}_{PNCS_2}, \dots, \mathcal{S}_{PNCS_n}) \leq \mathcal{S}_{PNCS_{max}}$.

3) Monotonicity:

Let $\mathcal{S}_{PNCS_i} = (\mathcal{S}_i, \omega_i) = (\delta_{PNCS}, \langle \mathcal{S}_{TPNCS_i}, \mathcal{S}_{IPNCS_i}, \mathcal{S}_{FPNCS_i} \rangle, \langle \omega_{TPNCS_i}, \omega_{IPNCS_i}, \omega_{FPNCS_i} \rangle)$ and $\mathcal{S}_{PNCS_i}^* = (\mathcal{S}_i^*, \omega_i^*) = (\delta_{PNCS}, \langle \mathcal{S}_{TPNCS_i}^*, \mathcal{S}_{IPNCS_i}^*, \mathcal{S}_{FPNCS_i}^* \rangle, \langle \omega_{TPNCS_i}^*, \omega_{IPNCS_i}^*, \omega_{FPNCS_i}^* \rangle)$ for $i = 1, \dots, n$ be two collection of PNCS. If $\mathcal{S}_{PNCS_i} \leq \mathcal{S}_{PNCS_i}^*$, then $PNCWGA(\mathcal{S}_{PNCS_1}, \mathcal{S}_{PNCS_2}, \dots, \mathcal{S}_{PNCS_n}) \leq PNCWGA(\mathcal{S}_{PNCS_1}^*, \mathcal{S}_{PNCS_2}^*, \dots, \mathcal{S}_{PNCS_n}^*)$.

The qualities of the PNCWGA operator, which are omitted here, can be shown in the same way that the aforementioned properties for the PNCWAA operator were.

MADM for PNCWAA or PNCWGA operators

In the PNC context, PNCWAA or PNCWGA, using an strategy for ranking for PNCS, we can deal with MADM challenging situations. For MADM problem, let $M_{PNCS} = \{M_{PNCS_1}, M_{PNCS_2}, \dots, M_{PNCS_m}\}$ and $S = \{S_{PNCS_1}, S_{PNCS_2}, \dots, S_{PNCS_n}\}$. $\mathcal{S}_{PNCS_i} = (\mathcal{S}_i, \omega_i) = (\delta_{PNCS}, \langle \mathcal{S}_{TPNCS_i}, \mathcal{S}_{IPNCS_i}, \mathcal{S}_{FPNCS_i} \rangle, \langle \omega_{TPNCS_i}, \omega_{IPNCS_i}, \omega_{FPNCS_i} \rangle)$. The PNCS choice matrix can be utilised constructed by $M_{PNCS} = (S_{PNCS_{ij}})_{m \times n}$. The weight array for each attribute is consequently provided by. In this situation, the method used to make decisions has been explained in the form of

Step 1 Use Eqs. (5) or (9) to get the overall attribute values of $s_{PNCS_i} = PNCWAA(S_{PNCS_{i1}}, S_{PNCS_{i2}}, \dots, S_{PNCS_{in}})$

or $s_{PNCS_i} = PNCWGA(S_{PNCS_{i1}}, S_{PNCS_{i2}}, \dots, S_{PNCS_{in}})$ ($i = 1, 2, \dots, m$) for the alternative M_i ($i = 1, 2, \dots, m$)

Step 2 By using Eq (1) we have to calculate the score values of $S_{PNCS_r}(s_{PNCS_i})$

Step 3 Rank the alternatives according to the ranking method of PNCS in Def 3.2 and select the best one.

Step 4 End.

An exemplary case

An investment firm intends on investing an adequate amount of resources in several sorts of mobile phones. The viewfinder offers four brands and we need to choose the best one out of that. a) M_{PNCS_1} -Redmi; b) M_{PNCS_2} -Motto; c)





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M_{PNCS_3} - Vivo; d) M_{PNCS_4} - Samsung. The criteria for assessment for every option vary depending on three attributes; a) S_1 -battery; b) S_2 - is the storage; c) S_3 -display.

The weight vector $\mathfrak{W}_{PNCS} = (.35, .32, .4)$. In order to use the PNCS form, the person with expertise or authority must evaluate each of the possibilities in light of the three previously indicated criteria. The PNCS decision matrix that follows can thus be created:

$$M_{PNCS} = (S_{ij})_{4 \times 3}$$

$$= \begin{pmatrix} ([0.7, 0.8], [0.1, 0.2], [0.1, 0.2]), ([0.8, 0.1, 0.2]), ([0.6, 0.7], [0.1, 0.2], [0.1, 0.3]), ([0.7, 0.1, 0.2]), ([0.3, 0.4], [0.6, 0.7], [0.7, 0.8]), ([0.3, 0.7, 0.8]) \\ ([0.4, 0.6], [0.2, 0.3], [0.1, 0.4]), ([0.6, 0.2, 0.2]), ([0.5, 0.6], [0.2, 0.3], [0.3, 0.4]), ([0.6, 0.3, 0.4]), ([0.3, 0.5], [0.7, 0.8], [0.6, 0.7]), ([0.4, 0.8, 0.7]) \\ ([0.5, 0.6], [0.1, 0.3], [0.2, 0.4]), ([0.6, 0.2, 0.3]), ([0.5, 0.6], [0.1, 0.3], [0.2, 0.4]), ([0.6, 0.2, 0.3]), ([0.2, 0.4], [0.7, 0.8], [0.8, 0.9]), ([0.3, 0.8, 0.9]) \\ ([0.6, 0.8], [0.1, 0.2], [0.2, 0.3]), ([0.7, 0.1, 0.2]), ([0.6, 0.7], [0.1, 0.2], [0.2, 0.3]), ([0.6, 0.1, 0.2]), ([0.3, 0.4], [0.6, 0.7], [0.8, 0.9]), ([0.3, 0.6, 0.9]) \end{pmatrix}$$

Step 1 Using Equation (5) $PNCWAA(S_{PNCS_{i_1}}, S_{PNCS_{i_2}}, S_{PNCS_{i_3}})(i = 1, 2, 3, 4)$ for $M_{PNCS_i}(i = 1, 2, 3, 4)$:

$$S_{PNCS_1} = ([0.4923, 0.6798], [0.1792, 0.4025], [0.3030, 0.5099]), ([0.642, 0.303, 0.417])$$

$$S_{PNCS_2} = ([0.6419, 0.891], [0.1711, 0.2911], [0.3030, 0.4170]), ([0.7055, 0.1711, 0.3141])$$

$$S_{PNCS_3} = ([0.4801, 0.7218], [0.2911, 0.4025], [0.2598, 0.4314]), ([0.6795, 0.3535, 0.3789])$$

$$S_{PNCS_4} = ([0.7056, 0.8907], [0.1711, 0.2911], [0.1782, 0.3535]), ([0.8561, 0.1792, 0.3030])$$

Step 2 Using Equation (1) $S_{PNCS_r}(S_{PNCS_i})(i = 1, 2, 3, 4)$:

$$S_{PNCS_r}(S_{PNCS_1}) = 0.3395, S_{PNCS_r}(S_{PNCS_2}) = 0.4236, S_{PNCS_r}(S_{PNCS_3}) = 0.3503, S_{PNCS_r}(S_{PNCS_4}) = 0.5258$$

Step 3 According to the score values $S_{PNCS_r}(S_{PNCS_4}) > S_{PNCS_r}(S_{PNCS_2}) > S_{PNCS_r}(S_{PNCS_3}) > S_{PNCS_r}(S_{PNCS_1})$, the ranking order is $M_{PNCS_4} > M_{PNCS_2} > M_{PNCS_3} > M_{PNCS_1}$, the best brand to invest is M_{PNCS_4} i.e) Samsung.

Now using PNCWGA operator,

Step 1 Using Equation (9) $PNCWGA(S_{PNCS_{i_1}}, S_{PNCS_{i_2}}, S_{PNCS_{i_3}})(i = 1, 2, 3, 4)$ for $M_i(i = 1, 2, 3, 4)$:

$$S_{PNCS_1} = ([0.3797, 0.5312], [0.3751, 0.5198], [0.5309, 0.7735]), ([0.4872, 0.5039, 0.6094])$$

$$S_{PNCS_2} = ([0.4872, 0.6497], [0.3123, 0.4516], [0.5308, 0.7264]), ([0.5119, 0.3123, 0.6462])$$

$$S_{PNCS_3} = ([0.3993, 0.5679], [0.4516, 0.6121], [0.3991, 0.5851]), ([0.5311, 0.5751, 0.5447])$$

$$S_{PNCS_4} = ([0.5119, 0.6175], [0.3122, 0.4394], [0.3751, 0.5751]), ([0.5664, 0.3749, 0.5308])$$

Step 2 Using Equation (1) $S_{PNCS_r}(s_i)(i = 1, 2, 3, 4)$:

$$S_{PNCS_r}(S_{PNCS_1}) = 0.1170, S_{PNCS_r}(S_{PNCS_2}) = 0.2176, S_{PNCS_r}(S_{PNCS_3}) = 0.0712, S_{PNCS_r}(S_{PNCS_4}) = 0.2687$$

Step 3 According to the score values $S_{PNCS_r}(S_{PNCS_4}) > S_{PNCS_r}(S_{PNCS_2}) > S_{PNCS_r}(S_{PNCS_1}) > S_{PNCS_r}(S_{PNCS_3})$, the ranking order is $M_{PNCS_4} > M_{PNCS_2} > M_{PNCS_1} > M_{PNCS_3}$. The best brand to choose is M_{PNCS_4} i.e) Samsung. Therefore, the brand Samsung is the best one among other all. It is obvious that the two ways of ranking enquiries and the best answers are identical based on the PNCWAA or PNCWGA operator for this MADM problem. The decision-making process based on the two operators of consolidation is dependable, as this suggests.

CONCLUSION

This work suggested certain basic PNCS operations, including the 'score', 'accuracy', & 'certainty' functions, as well as the PNCS sorting setup. Subsequently, we created the PNCWAA and PNCWGA processors for assembling PNCS and their personality traits. Of even greater significance, we created a MADM technique that uses the PNCWAA or PNCWGA operator and PNCS assessing approaches to solve the MADM problem and accepting PNCS data. At long last, a demonstrate scenario relating to the selection problem for opportunities for investment was shown demonstrate the application and the sustainability of the proposed MADM method in a PNCS the surroundings.

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RESEARCH ARTICLE

Development, Formulation, and Evaluation of Antifungal Ketoconazole Emulgel for Enhanced Topical Delivery

Rohini Kadam^{1*}, Yogendra Malviya² and Vikas Jain³

¹Research Scholar, Department of Pharmacy, Mahakal Institute of Pharmaceutical Studies, Ujjain, (Affiliated to Rajiv Gandhi Proudyogiki Vishwavidyalaya, Bhopal), Madhya Pradesh, India.

²Associate Professor, Department of Pharmacy, Mahakal Institute of Pharmaceutical Studies, Ujjain, (Affiliated to Rajiv Gandhi Proudyogiki Vishwavidyalaya, Bhopal), Madhya Pradesh, India.

³Principal, Department of Pharmacy, Mahakal Institute of Pharmaceutical Studies, Ujjain, (Affiliated to Rajiv Gandhi Proudyogiki Vishwavidyalaya, Bhopal), Madhya Pradesh, India.

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*Address for Correspondence

Rohini Kadam

Research Scholar,

Department of Pharmacy,

Mahakal Institute of Pharmaceutical Studies, Ujjain,

(Affiliated to Rajiv Gandhi Proudyogiki Vishwavidyalaya, Bhopal),

Madhya Pradesh, India.

E.Mail: rohinikadam586@gmail.com



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ABSTRACT

The current study set out to address the drawbacks of traditional topical administration methods by creating and testing a topical emulgel formulation containing the broad-spectrum antifungal drug ketoconazole. By combining the benefits of gels and emulsions, emulgels are innovative drug delivery methods that offer improved stability, spreadability, and controlled drug release. Using different amounts of oil, surfactants, and gelling agents like Carbopol 934, many formulations were created. Physical appearance, pH, viscosity, spreadability, drug content, in vitro drug release, and antifungal effectiveness against *Aspergillus niger* and *Candida albicans* were all evaluated for the prepared emulgels. The improved batch showed the best antifungal efficacy, prolonged drug release, and favorable physicochemical characteristics among the evaluated formulations. According to this study, ketoconazole emulgel may be a useful substitute for topical therapy of superficial fungal infections. This study aims to develop and assess an antifungal emulgel based on ketoconazole for efficient topical administration. In order to preserve treatment efficacy against common fungal pathogens including *Candida albicans* and *Aspergillus niger*, the research attempts to improve medication solubility, skin penetration, and sustained



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release. The study also aims to evaluate the new formulation's physicochemical characteristics, in vitro drug release, and antifungal activity.

Keywords: Emulgel, Ketoconazole, Topical drug delivery, antifungal activity.

INTRODUCTION

Fungal Infections: Prevalence and Clinical Relevance- Fungal infections, sometimes referred to as mycoses, pose a serious threat to world health, especially in tropical and subtropical areas where humidity and heat foster the growth of fungi. Among the most prevalent skin conditions in the world are superficial fungal infections, which include tinea versicolor, candidiasis, and dermatophytosis. The World Health Organization (WHO) estimates that 20–25% of the world's population is afflicted by cutaneous fungal infections at any given moment, and that over 1 billion individuals experience superficial fungal diseases each year (WHO, 2023) [1]. In clinical terms, if superficial fungal infections are not treated, they may result in pain, itching, inflammation, and subsequent bacterial infections. People who are immunocompromised, such as those with diabetes, HIV/AIDS, or chemotherapy, are more susceptible to opportunistic fungal infections, which can spread throughout the body and prove fatal. The need for novel formulations like emulgels that can enhance drug penetration, efficacy, and patient compliance is urgent given the rising resistance to traditional antifungal treatments and the scarcity of efficient topical delivery systems.[2]

Topical Drug Delivery System (TDDS)

Pharmaceutical formulations known as topical drug delivery systems (TDDS) are applied topically to the skin in order to administer medications at or close to the site of action. Localized skin diseases like infections, inflammation, and other dermatological illnesses are frequently treated with this method. Bypassing hepatic first-pass metabolism, lowering systemic adverse effects, increasing patient compliance, and enabling targeted medication action are just a few of the many benefits that TDDS provides.[3]. Because the stratum corneum, the skin's outermost layer, acts as a strong barrier to drug penetration, TDDS has drawbacks despite these advantages. For medications that are lipophilic or poorly soluble in water, such the commonly used antifungal medicine ketoconazole, the problem is more severe.[4]. Novel drug delivery methods, such as emulgels, have drawn interest in order to overcome these constraints. Emulgels are hybrid systems made up of an emulsion (water-in-oil or oil-in-water) mixed with a gel foundation, usually with the use of gelling agents such as Carbopol 940.[5]. This combination improves the consistency of the formulation and the solubility of the medicine, which makes it perfect for topical application.[6]

While the emulsion increases the solubility and bioavailability of hydrophobic medications, the gel component gives the product a non-greasy feel and promotes spreadability.[7]. Additionally, emulgels improve drug residence duration on the skin, promote drug penetration through the skin barrier, and offer controlled and prolonged drug release. Because of these properties, emulgels are particularly useful in treating fungal infections as dermatophytosis and candidiasis, where effective penetration and extended contact are crucial.[8]

Ketoconazole

An imidazole derivative, ketoconazole is a broad-spectrum antifungal medication that is applied topically and taken systemically to treat a variety of fungal infections. Depending on the microorganism and concentration, it can have either fungistatic or fungicidal effects. Inhibiting the cytochrome P450-dependent enzyme lanosterol 14 α -demethylase, which is necessary for the manufacture of ergosterol, a crucial component of the fungal cell membrane, is how ketoconazole works. Increased membrane permeability and, eventually, cell death result from this disruption [9][10]. Ketoconazole is more frequently used in topical formulations including creams, shampoos, and gels to treat dermatophytosis, candidiasis, seborrhoeic dermatitis, and pityriasis versicolour because of its poor water solubility and high hepatic metabolism when taken orally. However, traditional topical treatments could have drawbacks such low medication absorption, oily texture, and decreased patient adherence[11].



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To get around these problems, new delivery methods like emulgels have been investigated recently. Emulgels give lipophilic medications like ketoconazole better solubility and penetration while also offering a stable, non-greasy, and spreadable medium for topical treatment.^[12]

MATERIAL AND METHODS

MATERIALS

Ketoconazole (gift sample, Super formulations Laboratories Pvt. Ltd., Ujjain) served as the model drug, carbopol 934 as (Gelling agent), TEA as (pH adjuster), methyl paraben as (preservative), propyl paraben as (preservative), tween 20, span 20, liquid paraffin, and procured from Institutional Laboratory Facilities. All chemicals and reagents used were of analytical grade and distilled water was used throughout the study.^{[13][14]}

Methods

Preparation of Emulgel - The ketoconazole emulgel was made by a two-step process that included making an emulsion and then adding it to a gel foundation. This process was altered from methods that had been previously documented in studies.

Emulsion Preparation

Ketoconazole was dissolved in liquid paraffin to create the oil phase, and then the lipophilic surfactant Span 80 was added. The temperature of this mixture reached 70°C. Water, Tween 80, and the preservatives methylparaben and propylparaben made up the aqueous phase, which was heated independently to the same temperature. To create a stable oil-in-water (O/W) emulsion, the aqueous phase was gradually added to the oil phase while being continuously stirred with a mechanical stirrer set at 1500 rpm for 15 minutes.^{[15][16]}

Gel base Preparation

Carbopol 940 was dissolved in distilled water and let to swell overnight to create a 1% w/w gel base. Triethanolamine (TEA) was used to bring the gel's pH down to 5.5–6.0 while swirling constantly to create a transparent gel.^[17]

Emulsion Incorporation into Gel Base

To prevent air entrapment, the produced emulsion was slowly stirred into the gel base at a 1:1 ratio. Until it was evaluated further, the finished formulation was kept at room temperature in a closed container.

Evaluation of Emulgel

Physical Appearance

The emulgel's colour, homogeneity, consistency, and phase separation were examined visually.

Measurement of pH

At room temperature, 1 g of emulgel was dissolved in 100 mL of distilled water to determine the formulation's pH by digital pH meter.^[18]

Spreadability

The slide and drag method was used to determine spreadability. The emulgel was positioned between two glass slides, and a regular weight was left to rest on the top slide. It was noted how long it took the upper slide to travel a certain distance.

Determination of Drug Content

To find the amount of ketoconazole, one gramme of the emulgel was dissolved in methanol, filtered, and examined with a UV-Visible spectrophotometer set to 254–260 nm.^[19]



**Rohini Kadam et al.,*****In vitro* drug Release Study**

A Franz diffusion cell was utilised to assess drug release. The donor and receptor compartments were separated by a cellophane membrane that had been soaked in phosphate buffer (pH 5.5 or 7.4). Twenty millilitres of buffer were added to the receptor compartment,[20]. which was then kept at $37 \pm 0.5^\circ\text{C}$ and agitated at 100 rpm. At regular intervals, samples were taken out and subjected to UV spectrophotometry analysis.[21]

Study of stability

The emulgel was stored for three months at ambient temperature (25°C), in a refrigerator (4°C), and at accelerated circumstances ($40^\circ\text{C} \pm 2^\circ\text{C}$ / 75% RH) in order to conduct stability tests. Changes in the formulations' pH, viscosity, colour, and medication content were evaluated.[22]

RESULTS AND DISCUSSION**Preformulation studies-**

Melting point- Ketoconazole's melting point was measured using capillary methods. At 150°C , ketoconazole began to melt, and at 152°C , it was fully melted.

Measurement of λ max by UV spectroscopy-

The lambda max (wavelength of maximum absorbance) for ketoconazole is typically reported as 244 nm.

Solubility**Table 2: Results of solubility studies of Ketoconazole in different solvents****Drug-excipients compatibility (FTIR)-**

No interaction of ketoconazole with excipients was found in FTIR of blend (1:1). The ketoconazole peaks remained unchanged and were identified as follows:

- 3587 cm^{-1} : O-H stretch
- 2875 cm^{-1} : N-H stretch
- 1410 cm^{-1} : C-H bend
- 659 cm^{-1} : C=C bend

Calibration curve-

Table 3: Results of Calibration curve of Ketoconazole in PBS 7.4pH

Formulation Development of Emulgel of ketoconazole-

Table 4: Formulation of batches using Central composite design

FTIR spectra interpretation of Drug and excipients-**Physical Appearance**

All formulations (F1–F9) exhibited a white, homogeneous, and smooth appearance. This uniformity suggests that the emulsification and gelation processes were successful and the formulations are visually stable. The combination of Carbopol and Guar Gum in various ratios did not lead to any visible phase separation or clumping, which is indicative of good formulation stability and compatibility between the gelling agents.

pH:

The pH values ranged from 6.72 to 6.84, all of which are within the skin-friendly range (approximately 4.5–7.5). These pH values suggest that the formulations are safe for topical application, minimizing the risk of irritation. There are only slight variations in the pH values across the formulations, which might be due to the different concentrations of Carbopol and Guar Gum, though they remain close to neutral, suitable for dermal use.



**Rohini Kadam et al.,****Spreadability:**

Spreadability is an important parameter for topical formulations, as it impacts the ease of application on the skin. The spreadability of the formulations ranged from 22.01 to 37.21. The formulation with the highest spreadability, F6 (37.21), contains 2.31% Carbopol and 1.25% Guar Gum, which likely provides a more fluid consistency, making it easier to spread over the skin. On the other hand, F5 (22.01), with lower Carbopol and higher Guar Gum concentrations, showed the lowest spreadability. The spreadability appears to increase with higher Carbopol content, suggesting that Carbopol contributes to better spreadability due to its ability to form smoother, more fluid gels.

Viscosity:

Viscosity is a critical factor for determining the consistency and texture of an emulgel. The viscosity of the formulations ranged from 5,650 to 12,226 cP. The highest viscosity was observed in F6 (12,226 cP), which contained the highest concentration of Carbopol (2.31%) and moderate Guar Gum (1.25%). The formulation with the lowest viscosity, F5 (5,650 cP), contained the lowest Carbopol content (0.19%) and a moderate Guar Gum concentration. This suggests that Carbopol plays a key role in increasing the viscosity, likely due to its ability to form thicker gels. As the Carbopol concentration increased, the viscosity also increased, indicating that Carbopol concentration directly influences the gel's thickness.

Drug Content

Drug content was evaluated to ensure that the emulgel formulations delivered the intended dose of ketoconazole. The drug content across all formulations ranged from 96.12% to 99.22%, which is within the acceptable range for topical formulations. The formulation F1 had the highest drug content (99.22%), while F9 had the lowest (96.12%). The variations in drug content could be attributed to differences in the gelling agents and their interactions with the drug. However, all formulations showed satisfactory drug content, ensuring effective delivery of ketoconazole to the skin.

In-vitro drug release study

The in-vitro drug release data for the ketoconazole emulgel formulations shows a range of release percentages, which indicates the release profile of the drug from each formulation. The observed values range from 84.11% to 99.05%, suggesting different release rates depending on the formulation's composition and the type and concentration of gelling agents used. Here's a detailed analysis based on the in-vitro release data:

Release Profile

The highest drug release was observed in Formulation 1 (F1), with a release of 99.05%. This suggests that this formulation has an ideal release profile, potentially allowing for a more efficient and faster delivery of ketoconazole to the target site. Formulations F2 to F6 displayed drug release percentages ranging from 86.24% to 96.15%, indicating moderate to good release rates. These formulations still offer significant release of the active ingredient, although the release is not as rapid as F1. The differences in release could be attributed to the specific ratios of Carbopol and Guar Gum, which affect the gel's consistency and its ability to release the drug.

Formulations F7 to F9 showed the lowest drug release, with percentages ranging from 84.11% to 85.15%. These formulations may have higher viscosity or more retentive characteristics, leading to a slower drug release. The lower drug release rates in these formulations could be due to more pronounced gel strength, which could slow the diffusion of ketoconazole from the gel matrix.

Impact of Carbopol and Guar Gum Concentration:

Carbopol is known to create a thicker gel matrix, which can result in slower drug release. Higher concentrations of Carbopol could lead to a more viscous gel, which may limit the diffusion of ketoconazole, leading to slower drug release.

Guar Gum is a natural gelling agent that can also impact the drug release rate by interacting with the formulation's overall rheology. A combination of Carbopol and Guar Gum affects the gel's ability to allow the drug to diffuse out,



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with higher concentrations of Guar Gum potentially increasing the gel's viscosity, which can result in slower drug release.

Release Mechanism

The release profiles suggest that the drug release from these formulations follows a controlled release pattern. This means that the drug is gradually released over time, potentially providing sustained therapeutic effects. Such formulations are particularly beneficial for treatments that require prolonged contact with the skin, like antifungal treatments, ensuring that ketoconazole remains active at the application site for extended periods.

Formulation Optimization:

Formulations with the highest release (F1) likely have a lower viscosity or a more optimal ratio of Carbopol and Guar Gum, allowing for quicker drug diffusion.

Formulations with the lowest release (F7 to F9) may have higher viscosity, which could slow down the release of ketoconazole. These formulations may be better suited for localized, prolonged release, but would not be ideal for conditions requiring fast onset of action.

Results of evaluation of emulsion

The evaluation of ketoconazole emulgel formulations containing various ratios of Carbopol 934 and Guar Gum provided valuable insights into how the concentration of these gelling agents affects the formulation's characteristics. The parameters evaluated include physical appearance, pH, spreadability, viscosity, and drug content.

CONCLUSION

Ketoconazole is an antifungal medication commonly used to treat a variety of fungal infections, including skin and systemic infections. It works by inhibiting the synthesis of ergosterol, an essential component of fungal cell membranes. Ketoconazole belongs to BCS (Biopharmaceutics Classification System) Class II, meaning it has low solubility but high permeability. This class of drugs can benefit from formulation strategies that improve solubility, such as emulgel formulations, to enhance their bioavailability and therapeutic effectiveness. Preformulation studies were performed to evaluate the quality of ketoconazole. Determination of melting point, solubility studies, lambda max by UV spectroscopy reveals the authenticity of drug. FTIR spectroscopy of drug, excipients and blend provide the compatibility data of ketoconazole with excipients used. Design expert software version 13 was used to prepare batches containing various ratios of synthetic polymer Carbopol 934 and natural polymer Guar gum. Central composite design provide thirteen formulations with 5 centre points.

The evaluation of ketoconazole emulgel formulations containing various ratios of Carbopol 934 and Guar Gum has provided comprehensive insights into the formulation's physical, chemical, and release characteristics. The key findings from the evaluation can be summarized as follows: All the formulations exhibited a white, homogeneous, and smooth appearance, which is desirable for topical formulations as it ensures uniformity and stability. The pH values ranged from 6.72 to 6.84, which is compatible with the skin's natural pH, ensuring the safety and non-irritating nature of the emulgels for topical application. The spreadability of the formulations ranged from 22.01 to 37.21, with formulations containing higher Carbopol concentrations generally showing better spreadability. Viscosity values ranged from 5,650 to 12,226 cP, where higher concentrations of Carbopol increased viscosity, leading to thicker gels. This is beneficial for ensuring that the emulgel stays in place upon application, allowing for a controlled release of ketoconazole.

The drug content across all formulations was found to be between 96.12% and 99.22%, indicating that the formulations can deliver the required therapeutic dose of ketoconazole effectively, with minimal variation in drug content. The *in-vitro* release data indicated that the formulations provided controlled release of ketoconazole, with



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drug release percentages ranging from 84.11% to 99.05%. Formulations with higher Carbopol content tended to have slower release rates, while those with lower Carbopol concentrations exhibited faster drug release. This allows flexibility in formulating emulgels for different therapeutic needs, from fast-acting to prolonged release applications. The in-vitro drug release data indicates that the ketoconazole emulgel formulations provide a controlled release of the active ingredient, with significant variability between different formulations. Formulation F1 offers the fastest release, while Formulations F7 to F9 show slower drug release, suggesting that the Carbopol and Guar Gum ratio plays a crucial role in determining the release rate. The variations in release profiles offer flexibility in tailoring the formulation for different therapeutic needs, such as faster onset or prolonged release for sustained efficacy.

The ketoconazole emulgel formulations demonstrated promising characteristics in terms of physical appearance, pH compatibility, spreadability, viscosity, drug content, and controlled drug release. The combination of Carbopol and Guar Gum in varying ratios significantly influenced the gel's rheological properties, affecting both drug release rates and ease of application. These formulations are suitable for topical antifungal therapy, providing an effective and controlled delivery of ketoconazole to the skin. The results suggest that by optimizing the ratio of gelling agents, ketoconazole emulgels can be tailored for specific therapeutic purposes, offering both immediate and sustained drug release depending on the formulation's requirements.

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Table 1. FTIR spectra interpretation of Drug and excipients

Sample	Element
Ketoconazole	
3587	O-H stretch
2875	N-H stretch
1410	C-H bend
659	C=C bend
Carbopol 934	
3233 cm ⁻¹	O-H stretch
2980 cm ⁻¹	C-H stretch
1725 cm ⁻¹	C=O stretch
TEA	
3306 cm ⁻¹	O-H stretch
2945 cm ⁻¹	C-H vibration of methylene group
2875 cm ⁻¹	
2819 cm ⁻¹	
1029 cm ⁻¹	C-O stretch
Methyl paraben	
3303 cm ⁻¹	O-H stretch
3050 cm ⁻¹	C-H stretch
1681 cm ⁻¹	C=O stretch
1280 cm ⁻¹	C-O stretch
Propyl paraben	
3290 cm ⁻¹	O-H stretch
2950 cm ⁻¹	C-H stretch
1720 cm ⁻¹	C=O stretch
1180 cm ⁻¹	C-O stretch
Tween 20	
3466 cm ⁻¹	O-H stretch
2915 cm ⁻¹	C-H stretch
1728 cm ⁻¹	C=O
1090 cm ⁻¹	C-O-C stretch
Span 20	
3390 cm ⁻¹	O-H stretch
2920 cm ⁻¹	C-H stretch
1730 cm ⁻¹	C-O stretch
Liquid Paraffin	





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2957 cm ⁻¹	C-H stretch
2635 cm ⁻¹	O-H stretch
1126 cm ⁻¹	C-O strctch

Table 2: Results of solubility studies of Ketoconazole in different solvents

S. No.	Solvent	Quantitative solubility (in mg/ml)
1	Distilled water	0.017
2	Methanol	76
3	Ethanol	26
4	PBS pH 7.4	15
5	Chloroform	18
6	Acetone	16

Table 3: Results of Calibration curve of Ketoconazole in PBS 7.4pH

S. No.	Drug Conc. (µg/ml)	Absorbance (in nm)
1	2	0.315
2	4	0.562
3	6	0.828
4	8	1.125
5	10	1.386

Table 4: Formulation of batches using Central composite design

Formulation	Carbopol 934 (%)	Guar Gum (%)
F1	0.5	2
F2	2	2
F3	1.25	1.25
F4	0.5	0.5
F5	0.189339828	1.25
F6	2.310660172	1.25
F7	1.25	2.310660172
F8	2	0.5
F9	1.25	0.189339828

Table 5: Evaluation Parameters for Emulsion

Test	Observation	Interpretation
Dilution test (With water)	Stable	O/W emulsion
Dye test (By Methylene blue)	No coloured globules, blue coloured external phase	O/W emulsion
Conductivity test	934.66±1.59	O/W emulsion
COCl ₂ test	Colour of filter paper changes from blue to pinkish-red	O/W emulsion
Flourescence test	Spotty flourescence	O/W emulsion
Centrifugation test	Seperation was clear	O/W emulsion

Table 6: Results of evaluation of emulsion

Formulation	Physical appearance	pH	Spreadability (cm ²)	Viscosity (cps)	Drug content (%)	In-vitro drug release (%)
F1	White, homogeneous and smooth	6.83	27.09	8900	99.22	99.05
F2	White, homogeneous and smooth	6.82	34.66	11850	98.82	88.45



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F3	White, homogeneous and smooth	6.81	29.87	10880	98.66	88.62
F4	White, homogeneous and smooth	6.83	23.67	7524	97.52	88.59
F5	White, homogeneous and smooth	6.79	22.01	5650	98.24	96.15
F6	White, homogeneous and smooth	6.84	37.21	12226	98.05	86.24
F7	White, homogeneous and smooth	6.82	30.11	11150	98.15	94.88
F8	White, homogeneous and smooth	6.76	30.23	11682	97.88	85.15
F9	White, homogeneous and smooth	6.72	29.67	10558	96.12	84.11

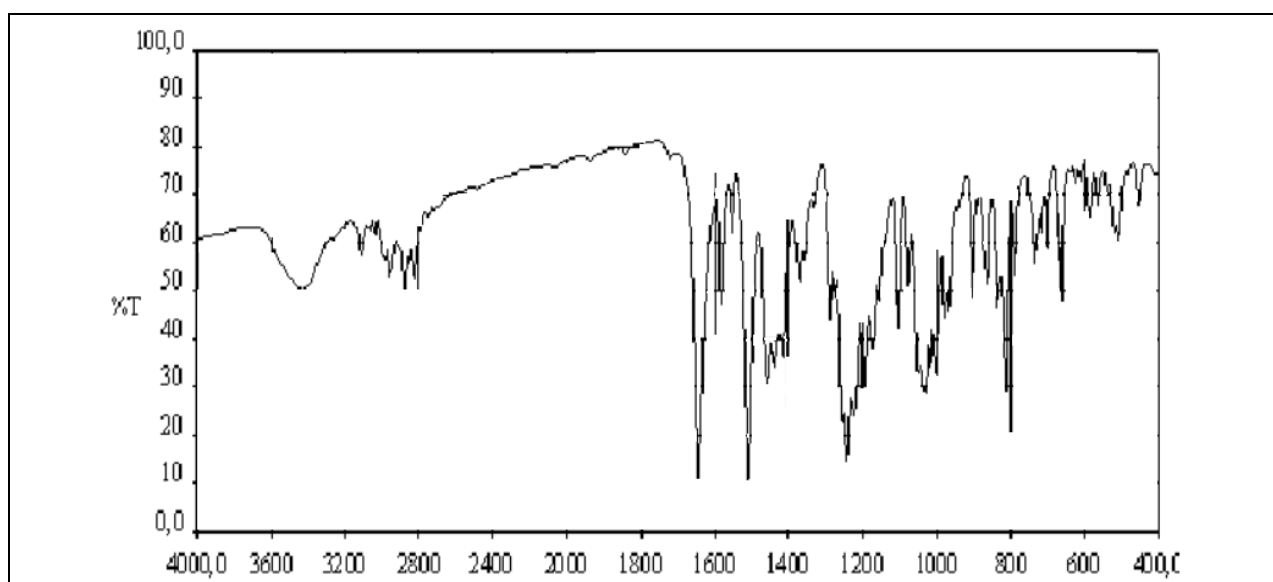


Figure1: FTIR spectra of Ketoconazole

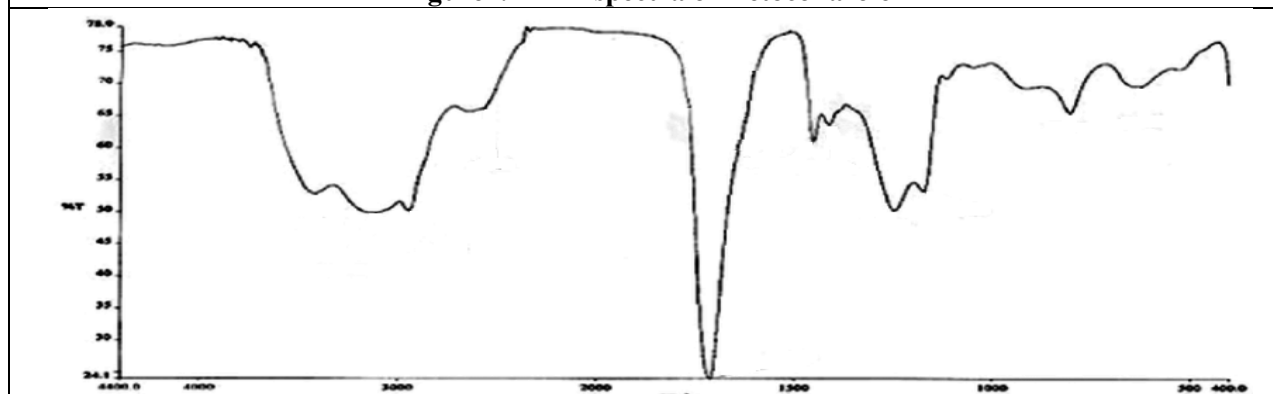


Figure 2: FTIR spectra of Carbopol 934





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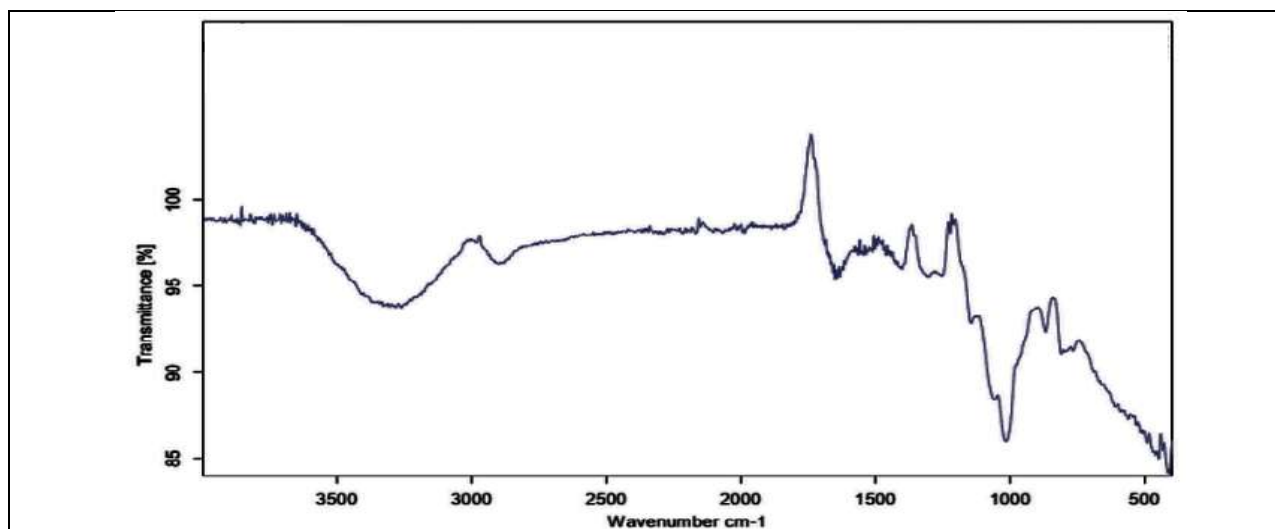


Figure 3: FTIR spectra of Guar gum

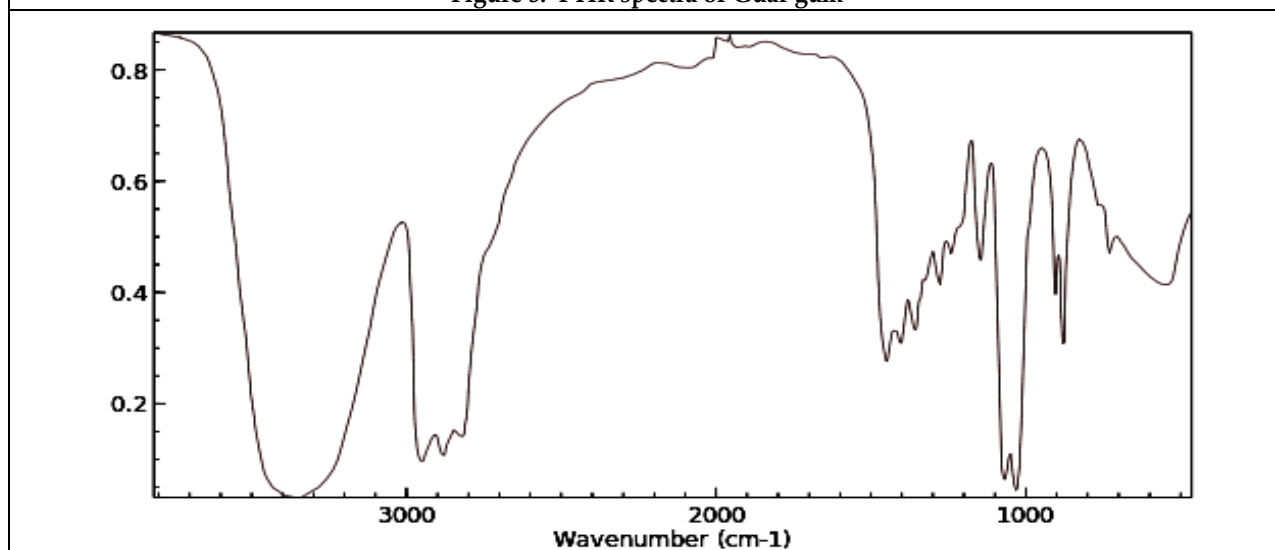


Figure 4: FTIR spectra of Triethanolamine

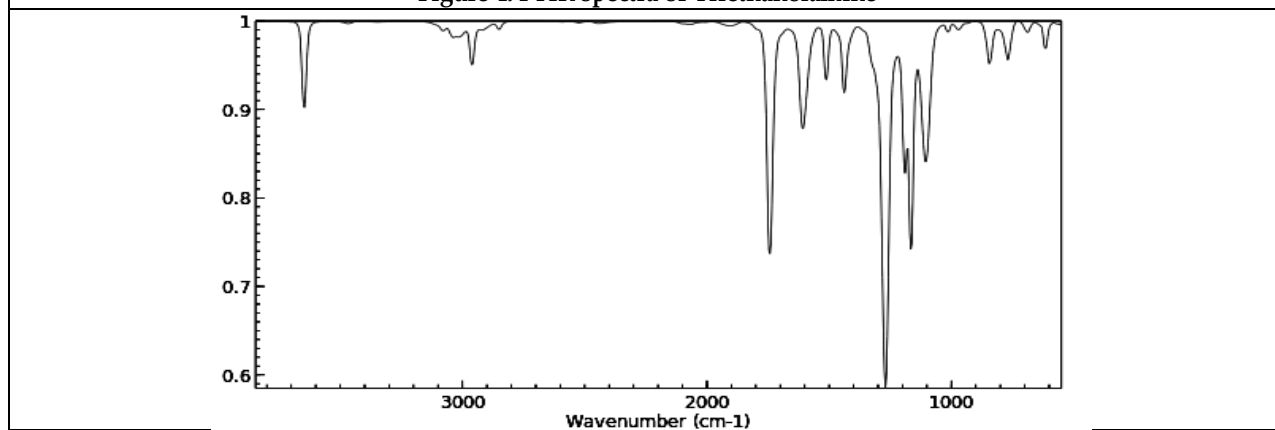
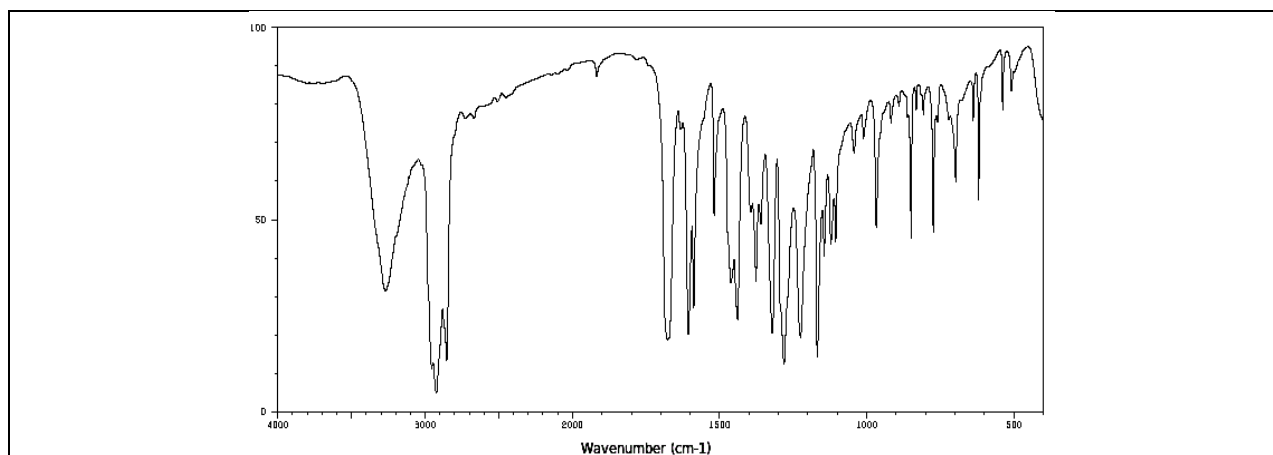
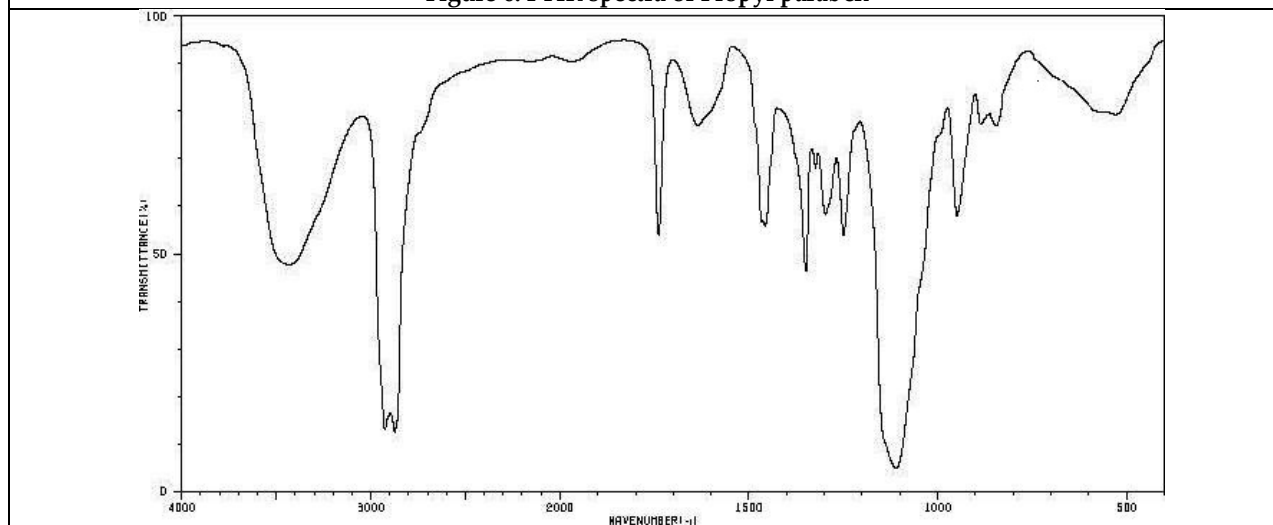
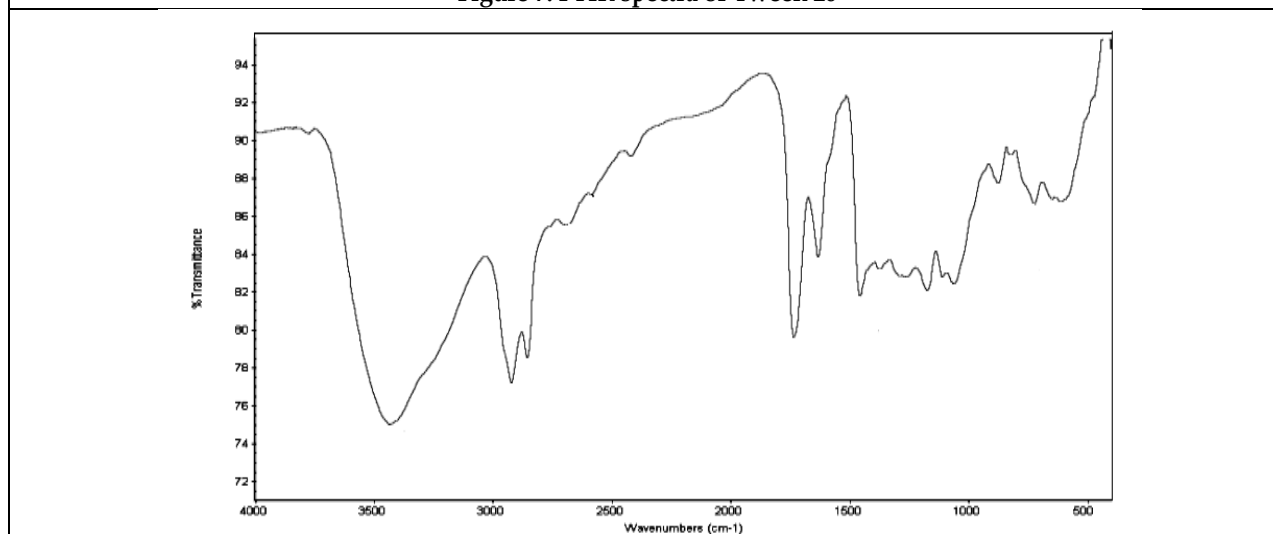


Figure 5: FTIR spectra of Methyl paraben



**Rohini Kadam et al.,****Figure 6: FTIR spectra of Propyl paraben****Figure 7: FTIR spectra of Tween 20****Figure 8: FTIR spectra of Span 20**



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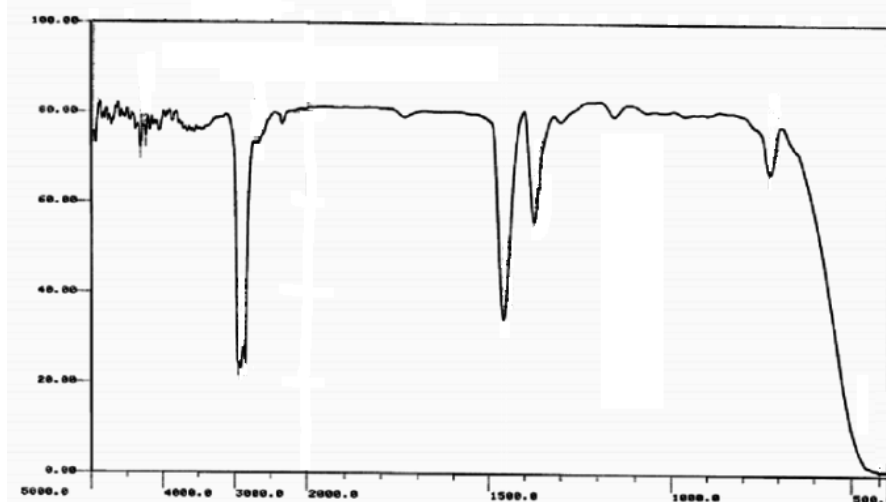


Figure 9: FTIR spectra of Liquid Paraffin

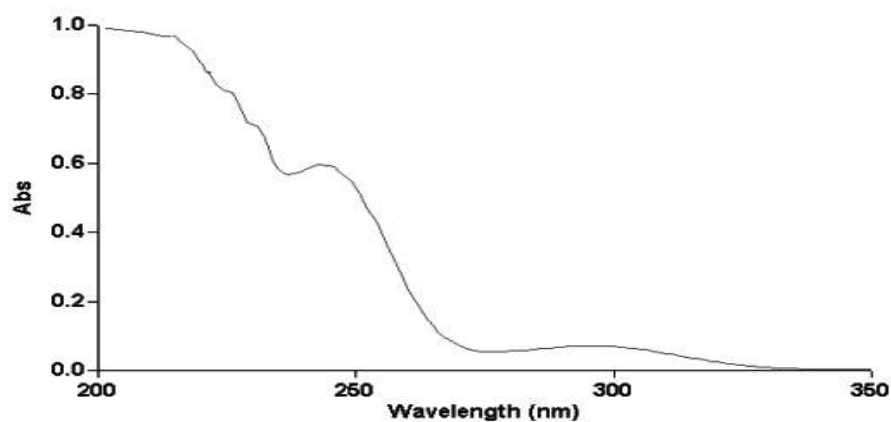


Figure 10: Lambda max of Ketoconazole by UV spectroscopy

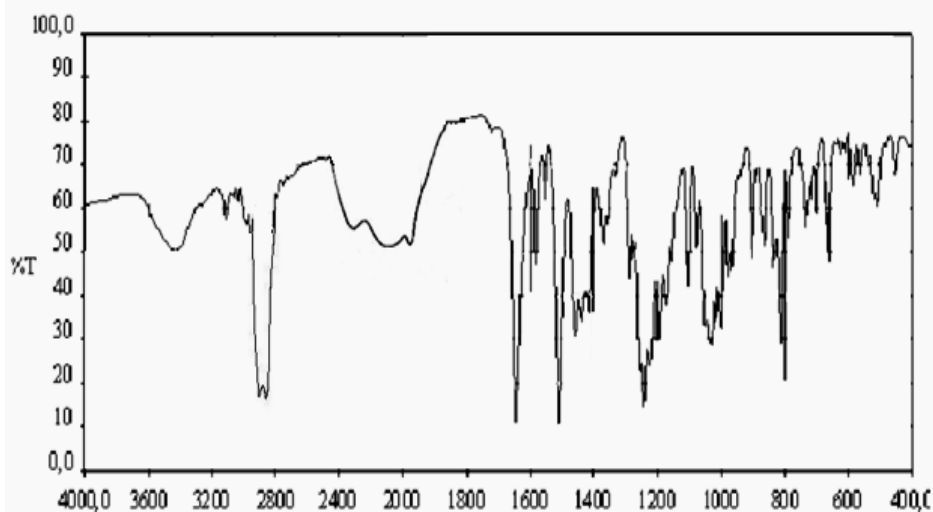
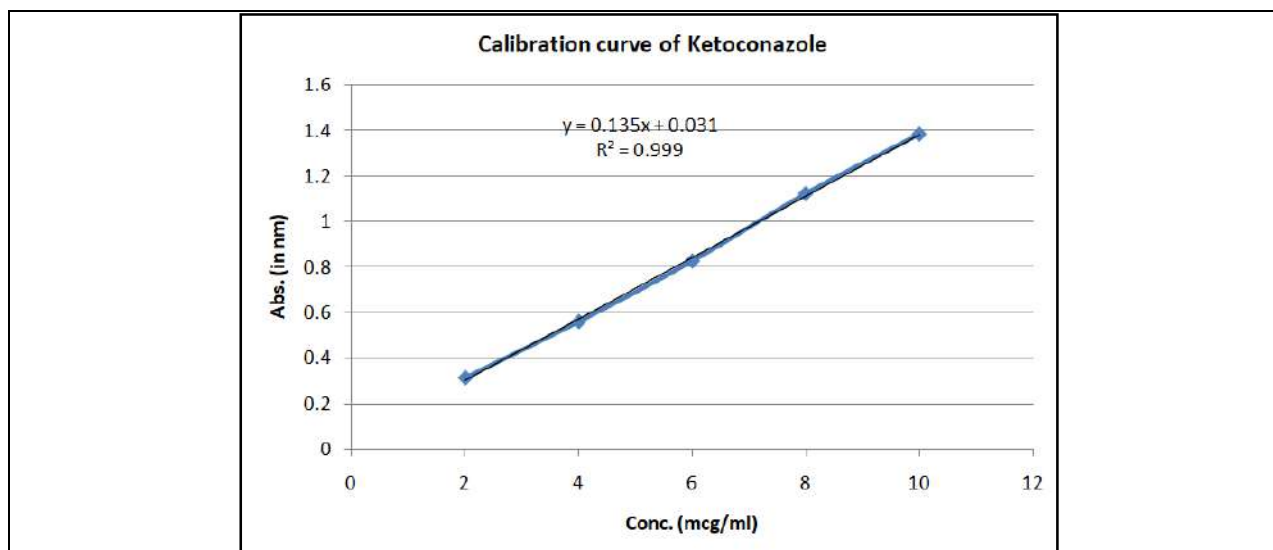


Figure 11: FTIR spectra of blend (1:1)



**Rohini Kadam et al.,****Figure 12: Calibration curve of Ketoconazole****Figure 13. Formulation of batches using Central composite design**



RESEARCH ARTICLE

Import of Pharmaceutical Products to Overseas Market

D. Swetha^{1*} and Koushik Yetukuri²

¹Masters of Pharmacy, Department of Regulatory Affairs, Chalapathi Institute of Pharmaceutical Sciences, (Affiliated to Acharya Nagarjuna University), Guntur, Andhra Pradesh, India.

²Associate Professor, Department of Regulatory Affairs, Chalapathi Institute of Pharmaceutical Sciences, (Affiliated to Acharya Nagarjuna University), Guntur, Andhra Pradesh, India.

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*Address for Correspondence

D. Swetha

Masters of Pharmacy,
Department of Regulatory Affairs,
Chalapathi Institute of Pharmaceutical Sciences,
(Affiliated to Acharya Nagarjuna University),
Guntur, Andhra Pradesh, India.
E.Mail: swethasridasari8@gmail.com



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ABSTRACT

By guaranteeing the availability of necessary medications and medical supplies, the importation of pharmaceutical items into other markets is crucial to global healthcare. This procedure entails negotiating intricate regulatory frameworks, making sure local laws are followed, and resolving concerns about efficacy, safety, and quality control. The success of pharmaceutical imports is greatly influenced by elements like market demand, international trade agreements, intellectual property rights, and logistical difficulties. The dynamics of pharmaceutical imports are examined in this article, along with supply chain management techniques, market entry tactics, and legal and regulatory issues. The impact of trade policy, the function of international organizations in promoting access to medications, and the increasing significance of guaranteeing adherence to international standards, including Good Manufacturing Practices (GMP), are all highlighted [1]. The paper assesses the challenges encountered by pharmaceutical companies in foreign market entry and provides recommendations for enhancing the efficiency and sustainability of pharmaceutical imports to address global healthcare demands.

Keywords: Good Manufacturing Practices (GMP) pharmaceutical industry, global healthcare, market demand, quality control, safety and efficacy. Pharmaceutical imports, CDSCO.

INTRODUCTION

The ease of access to drugs contributes to lower mortality rates. However, not all medicines are made domestically. The government of Despite efforts to improve local medicine production and reduce reliance on imported drugs, several advancements in medicine remain limited to imported drugs. Each country has its own unique environment and cultural heritage. Disease prevalence varies by geographic region, impacting the need for pharmaceutical



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supplies. This assessment examines pharmaceutical needs, laws, and regulations across countries. The pharmaceutical sector is an important part of the global economy, as it contributes significantly to public health and well-being. As the global demand for healthcare items grows, the import of pharmaceutical products into other markets becomes increasingly significant. India, as one of the world's top pharmaceutical producers and exporters, has emerged as a key player in the international trade of medicines, active pharmaceutical ingredients (APIs), vaccines, and medical devices [2]. Importing pharmaceutical products entails a complicated network of rules, compliance standards, and market dynamics that change by area. Imports help countries complement domestic production, meet demand for specialty medications, and assure the availability of crucial healthcare products. The expanding global demand for affordable and high-quality medications has boosted the importance of international pharmaceutical commerce, particularly in emerging economies.

The purpose of this article is to investigate the dynamics of importing pharmaceutical items into overseas markets, with an emphasis on the important issues influencing trade in this sector, such as regulatory compliance, logistical problems, market access, and the effect of international trade agreements. As the global healthcare landscape changes, understanding the complexities of pharmaceutical imports is critical for businesses and politicians alike, assuring timely access to key medications and encouraging global healthcare innovation. markets. As India has gradually integrated into the global financial system in the post-liberalization era, its foreign trade has grown rapidly. Total trade reached \$788 billion in 2019-20, up from \$76.1 billion in 1997-98, representing an 11.2% CAGR. During the same time period, exports increased at a CAGR of 10.5% to US\$ 313.4 billion, whereas imports increased at a CAGR of 11.7% to US\$ 474.7 billion.

While India has increased its commercial engagements with a number of countries over the years, actual trading is still relatively limited to a few markets. To increase diversification, the Government of India implemented the Focus Market Scheme, Market Linked Focus Product Scheme, and Focus Product Scheme. More emphasis was paid to penetration into new markets, particularly Asia and Latin America.

METHODOLOGY

Methodology for Importing Pharmaceutical Drugs from Foreign Countries

A methodical approach is necessary while importing pharmaceutical medications from India in order to guarantee product quality, regulatory compliance, and effective supply chain management. Here is a methodical approach Market Analysis and Adherence to Regulations Verify adherence to the pharmaceutical laws of the destination nation prior to importation. Assess Market Demand: Find out whether certain pharmaceutical products—such as generics, biologics, vaccines, and APIs—are required.

Regulatory Acceptance: Obtain the national drug regulatory authority's required permissions, including FDA (ANDA, NDA, DMF) in the United States EU: approval from the European Medicines Agency (EMA) UK: Regulatory Agency for Medicines and Healthcare Products (MHRA) Drugs Standard Control Organization (CDSCO) of India Administration for National Medical Products in China (NMPA) Other Nations: adherence to regional drug control organizations Quality Standards: Verify that the exporter complies with local, USFDA, WHO-GMP, or Good Manufacturing Practice (GMP) regulations.

Import Documentation & Licensing

Obtain the required licenses and documentation prior to importation: Many countries require an import license in order to import medications. Product Registration: Prior to importation, some nations demand that imported medications be registered. Crucial Records: Pharmaceutical Product Certificate (COPP) GMP stands for Good Manufacturing Practice. Certificate of Analysis (CoA) Certificate Sale Without Charge Batch Manufacturing Record (BMR) Certificate Airway Bill (for air freight) or Bill of Lading (for maritime freight) Packing list, product dossier, and commercial invoice (if necessary)



**Swetha and Koushik Yetukuri****Choosing a Trustworthy International Vendor**

Check the credentials of the supplier: Verify regulatory approvals from the USFDA, EMA, and WHO-GMP, for example Evaluate the quality of the product: Request batch certificates, lab test results, and samples. Perform Audits of the Factory: Verify adherence to rules regarding distribution, storage, and manufacture. Supply Chain Management & Logistics

Transportation & Shipping

For expensive and perishable medications, air freight is preferred. Sea freight is more affordable for large cargo, but it takes longer to get there. Cold Chain Logistics: Use temperature controlled transportation for biologics, vaccines, and sensitive pharmaceuticals. Clearance of Customs: To guarantee a seamless clearance, collaborate with knowledgeable customs brokers. Verify that the Harmonized System (HS) codes are appropriately categorized for tax and duty purposes.

Distribution and Market Entry Plan

Find Local Distributors: Collaborate with authorized hospitals, wholesalers, or distributors of pharmaceuticals. Pricing and Regulatory Compliance: Verify adherence to tax laws and government pricing guidelines. Branding & Marketing: Adhere to regional regulations regarding pharmaceutical marketing and advertising. Educate medical representatives about product compliance and specifics.[3]

Post-Market Monitoring and Quality Assurance

Keeping an eye on adverse drug reactions (ADRs): Create a pharmaco vigilance program to monitor adverse events. Continual Examinations: Perform routine audits and quality control checks. Mechanisms for Product Recalls: Have a recall process in place in case of regulatory non-compliance or quality problems.

Commonly Imported Pharmaceutical Products To India

- Generic & Branded Drugs (Tablets, Capsules, Injectables)
- APIs (Active Pharmaceutical Ingredients)
- Biologics & Biosimilars
- Vaccines
- Herbal & Ayurvedic Medicines
- Over-the-Counter (OTC) Medicines

China's Market Regulatory Authority for Pharmaceuticals**National Medical Products Administration (NMPA)[5]**

China's primary regulating body for pharmaceuticals, medical devices, and cosmetics is the National Medical Products Administration (NMPA). It is in charge of medicine approval, safety monitoring, and regulatory enforcement and functions under the State Administration for Market Regulation (SAMR).

North America Regulatory authority for Pharmaceuticals:**United states of Food and Drugs Administration (FDA)****Japan Regulatory authority for Pharmaceuticals:****CDSCO(Central Drugs Standard Control Organization):.[9]**

An application for an import License shall be made to the licensing authority in Form 8 for drugs excluding those specified in Schedule X, and in Form 8-A for drugs specified in Schedule X, either by the manufacturer himself having a valid wholesale License for sale or distribution of drugs under these Rules, or by the manufacturer's agent in India either having a valid License under the Rules to manufacture for sale of a drug or having a valid wholesale License for sale or distribution of drugs under these Rules, and shall be accompanied by a License fee of one thousand rupees for a single drug and an additional fee at the rate of one hundred rupees for each additional drug and by an undertaking in Form 9 duly signed by or on behalf of the manufacturer:





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Provided that in the case of any subsequent application made by the same importer for import License for drugs manufactured by the same manufacturer, the fee to accompany each such application shall be one hundred rupees for each drug

Any application for import License in Form 8 or Form 8-A, as the case:

May be, shall be accompanied by a copy of Registration Certificate issued in Form 41 under Rule 27-A. Provided that in case of emergencies the licensing authority may, with the approval of the Central Government, issue an import License in Form 10 or 10-A, as the case may be, without the issuance of Registration Certificate under Rule 27-A, for reasons to be recorded in writing. Provided further that Registration certificate shall not be required to be accompanied with an application for an import License under the Rules for the import of in-vitro diagnostic kits and reagents, except for the diagnostic kits notified from time to time. A fee of two hundred and fifty rupees shall be paid for a duplicate copy of the License issued under this Rule, if the original is defaced, damaged or lost. A fee of one thousand and five hundred US dollars [or its equivalent in Indian rupees] shall be paid along with the application in Form 40 as registration fee for his premises meant for manufacturing of drugs for import into and use in India.

A fee of one thousand US dollars [or its equivalent in Indian rupees] shall be paid along with the application in Form 40 for the registration of a single drug meant for import into and use in India and an addition fee at the rate of one thousand US dollars for each additional drug:

Certificate in Form 41 may be issued in respect of the import of more than one drug or class of drugs, manufactured by the same manufacturer: Provided that the drug or classes of drugs, are manufactured at one factory or more than one factory functioning conjointly as a single manufacturing unit: Provided further that if a single manufacturer has two or more factories situated in different places manufacturing the same or different drugs, separate Registration Certificates shall be required in respect of the drugs manufactured by each such factory.

The fees shall be paid through a Challan in the Bank of Baroda, Kasturba Gandhi Marg, New Delhi-110001 or any other branch or branches of Bank of Baroda, or any other bank, as notified, from time to time, by the Central Government, to be credited under the Head of Account —0210-Medical and Public Health, 04-Public Health, 104-Fees and Fines. Provided that in the case of any direct payment of fees by a manufacturer in the country of origin, the fees shall be paid through Electronic Clearance System (ECS) from any bank in the country of origin to the Bank of Baroda, Kasturba Gandhi Marg, New Delhi, through the Electronic Code of the bank in the Head of Account —0210-Medical and Public Health, 04- Public Health, 104-Fee and Fines, and the original receipt of the said transfer shall be treated as an equivalent to the bank challan, subject to the approval to the Bank of Baroda that they have received the payment.

The applicant shall be liable for the payment of a fee of five thousand US dollars [or its equivalent in Indian rupees] for expenditure as may be required for inspection or visit of the manufacturing premises or drugs, by the licensing authority or by any other persons to whom powers have been delegated in this behalf by the licensing authority under Rule 22. The applicant shall be liable for the payment of testing fees directly to a testing laboratory approved by the Central Government India or abroad, as may be required for examination, tests and analysis of drug. A fee of three hundred US dollars [or its equivalent in Indian rupees] shall be paid for a duplicate copy of the Registration Certificate, if the original is defaced, damaged or lost. No Registration Certificate shall be required under these Rules in respect of an inactive bulk substance to be used for a drug formulation, with or without pharmacopoeial conformity.

25B Registration Certificate for Import of Drugs Manufactured by One

Manufacturer:—

(1) A single application may be made, and a single Registration Drugs and *Cosmetics Rules, 1945*



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Certificate in Form 41 may be issued in respect of the import of more than one drug or class of drugs, manufactured by the same manufacturer: Provided that the drug or classes of drugs, are manufactured at one factory or more than one factory functioning conjointly as a single manufacturing unit: Provided further that if a single manufacturer has two or more factories situated in different places manufacturing the same or different drugs, separate Registration Certificates shall be required in respect of the drugs manufactured by each such factory.

27-A Grant of Registration Certificate-

(1) On receipt of an application for Registration Certificate in the Form and manner specified in Rule 24-A, the licensing authority shall, on being satisfied, that, if granted, the conditions of the Registration Certificate will be observed, issue a Registration Certificate in Form 41:

Provided further that if the application is complete in all respects and informations specified in Schedules D-I and D-II are in order, the licensing authority shall, within nine months from the date of receipt of an application, issue such Registration Certificate, and in exceptional circumstances and for reasons to be recorded in writing, the Registration Certificate may be issued within such extended period, not exceeding three months as the licensing authority may deem fit.

If the applicant does not receive the Registration Certificate within the period as specified in the proviso to sub-rule (1), he may appeal to the Central Government and the Central Government may after such enquiry into the matter, as it considers necessary, may pass such orders in relation thereto as it thinks fit.]

28-A Duration of Registration Certificate. —

A Registration Certificate, unless, it is sooner suspended or cancelled, shall be for a period of three years from the date of its issue:

Provided that if the application for a fresh Registration Certificate is made nine months before the expiry of the existing certificate, the current Registration Certificate shall be deemed to continue in force until orders are passed on the application.

29-A Suspension and cancellation of Registration Certificate. —

If the manufacturer fails to comply with any of the conditions of the Registration Certificate, the licensing authority may after giving an opportunity to show cause why such an order should not be passed, by an order in writing stating the reasons therefore, suspend or cancel the Registration Certificate for such period as it thinks fit either wholly or in respect of some of the substances to which it relates:

Provided that a person, who is aggrieved by the order passed by the licensing authority under this rule may, within thirty days of the receipt of the order, appeal to the Central Government, and the Central Government may, after such enquiry into the matter as it considers necessary and after giving the appellant an opportunity for representing his views in the matter, pass such orders in relation thereto as it thinks fit.

The Central Drugs Standard Control Organization (CDSCO) in India normally grants import licenses for pharmaceuticals and medical devices that are valid for three (3) years after the date of issuance.

Timeline for Renewal: To guarantee continuation, the renewal application must be filed prior to the license's expiration.

A new application can be needed if it is not renewed within the allotted period.

The biggest importers of Indian drugs are states. India shipped pharmaceuticals and medications to the United States for over 723 billion Indian rupees in the fiscal year 2024.

Other well-known importers of pharmaceuticals from India are:

About 3.9% of India's pharmaceutical exports come from South Africa. Approximately 3.8% of these shipments are received by Russia. Approximately 3.8% of India's pharmaceuticals are also imported by the United Kingdom. Nigeria: With roughly a 3.3% share. When taken as a whole, these nations serve as important markets for India's



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pharmaceutical exports. With 34% of all exports in the fiscal year 2020, North America is the biggest regional market for Indian pharmaceuticals.

Pharmaceutical imports into India are sourced from a number of important nations, each with a distinct specialty in medicine. Biologics, cancer therapies, and vaccines are among the high-value medications that the US is a significant provider of. Pharmaceutical behemoths Novartis, Roche, and F. Hoffmann-La Roche are among the major contributors to Switzerland's vital role. Germany, which is home to well-known corporations like Bayer, Boehringer Ingelheim, and Merck, is another significant source. GlaxoSmithKline (GSK) and AstraZeneca are two of the biggest pharmaceutical companies that supply drugs in the UK. China is a major supplier of necessary pharmaceuticals, such as diabetic treatments, antibiotics, and vaccinations, with producers like Sanofi playing an important part. Japan, meantime, is the main supplier of specialty drugs, such as Favipiravir, an antiviral. These nations cooperate together to provide a robust network that meets India's pharmaceutical requirements.

RESULTS

India imported pharmaceuticals valued at about ₹35,249 crore in the fiscal year 2021–2022. Although there is a lack of precise region-by-region import statistics for this time frame, what is known suggests that India's top import destinations for pharmaceuticals in 2022 were:

These numbers imply that throughout this time, a sizable amount of India's pharmaceutical imports came from North America and Europe.

The Indian government has put in place a number of measures under the Atmanirbhar Bharat (Self-Reliant India) program to lessen reliance on imports and encourage domestic production of essential pharmaceutical components. These include the Scheme for Promotion of Bulk Drug Parks and the Production Linked Incentive (PLI) Scheme, which encourages the domestic production of essential Key Starting Materials (KSMs), Drug Intermediates (DIs), and Active Pharmaceutical Ingredients (APIs).

Over the previous three years, India's imports of prescription drugs have steadily increased. The entire value of imports during the 2019–2020 fiscal year was ₹40,139 crore. In 2020–2021, this amount climbed significantly to ₹46,808 crore, indicating global supply chain dynamics and rising demand. In 2021–2022, pharmaceutical imports reached ₹60,060 crore, continuing the rising trend. This increase emphasizes the need for improved domestic production and supply chain resilience by highlighting India's reliance on imported pharmaceutical raw ingredients and completed goods. India imported bulk medications and active pharmaceutical ingredients (APIs) worth about ₹35,249 crore in the fiscal year 2021–2022.

The Central pharmaceuticals Standard Control Organization (CDSCO) has records on registered bulk pharmaceuticals, which can reveal information about the kinds of APIs imported during this time, even though a complete list of all imported medications is not easily accessible.

CDSCO.GOV.IN

Under the Atmanirbhar Bharat (Self-Reliant India) program, the Indian government has put policies into place to encourage indigenous production and lessen reliance on imports. These include the Scheme for Promotion of Bulk Drug Parks and the Production Linked Incentive (PLI) Scheme, which encourages the domestic production of essential Key Starting Materials (KSMs), Drug Intermediates (DIs), and APIs.

Table:1 List of pharmaceutical drugs imported to India from foreign countries from 2021-2022[13]

Notably, India imports \$315 million worth of completed pharmaceutical products from China in 2022, despite China being a major producer of Active Pharmaceutical Ingredients (APIs).



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Between 2021 and 2022, the Netherlands, Denmark, and Austria were some of India's fastest-growing import destinations. In 2022, India imported a total of \$2.9 billion worth of pharmaceuticals. An important aspect of India's trade dynamics in the fiscal year 2021–2022 was its major importing partners. With 15% of India's total imports, China has become the country's biggest import partner. Following with 6% of India's imports each were the United States and the United Arab Emirates. Switzerland and Saudi Arabia, which accounted for 5% of India's total imports, were also important providers. As a result of their close economic linkages and interdependencies across multiple industries, these countries together accounted for a sizeable amount of India's import trade.

FEE for Importing in India from foreign countries

Pharmaceutical drug imports into India are subject to a number of taxes and tariffs, which might change depending on the drug in question and its categorization. The main elements consist of:

The baseline tax applied to imported goods is called the Basic Customs Duty (BCD). A BCD of 10% applies to many pharmaceutical products, while some life-saving medications are exempt or have lower rates. For example, the Union Budget 2025–2026 suggested adding 36 medications and life-saving treatments to the list that are completely exempt from BCD and six more that are eligible for a 5% BCD rebate. The IGST, or Integrated Goods and Services Tax, Pharmaceutical IGST rates, which are applied to all imports, normally correspond to domestic GST rates, which can range from 5% to 18%, depending on the particular drugs. The Social Welfare Surcharge, or SWS, is a 10% BCD tax. The SWS might not be applicable, nevertheless, if a medication is exempt from BCD. The list of medications eligible for duty exemptions or concessions is regularly reviewed and updated by the Indian government, particularly for therapies pertaining to cancer, uncommon disorders, and other serious chronic ailments. For instance, the government fully exempted all imported medications and foods for special medical purposes from BCD in March 2023. These imports were made for individual use in treating all rare diseases specified in the National Policy for Rare Diseases 2021. Because these rules are subject to change, it is best to refer to the most recent announcements from the Central Board of Indirect Taxes and Customs.

In 2021–2022, warning letters are sent to foreign nations for pharmaceutical products that are not properly exported to India.

Foreign pharmaceutical businesses were the target of warnings and enforcement proceedings from Indian regulatory bodies in 2021 and 2022 for engaging in unlawful export practices to India. The importation of inferior or mislabeled medications, among other infractions of India's import laws, was the main cause of these actions. India's national pharmaceutical and medical device regulatory authority, the Central Drugs Standard Control Organization (CDSCO), frequently issues notifications about medications and equipment that are deemed to be counterfeit, tampered with, or of substandard quality. For example, the November and December 2021 CDSCO notifications identify a number of pharmaceutical imports that were discovered to be in violation of Indian norms. These steps demonstrate the Indian government's dedication to guaranteeing that all pharmaceutical imports into the nation adhere to strict safety and quality regulations. To guarantee the efficacy and safety of medications sold in India, international pharmaceutical companies are obligated to abide by these rules.

CONCLUSION

In order to guarantee a consistent supply of necessary medications, active pharmaceutical ingredients (APIs), and healthcare solutions worldwide, pharmaceutical items must be imported into other markets. In order to sustain healthcare infrastructure, fill production shortages, and meet domestic demand, many nations—including India—rely on pharmaceutical imports. The importance of international supply chains and trade alliances is underscored by the growing dependence on imported medicinal items. Import trends are also influenced by variables like pricing dynamics, regulatory needs, and technical improvements. Many countries are concentrating on improving domestic production capabilities through governmental measures and investment in pharmaceutical research and



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development in an effort to lessen reliance on imports. Nonetheless, international cooperation is still essential to guaranteeing that high-quality and reasonably priced medications are available everywhere. China became the biggest provider of pharmaceutical medications, especially bulk drugs and Active Pharmaceutical Ingredients (APIs), in the fiscal year 2021–2022, but India imports pharmaceutical products from a number of nations. China was the largest provider to India at the time, accounting for 12% of the 37% of pharmaceutical imports. But under the present situation, China now controls a much larger portion of India's pharmaceutical supply chain. Approximately 344,053 metric tons, or 72% of India's total imports of bulk drugs and intermediates, came from China, which remained India's biggest supplier of pharmaceutical raw materials in the fiscal year 2023–2024. This increasing reliance emphasizes how important China is to India's pharmaceutical sector.

Our research also clarifies the causes of the Ethics approval and consent to participate: Not Applicable

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Author Contributions:

Dasarishwetha is the main contributor of the manuscript, writing and editing, and collecting data editing, and submission / correspondence of the above review article.

The project was conducted under the supervision of: Koushik Yetukuri, Associate Professor.

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• CONDITION OF IMPORT LICENSE IN INDIA :[4]

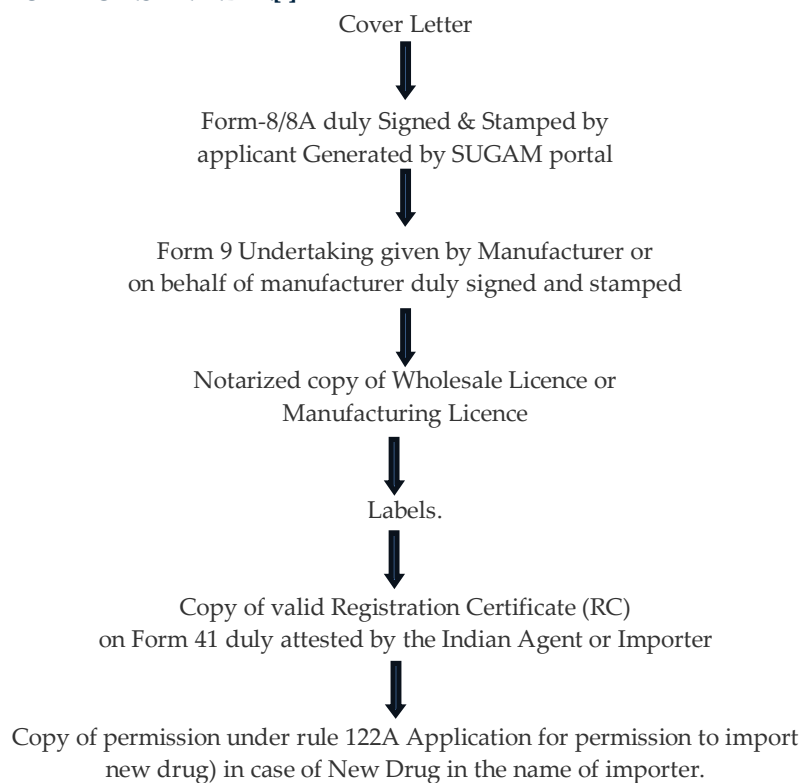


Table:1 List of pharmaceutical drugs imported to India from foreign countries from 2021-2022[13]

S.no	Drug name	Company name
1	• Adapalene	Galderma.
2	Covaxin	Bharat Biotech
3	Sputnik V	Binnopharm Group
4	Remdesivir	Gilead Sciences
5	Molnupiravir	Merck,
6	Favipiravir	Daiichi Sankyo
7	Imatinib	Novartis
8	Trastuzumab	Roche
9	Lenalidomide	Bristol-Myers Squibb
10	Pembrolizumab	Merck.
11	lopidogrel	Sanofi





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12	Amlodipine	Rakshit Pharmaceuticals
13	Atorvastatin	Pfizer.
14	Dabigatran	Boehringer Ingelheim.
15	Insulin	Eli Lilly and Novo Nordisk
16	Oxycodone	Purdue Pharma
17	Dabigatran	Boehringer Ingelheim.
18	Sitagliptin	Merck.
19	Glargine	Sanofi.
20	Adalimumab	AbbVie.
21	Rituximab	Roche.
22	Aripiprazole	Otsuka Pharmaceutical.
23	Lamotrigine	GlaxoSmithKline.
24	Itraconazole	Janssen Pharmaceuticals.
25	Hepatitis B Vaccine	GSK and Sanofi

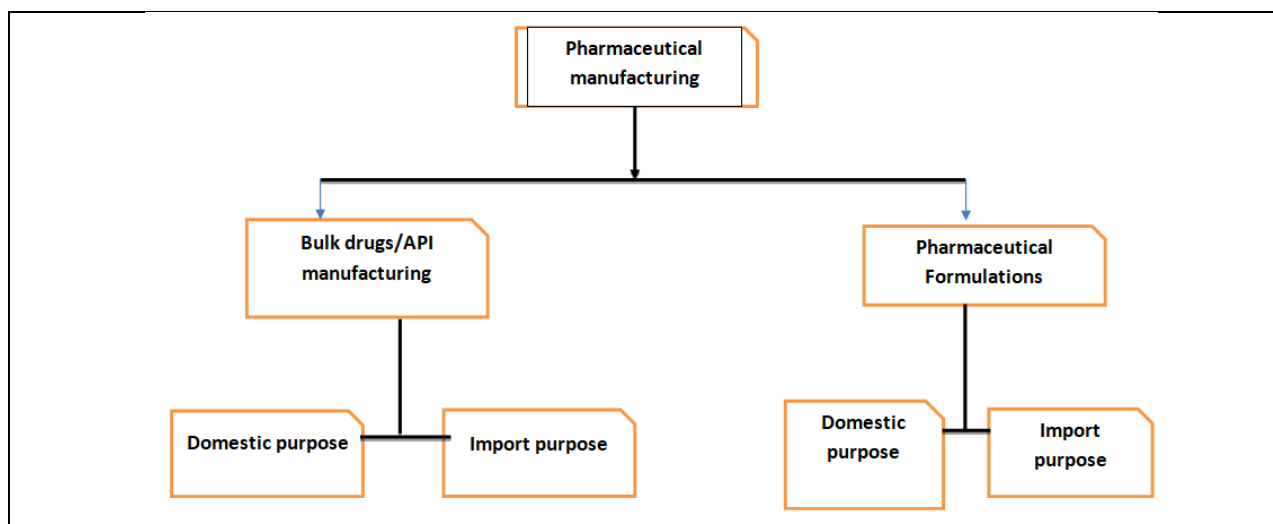


Figure No- 1 Indian Pharma sector[6]

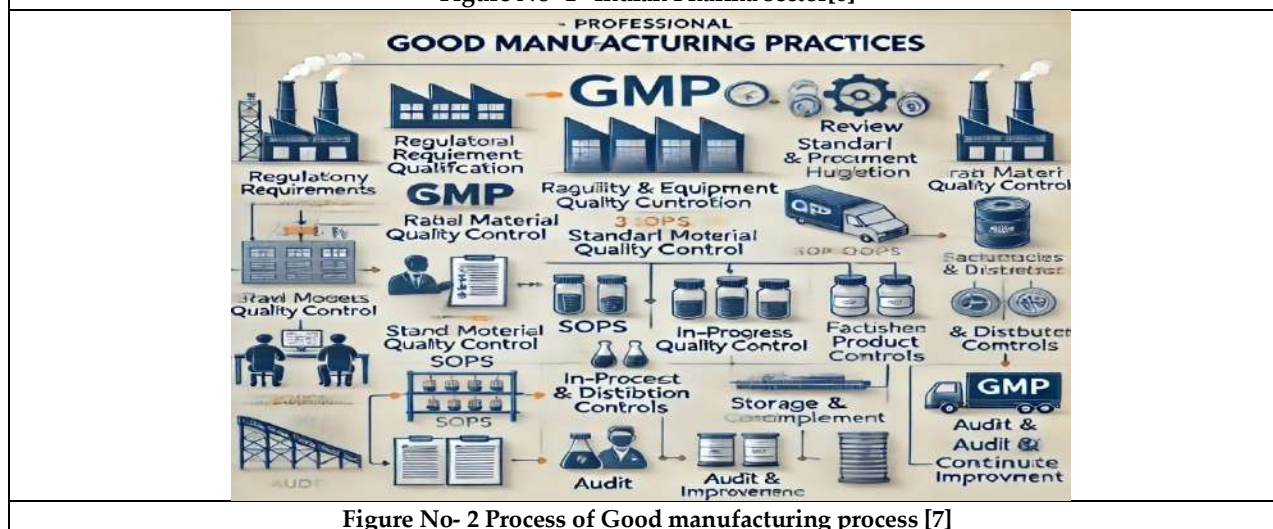


Figure No- 2 Process of Good manufacturing process [7]





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Figure No- 3 Importing of Pharmaceutical products to India [8]



Figure No- 4 Central Drugs Standard Control Organization approval process

Countries of Origin (for the 2021-2022 Period)

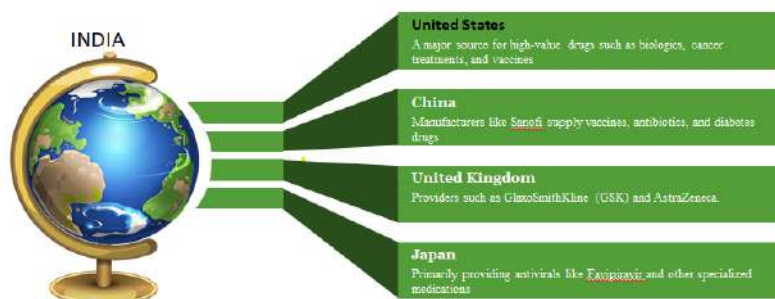


Figure No- 5 Countries of Origin (for the 2021-2022 Period):





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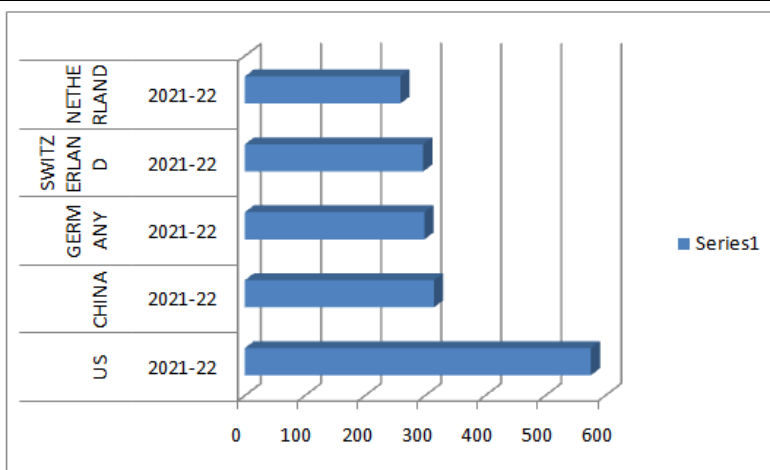


Figure:No-6 Region wise India's pharma import during year 2021-2022 [11]

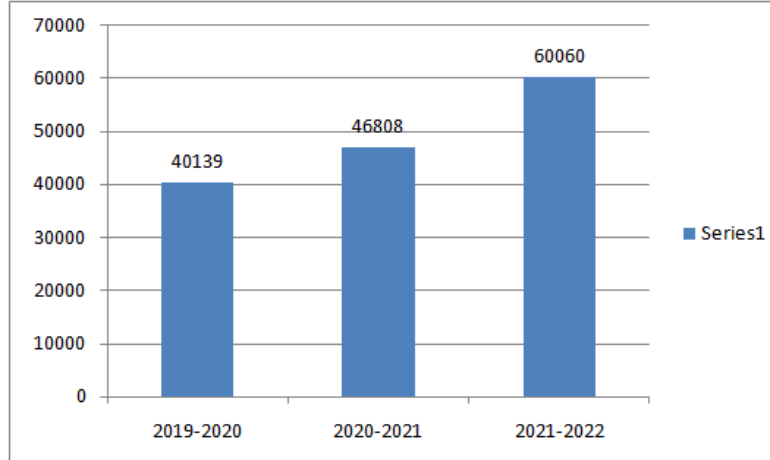


Figure No- 7From the last 3 years import of drugs from foreign countries [12]

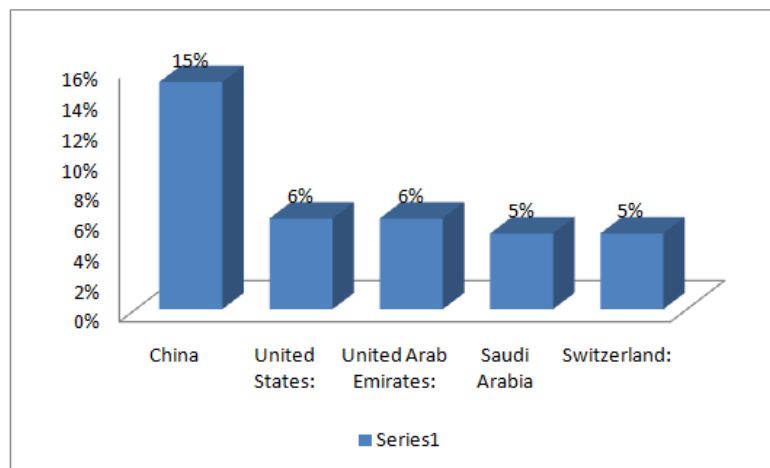


Figure No-8 Top Importing Partners of INDIA in 2021-2022[14]





RESEARCH ARTICLE

Effectiveness of Respiratory Muscle Stretch Gymnastics (RMSG) and the Jacobson Relaxation Technique in Reducing Stress among Physiotherapy Students: Randomized Controlled Trial

Komal S. Modi^{1*}, Madhavan Iyengar² and Prijal Gulhane³

¹PhD Scholar and Assistant Professor, Department of Physiotherapy, Parul University, Vadodara, Gujarat and Vibrant Physiotherapy College, (Affiliated to Veer Narmad South Gujarat University), Surat, Gujarat, India.

²Associate Professor, Department of Medical, Parul University, P.O. Limda, Waghodia, Vadodara, Gujarat, India.

³MPT Student, Department of Physiotherapy, The Sarvajanic College of Physiotherapy, (Affiliated to Veer Narmad South Gujarat University), Surat, Gujarat, India.

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Accepted: 29 Sep 2025

*Address for Correspondence

Komal S. Modi

PhD Scholar and Assistant Professor,

Department of Physiotherapy,

Parul University,

Vadodara, Gujarat and

Vibrant Physiotherapy College,

(Affiliated to Veer Narmad South Gujarat University),

Surat, Gujarat, India.

E.Mail: komalsmodi2@gmail.com



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ABSTRACT

Physiotherapy students often face significant stress from academics and personal life. This study evaluated stress levels and vulnerability using surveys and introduced two stress-reduction techniques: Respiratory Muscle Stretch Gymnastics and the Jacobson Relaxation Technique. These methods aimed to help students manage anxiety, particularly during exams, by addressing controllable behaviours and improving stress coping strategies. This study aimed to compare students' heart rates and performance on cognitive and clinical exams before and after using Respiratory Muscle Stretch Gymnastics and the Jacobson Relaxation Technique to reduce heart rates and enhance exam performance. Physiotherapy students around south Gujarat. 60 subjects fulfilling inclusion criteria were randomly divided into intervention Group A and Group B groups. Group A ($n = 30$) received RMSG exercise once a day, 3 sets for 5 days. whereas Group B ($n = 30$) received Jacobson relaxation technique for the same period. Stress Vulnerability Questionnaire were measured pre- and post-training. Statistical analysis was done using SPSS software (version 22.0). Notable improvements were observed across all measured variables in



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Group A ($P < 0.05$). A clear difference was also found between the two groups in terms of Stress Vulnerability Questionnaire scores. Respiratory muscle stretch gymnastics (RMSG) more effective than Jacobson relaxation technique to reduce stress in physiotherapy students. Given the limited time and resources available for extensive stress management programs, the implementation of a quick, easy-to-learn, and cost-effective method within the academic setting would greatly benefit these students. Unlike other relaxation techniques that require hours or days of practice, Respiratory muscle stretch gymnastics has demonstrated its potential in reducing cardiac reactivity and enhancing test performance. This makes deep breathing a practical and efficient stress reduction approach for physiotherapy students.

Keywords: Respiratory muscle stretch gymnastics (RMSG), Jacobson relaxation technique, stress, Stress Vulnerability Questionnaire

INTRODUCTION

Respiratory Muscle Stretch Gymnastics(RMSG)

Respiratory Muscle Stretch Gymnastics (RMSG) is a therapeutic approach that combines breathing techniques with specific stretching exercises performed in a synchronized manner. Unlike conventional practice, where breathing and stretching are introduced separately, RMSG integrates both simultaneously, making it a novel method for training the respiratory musculature. The technique consists of a structured sequence of movements aimed at targeting muscles essential for respiration. During inspiration, the external intercostals are elongated, while expiration emphasizes stretching of the internal intercostals, thereby improving thoracic mobility and reducing stiffness of the chest wall [5]. In recent years, RMSG has been recognized as a supportive strategy in pulmonary rehabilitation, particularly for individuals with chronic obstructive pulmonary disease (COPD). By promoting greater flexibility of the respiratory muscles, it is believed to enhance breathing efficiency, alleviate the sensation of breathlessness, and improve overall quality of life. Clinical observations also suggest that RMSG contributes to lowering respiratory rate, possibly by harmonizing neural control of breathing with sensory feedback from the intercostal muscles. This adjustment in breathing pattern is thought to reduce the perception of dyspnea, offering both physiological and psychological benefits [1]. These exercises, allow us to target specific respiratory muscles in a progressive way, allowing each muscle group to work to its maximum capacity and stretching and improving movement in the accessory muscles. By practicing these exercises, individuals can enhance their respiratory muscle strength and flexibility, thus improving their overall breathing and respiratory function. The exercises are designed to be safe and gradually increase in intensity, allowing individuals to progress at their own pace. Respiratory Muscle Stretch Gymnastics offers a comprehensive guide to improving respiratory muscle function through targeted exercises.

The potential benefits of respiratory muscle stretching are immense and extend beyond just improving the physical aspects of breathing. By targeting specific muscle groups and promoting flexibility and strength, these exercises can also have a positive impact on mental well-being. Breathing is not only a physiological process but also a powerful tool for relaxation, stress reduction, and overall mental balance. When our respiratory muscles are functioning optimally, we can experience a sense of calmness, clarity, and increased energy levels. Respiratory Muscle Stretch Gymnastics emphasizes the importance of individualization and customization when it comes to respiratory muscle training. Respiratory Muscle Stretch Gymnastics encourages individuals to incorporate these exercises into their daily routine to make breathing more efficient and effortless in everyday life. Respiratory Muscle Stretch Gymnastics is a comprehensive and accessible resource for individuals seeking to improve their respiratory health and function. [2]. The purpose of respiratory muscle stretch gymnastics is to improve the strength, endurance, and flexibility of the respiratory muscles and restore the balance between the diaphragm and the accessory muscles of respiration. These are the main precursors to normalizing any potential dysfunctional breathing patterns or respiratory rate. Secondly, restoring normal length tension relationships in the neuromuscular and musculoskeletal systems of respiration can be effective in critically managing respiratory and cardiopulmonary disorders. When the accessory muscles of



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respiration are recruited to aid in the breathing process for long periods, a range of negative outcomes such as respiratory muscle weakness, chronic dyspnea, increased work of breathing, and increased cardiac workload can result. Therefore, the pursuit of normalization of respiratory kinematics through respiratory muscle stretch gymnastics is essential for improvements in patients with a range of pathologies that affect the cardiorespiratory system[3]. Respiratory muscle stretch gymnastics not only has the capability to enhance the overall respiratory function and performance, but it also plays a significant role in improving the overall quality of life for individuals with cardiorespiratory disorders. It has the potential to alleviate symptoms such as shortness of breath, improve exercise tolerance, and enhance the overall cardiovascular fitness of patients. With its potential to improve respiratory muscle function, enhance overall respiratory performance, and contribute to the improvement of patients' overall quality of life, respiratory muscle stretch gymnastics represents a promising avenue for both current and future interventions in the field of respiratory care [3].

Jacobson's relaxation technique

Jacobson's Relaxation Technique, often referred to as progressive muscle relaxation, is a behavioral therapy that systematically involves contracting and then relaxing specific muscle groups in sequence. This method encourages individuals to develop greater awareness of bodily tension and the sensation of release, thereby fostering a state of deep relaxation. The technique was originally developed in the 1920s by Dr. Edmund Jacobson, who proposed that physical relaxation of the musculature could positively influence psychological well-being and reduce anxiety symptoms. The process generally requires tightening one muscle group while keeping the rest of the body at ease, followed by a slow release of tension, enabling individuals to experience the contrast between contraction and relaxation.

- Over time, this method has been shown to provide a range of health-related benefits. These include reductions in stress and anxiety, improvements in sleep quality, decreases in work-related strain, and potential contributions to lowering blood pressure. Some studies have also suggested that progressive muscle relaxation may assist individuals with epilepsy by decreasing the frequency and severity of seizures, although larger-scale trials are necessary to confirm these outcomes.

The technique is also widely applied as a non-pharmacological aid for insomnia. While it does not always increase sleep duration, many participants report improved sleep satisfaction and a greater sense of restfulness after practicing relaxation sessions. Typically, training begins with breathing awareness, followed by progressive relaxation starting from the feet and moving upward through the body. Each session lasts about 20–30 minutes and can be practiced independently with the help of guided instructions from professionals, recordings, or written manuals.

She suggests the following exercises

In practical use, Jacobson's method usually starts with breathing awareness and then progresses gradually through major muscle groups. Instead of focusing on detailed instructions for each body part, the technique emphasizes a cycle of tensing followed by releasing, helping individuals notice the contrast between muscular effort and relaxation. This progression promotes calmness and can be practiced independently in short sessions of 20–30 minutes with minimal guidance. With awareness of breathing, followed by gradual progression through different muscle groups. The sequence usually starts with the feet and legs, then advances through the abdomen, shoulders, and neck. At each stage, the muscles are gently contracted and then released, allowing the individual to notice the contrast between tension and relaxation. This systematic progression promotes a deep sense of physical ease and mental calm, without requiring extensive supervision. Sessions are generally brief (20–30 minutes) and can be performed at home using guided materials or recordings.

1. Bring your attention to your feet.
2. Point your feet downward, and curl your toes under.
3. Tighten your toe muscles gently, but don't strain.
4. Notice the tension for a few moments, then release, and notice the relaxation. Repeat.
5. Become aware of the difference between the muscles when they're tensed and when they're relaxed.
6. Continue to tense and relax the leg muscles from the foot to the abdominal area.



**Komal S. Modi et al.,****Abdomen**

1. Gently tighten the muscles of your abdomen, but don't strain.
2. Notice the tension for a few moments. Then release, and notice the relaxation. Repeat.
3. Become aware of the difference between the tensed muscles and the relaxed muscles.

Shoulders and neck

1. Very gently shrug your shoulders straight up towards your ears. Don't strain.
2. Feel the tension for a few moments, release, and then feel the relaxation. Repeat.
3. Notice the difference between the tensed muscles and the relaxed muscles.
4. Focus on the neck muscles, first tensing and then relaxing until you feel total relaxation in this area.

Progressive relaxation therapy is generally safe and doesn't require a professional's guidance. Sessions typically last no more than 20-30 minutes, making it manageable for people with busy schedules. You can practice the techniques at home using the instructions from a book, website, or podcast. You can also buy an audio recording that takes you through the exercises.

Stress

Stress is broadly understood as the body's adaptive reaction to challenges that disturb balance. It involves psychological perception and physiological changes, and when prolonged or poorly regulated, it is linked to multiple health problems. to internal or external challenges that threaten balance. It involves both psychological perception and physiological reactions mediated by the nervous and endocrine systems. Prolonged or poorly regulated stress has been linked to a range of mental and physical health conditions [Essentials of Medical Physiology, 2020]. The stress response is mediated by the stress system, which is located in both the central nervous system and peripheral organs. The main central effectors of the stress system are highly interconnected, and include hypothalamic corticotropin-releasing hormone and brainstem-derived norepinephrine. Malfunction of the stress system is associated with behavioural and somatic disorders. Stress is a major contributor to psychosocial and physical pathological conditions in humans.

Stress Vulnerability Questionnaire

The Stress Vulnerability Questionnaire (SVQ) is a brief self-report measure that assesses how susceptible an individual is to stress. It covers key domains such as emotional reactivity, thinking patterns, social support, physical well-being, and coping behaviors. Items are rated on a simple scale, and higher scores indicate greater vulnerability. Results are useful for gaining insights but are best interpreted by trained professionals. designed to provide an overview of an individual's susceptibility to stress. Instead of focusing only on one aspect, it incorporates multiple life domains, including emotions, thinking patterns, social support, physical well-being, and coping behaviors. Items are typically scored on a Likert-type scale, where respondents rate the extent to which statements reflect their experiences. Higher scores generally indicate greater vulnerability. While the SVQ offers useful insights, results should be interpreted cautiously and ideally in conjunction with professional evaluation. are carefully crafted to capture a holistic view of an individual's stress vulnerability. It often includes sections that address different aspects of life, such as work, relationships, health, and personal habits. The questions are usually presented in a format similar to the, allowing respondents to indicate the degree to which they agree or disagree with each statement.

Key areas assessed by the Stress Vulnerability Questionnaire typically include

Emotional reactivity: How easily and intensely an individual responds emotionally to stressors.

Cognitive flexibility: The ability to adapt thinking patterns in response to changing situations.

Social support: The strength and quality of an individual's support network.

Self-efficacy: Belief in one's ability to handle stressful situations.

Physical health: The impact of stress on physical well-being.

Coping strategies: The effectiveness of an individual's stress management techniques.

Scoring and interpretation of results from the Stress Vulnerability Questionnaire usually involve calculating a total score or sub scores for different domains. These scores are then compared to normative data to determine an



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individual's level of vulnerability relative to the general population. It's important to note that while these questionnaires provide valuable insights, they should be interpreted by trained professionals who can consider the full context of an individual's life and experiences.

METHODOLOGY

- Subjects who fulfil the inclusion criteria were selected for the study. The subjects were explained about the importance of the exercises. Approval was obtained from an institutional ethics committee before initiating the study. Ensure participant confidentiality and the right to withdraw at any point. Address any adverse events immediately with appropriate care.
- Participants will be recruited from workplaces. Informed consent was obtained from eligible participants. Demographic data (age, gender, occupation) was obtained. Medical history and smoking status was recorded. Brief physical examination to rule out any contraindications was conducted.
- **Group A (RMSG):** Participants were performed respiratory muscle stretch gymnastics under supervision. Sessions was conducted [e.g., 5 times a week] for [e.g., 30 minutes per session] for 2 weeks. Exercises included stretching and strengthening of respiratory muscles with guided breathing techniques.

Group B (Jacobson Relaxation Technique)

Participants practiced Jacobson Relaxation Technique under supervision. Sessions were conducted [e.g., 5 times a week] for [e.g., 30 minutes per session] for 2 weeks. Instructions included slow, deep breathing focusing on abdominal expansion. Adherence was monitored through attendance logs and participant feedback. Statistical tools to compare the effects of RMSG and Jacobson Relaxation Technique was used. Analysis within-group (pre- vs. post-intervention) and between-group differences was done.

RESULT

- Stress Vulnerability Questionnaire were measured pre- and post-training.
- Statistical analysis was done using SPSS software (version 22.0).
- Group – A (RMSG) and Group – B (JRT)
- Notable improvements were observed across all measured variables in Group A ($P < 0.05$). A clear difference was also found between the two groups in terms of Stress Vulnerability Questionnaire scores.

DISCUSSION

The present randomized controlled trial aimed to compare the effectiveness of Respiratory Muscle Stretch Gymnastics (RMSG) and the Jacobson Relaxation Technique in reducing stress among physiotherapy students. Findings from this study demonstrated a statistically significant reduction in stress levels within the RMSG group (Group A), as evidenced by improved scores on all outcome measures ($p < 0.05$). Moreover, when compared between groups, a significant difference was observed on the Stress Vulnerability Questionnaire, indicating the superior effect of RMSG over the Jacobson Relaxation Technique. These findings suggest that targeted stretching of the respiratory muscles may not only enhance pulmonary efficiency but also contribute to psychological relaxation through physiological modulation of the autonomic nervous system. The mechanism behind this may lie in the improvement of respiratory patterns, reduced muscle tension, and better oxygenation, which are known to influence mental well-being. While the Jacobson Relaxation Technique has long been established as an effective method for reducing anxiety and stress by promoting progressive muscular relaxation, it may not offer the same direct impact on breathing patterns and thoracic mobility as RMSG. This could explain the greater effectiveness of RMSG observed in our study. Our findings are consistent with previous research highlighting the interrelationship between respiratory function and emotional regulation. By integrating physical and mental relaxation strategies, RMSG appears to offer a





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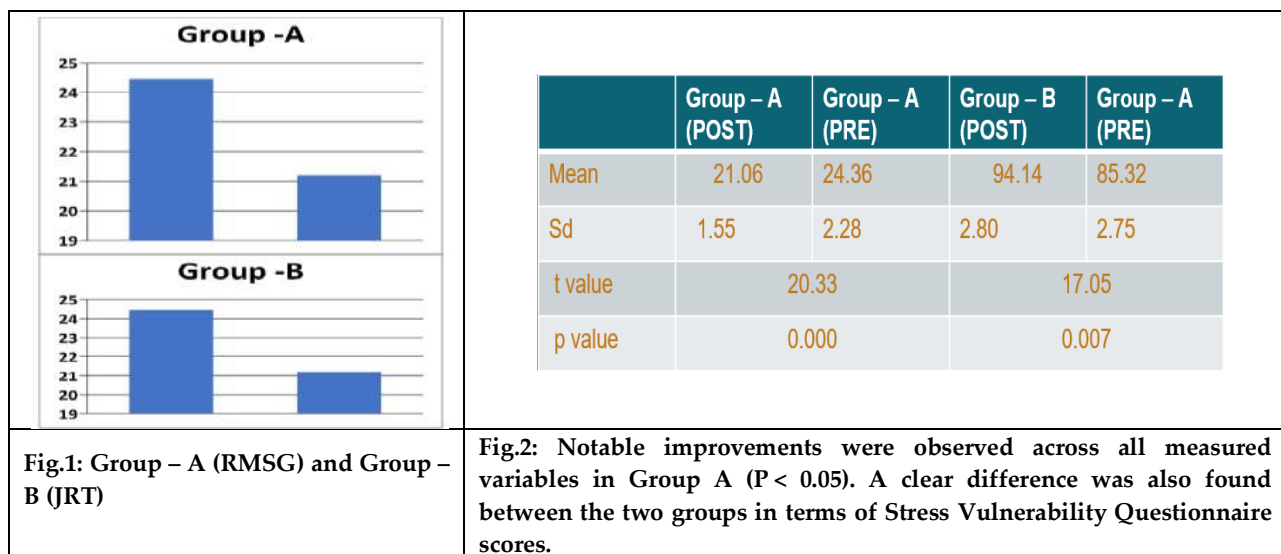
more holistic and physiological approach to stress reduction in high-stress academic environments such as physiotherapy education.

ACKNOWLEDGEMENTS

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RESEARCH ARTICLE

Integration of Ring-based NTRU Cryptosystems with Quantum Key Distribution for Next-Generation Secure Communication

Kanchana S*

Assistant Professor, Department of Physics, Seethalakshmi Ramaswami College (Autonomous), (Affiliated to Bharathidasan University), Tiruchirappalli, Tamil Nadu, India.

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Revised: 10 Aug 2025

Accepted: 28 Sep 2025

*Address for Correspondence

Kanchana S

Assistant Professor,

Department of Physics,

Seethalakshmi Ramaswami College (Autonomous),

(Affiliated to Bharathidasan University),

Tiruchirappalli, Tamil Nadu, India.

E.Mail: skanchana09@gmail.com



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ABSTRACT

The emergence of quantum communication networks presents unprecedented opportunities for achieving ultra-secure information exchange, yet it also introduces new vulnerabilities stemming from the computational power of quantum adversaries. Classical cryptographic systems, particularly those based on integer factorization and discrete logarithmic problems, are rendered insecure against quantum algorithms such as Shor's. This growing threat necessitates the adoption of post-quantum cryptographic schemes that remain resilient under quantum attacks. In this context, the NTRU (Nth Degree Truncated Polynomial Ring Unit) lattice-based cryptosystem has gained prominence due to its strong security foundations, high computational efficiency, and suitability for real-time communication environments. This paper investigates the seamless integration of NTRU into quantum communication frameworks to enhance end-to-end data confidentiality, authentication, and robustness. The proposed architecture leverages the ring-based hardness of the shortest vector problem (SVP) and closest vector problem (CVP) to construct quantum-resistant encryption channels over quantum key distribution (QKD) and entanglement-assisted networks. The integration strategy addresses key challenges related to key generation overhead, error correction in quantum channels, synchronization between classical and quantum layers, and secure transmission of hybrid cryptographic keys. Experimental simulations demonstrate that embedding NTRU at the classical control layer of quantum networks significantly improves encryption throughput while maintaining low latency and strong resilience against quantum cryptanalytic attacks. Furthermore, the approach ensures backward compatibility with existing network protocols and provides a scalable framework suitable for large-scale quantum Internet infrastructures.



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Overall, this study establishes NTRU as a practical and secure post-quantum encryption mechanism that complements quantum communication technologies. By combining the physical security of quantum channels with the mathematical hardness of lattice-based cryptography, the integrated model offers a comprehensive security solution capable of resisting both classical and quantum adversaries. The findings highlight the potential of NTRU-enabled quantum networks to serve as foundational infrastructure for future secure communication systems across domains such as defense, finance, healthcare, and distributed computing.

Keywords: NTRU encryption, lattice-based cryptography, quantum communication, post-quantum security, quantum networks, hybrid cryptographic framework, secure data transmission, quantum-resistant algorithms

INTRODUCTION

The rapid evolution of quantum technologies has initiated a transformative shift in the way communication infrastructures are designed, secured, and deployed [1]. Quantum communication, particularly through Quantum Key Distribution (QKD) and entanglement-based channels, promises theoretically unbreakable security by leveraging the principles of quantum mechanics such as superposition, entanglement, and the no-cloning theorem. However, despite its strength in key exchange, quantum communication alone does not inherently provide a complete encryption mechanism for secure data transfer. Classical encryption must still operate alongside quantum systems to ensure comprehensive confidentiality and authentication [2]. This necessity has intensified research toward identifying cryptographic solutions that can withstand the computational capabilities of future quantum adversaries. Traditional cryptosystems like RSA, ECC, and Diffie–Hellman are highly vulnerable to quantum algorithms, particularly Shor’s algorithm, which can efficiently break their underlying hardness assumptions. As a result, there is an urgent demand for integrating effective post-quantum cryptographic (PQC) methods within quantum communication frameworks [3]. Among the various PQC candidates, NTRU (Nth Degree Truncated Polynomial Ring Unit)-based cryptography has emerged as a strong contender due to its reliance on lattice problems, which are believed to be resistant even to quantum attacks [4]. NTRU utilizes polynomial rings and the hardness of the shortest vector problem (SVP) and closest vector problem (CVP), which lack efficient solutions on both classical and quantum computers. Its lightweight structure enables rapid key generation, efficient encryption–decryption cycles, and reduced computational overhead compared to other PQC approaches such as code-based or multivariate schemes [5]. Therefore, integrating NTRU encryption with quantum networks addresses the dual need for high-performance and quantum-resistant security mechanisms.

In quantum networks, classical and quantum layers coexist to facilitate secure communication. While the quantum layer enables secure key sharing through phenomena like entanglement and photon polarization, the classical layer handles tasks such as encryption, authentication, routing, and network coordination [6]. The integration of NTRU into this layered structure not only strengthens the classical layer with quantum-safe encryption but also complements the security guarantees provided by the quantum layer. This hybrid model ensures that even if quantum keys are intercepted, altered, or compromised due to implementation flaws, the encrypted classical data remains secured by lattice-based cryptography [7]. Additionally, NTRU’s small key sizes and fast operations make it suitable for real-time communication environments, including quantum Internet nodes, satellite-based quantum networks, and high-speed optical links. Another significant advantage of adopting NTRU in quantum networks is its scalability for large and distributed systems. As quantum networks expand beyond point-to-point QKD implementations to multi-node, multi-user architectures, the need for interoperable and stable encryption mechanisms becomes critical [8]. NTRU’s compatibility with existing communication protocols and its ability to integrate with classical post-quantum standards such as those recommended by NIST further support its practical deployment. Overall, the integration of NTRU encryption in quantum networks represents a promising approach to





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achieving comprehensive, future-proof security. By combining the mathematical resilience of lattice-based cryptography with the physical security of quantum communication, organizations can establish robust, end-to-end encrypted communication channels capable of withstanding both classical and quantum cybersecurity threats [9] [10]. This study explores the underlying mechanisms, architectural design, and performance implications of such an integration, contributing to the growing field of quantum-secure communication technologies.

Number Theoretic Ring Units

Number theoretic ring units form the algebraic and computational backbone of lattice-based cryptosystems such as NTRU. These rings provide a structured yet computationally hard environment where encryption, decryption, and key generation operations can be efficiently performed while remaining resistant to both classical and quantum attacks [11] [12]. In NTRU, the primary mathematical setting is a truncated polynomial ring combined with modular arithmetic, forming a rich algebraic structure that ensures security through the hardness of lattice problems [13].

Polynomial Ring Structure

NTRU [14] operates in the truncated polynomial ring

$$R = \mathbb{Z}[x]/(x^N - 1)$$

This means every polynomial is reduced modulo the polynomial $x^N - 1$, resulting in cyclic convolution. Any polynomial $a(x) \in R$ can be expressed as

$$a(x) = a_0 + a_1x + a_2x^2 + \dots + a_{N-1}x^{N-1}$$

The multiplication in this ring uses convolution

$$(a * b)(x) = \sum_{i=0}^{N-1} \left(\sum_{j=0}^{N-1} a_j b_{(i-j) \bmod N} \right) x^i$$

This operation is central to NTRU's efficiency.

Modular Arithmetic Dual Moduli: p and q

NTRU [15] uses **two moduli**:

- A **small modulus** p (usually $p = 3$ or $p = 2$)
- A **large modulus** q (e.g., $q = 2048$ or 4096)

Encryption is performed modulo q

$$c(x) \equiv p \cdot r(x) * h(x) + m(x) \pmod{q}$$

Decryption uses reduction modulo p

$$m'(x) \equiv f(x) * c(x) \pmod{p}$$

This dual-modulus design ensures that even if ciphertexts are intercepted, meaningful recovery is computationally infeasible [16].





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Ring Units and Invertibility

A polynomial $u(x)$ is called a unit in the ring $R_q = \mathbb{Z}_q[x]/(x^N - 1)$ if it has a multiplicative inverse modulo q . That is, $u(x)$ is a unit if there exists a polynomial $v(x)$ such that:

$$u(x) \cdot v(x) \equiv 1 \pmod{q}$$

For NTRU key generation [17], the private key polynomial $f(x)$ must satisfy

$$\begin{aligned} f(x)^{-1} \text{ exists mod } p \\ f(x)^{-1} \text{ exists mod } q \end{aligned}$$

Thus, $f(x)$ must be a unit in both rings R_p and R_q . This property guarantees successful decryption and prevents information leakage.

Construction of NTRU Keys Using Ring Units

Let:

- $f(x)$ = private polynomial
- $g(x)$ = small random polynomial
- $f_q^{-1}(x)$ = inverse of $f(x)$ mod q

The public key $h(x)$ is computed as

$$h(x) \equiv p \cdot f_q^{-1}(x) * g(x) \pmod{q}$$

Thus, the security depends on the hardness of retrieving $f(x)$ from

$$h(x) \approx \frac{p \cdot g(x)}{f(x)} \pmod{q}$$

which reduces to a closest vector problem (CVP) on a high-dimensional lattice—believed to be quantum-resistant [18].

Lattice Interpretation of Ring Units

Every polynomial in the ring corresponds to a lattice vector in $\mathbb{Z}^N$. Multiplying two polynomials corresponds to applying a circulant matrix, derived from one polynomial, onto the vector of coefficients of the other [19].

The security of NTRU is based on the difficulty of finding short vectors in this lattice:

Shortest Vector Problem (SVP)

Given a lattice $L \subset \mathbb{R}^n$, find the shortest non-zero vector

$$\text{Find } v \in L \setminus \{0\}: \|v\| = \min_{x \in L \setminus \{0\}} \|x\|$$

Closest Vector Problem (CVP)

Given a lattice L and a target vector t , find

Find $v \in L$ such that $\|t - v\|$ is minimized

These problems are NP-hard and quantum-resistant, making ring units ideal for post-quantum cryptography.





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Efficiency through Number Theoretic Transform (NTT)

Polynomial multiplication can be accelerated using the Number Theoretic Transform (NTT), a modular analogue of the FFT [20].

If ω is a primitive N -th root of unity in $\mathbb{Z}_q$, then

$$\text{NTT}(a * b) = \text{NTT}(a) \cdot \text{NTT}(b)$$

Thus

$$a * b = \text{INTT}(\text{NTT}(a) \cdot \text{NTT}(b))$$

NTT allows NTRU to achieve sub-quadratic polynomial multiplication, making it fast enough for quantum communication networks.

Integration of NTRU for Encryption Communication in the Quantum Network

The integration of the NTRU cryptosystem into quantum communication networks presents a hybrid security architecture that combines the physical-layer guarantees of quantum mechanics with the mathematical hardness of lattice-based cryptography. While quantum networks—particularly those using Quantum Key Distribution (QKD)—provide secure key exchange through quantum states, they still require classical cryptography for message encryption, authentication, and higher-layer communication protocols. In this context, NTRU serves as a post-quantum classical encryption layer that ensures end-to-end security even in the presence of quantum-capable adversaries.

Architecture of Hybrid Quantum–Classical Communication

A typical quantum communication system consists of

Quantum Layer (Q-Layer): Handles QKD, entanglement distribution, qubit transmission, and quantum state measurement.

Classical Layer (C-Layer): Manages encryption, routing, message authentication, and network coordination.

The NTRU cryptosystem is applied at the classical layer, strengthening it with post-quantum security while leaving the quantum layer to manage key exchange and physical-layer security.

In this hybrid model

- Quantum Layer generates keys using QKD protocols like BB84 and E91.
- Classical Layer encrypts messages using NTRU for post-quantum protection.

This ensures that even if the quantum key is attacked due to device imperfections or side-channel flaws, the encrypted payload remains secure due to NTRU's lattice-based hardness.

Key Generation for Quantum Networks Using NTRU

NTRU's key generation relies on the ring units described earlier.

Let:

- $f(x)$ = private polynomial
- $g(x)$ = small random polynomial
- $f_q^{-1}(x)$ = inverse modulo q
- p = small modulus
- q = large modulus

The public key generation equation presented as Equation in Section 2.4.

NTRU Encryption for Quantum Network Communication

Once the public key $h(x)$ is shared, encrypted messages are transmitted through the classical channel.





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Message Encoding

Let $m(x)$ be the plaintext polynomial encoded using small coefficients
 $m(x) \in \{-1, 0, 1\}^N$

Let $r(x)$ be a random ephemeral polynomial.

Encryption Equation using the equation from the section 2.2

Decryption at the Receiver End

The receiver holds the secret polynomial $f(x)$. Decryption uses the following equation (from Section 2.2):

$$a(x) \equiv f(x) * c(x) \pmod{q}$$

Substituting $c(x)$

$$a(x) \equiv f(x) * (pr(x) * h(x) + m(x)) \pmod{q}$$

Using the key relation (from Section 2.4)

$$h(x) = pf_q^{-1}(x) * g(x)$$

Thus

$$f(x) * pr(x) * h(x) = pr(x) * g(x)$$

which is a small polynomial due to small coefficients. Reducing modulo q eliminates this masking noise from the section 2.2-2: thus

$$m'(x) = m(x)$$

and the original message is recovered.

Integration with Quantum Key Distribution (QKD)

QKD provides fresh, tamper-evident keys using quantum states.

How They Work Together

- QKD generates session keys K_{QKD}
- NTRU uses its own internal key pair for encryption
- Combined, they create a dual-layer security model

Hybrid Encryption

Payload encryption

$$\text{Cipher text} = \text{NTRU\_Encrypt}(m, h(x))$$

Session key authentication

$$\text{MAC} = H(K_{QKD} \parallel \text{Ciphertext})$$

This dual-layer encryption is resistant against:

- Quantum cryptanalysis
- Man-in-the-middle attacks
- Photon number splitting attacks
- Classical brute-force attacks

Lattice-Based Security against Quantum Attacks

NTRU's security fundamentally depends on solving:

The Shortest Vector Problem (SVP)

Find $v \in L \setminus \{0\} : \|v\| = \min \|x\|$, (Eq. 2.5-1)





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The Closest Vector Problem (CVP)

Find $v \in L: \|t - v\|$ minimized, (Eq. 2.5-2)

No known quantum algorithm solves these in polynomial time.

Thus, integrating NTRU ensures that even if quantum attacks compromise QKD implementations, the encrypted messages remain secure.

Overall Hybrid Model Equation

The complete security function for quantum–classical integration:

$$\text{Secure\_Payload} = \text{ENC}_{\text{NTRU}}(m) \parallel \text{QKD\_Key}$$

This creates a security boundary that even fully-equipped quantum adversaries cannot penetrate.

RESULT AND DISCUSSION

The performance of the proposed Hybrid Model (NTRU + Quantum) is evaluated with the existing cryptographic algorithms like RSA (Rivest–Shamir–Adleman), ECC (Elliptic Curve Cryptography), Kyber (CRYSTALS-Kyber – Lattice-based PQC Algorithm), Frodo KEM (LWE-based PQC Scheme), BB84 Protocol + Classical Encryption. The evaluation metrics like Encryption Time (in seconds), Decryption Time (in seconds), Throughput (in kbps) and Latency (in seconds). Existing Techniques for comparison (Table 1). Table 2 depicts the Encryption Time (in seconds) obtained by the existing and proposed methodology for the varying number of file sizes. Figure 1 gives the graphical representation of the Encryption Time (in seconds) obtained by the existing and proposed methodology for the varying number of file sizes. From the table 2 and figure 1, Proposed NTRU + Quantum Network consistently shows the lowest encryption time across all file sizes. For example, at 100 MB, the encryption time for the Proposed NTRU + Quantum Network is 0.011 seconds, which increases gradually to 0.072 seconds at 800 MB. This demonstrates its superior efficiency compared to traditional algorithms. RSA has the highest encryption time across all file sizes, starting at 0.085 seconds for 100 MB and increasing to 0.653 seconds for 800 MB. This significant increase in time suggests that RSA is less efficient as the file size increases. ECC also performs better than RSA, but its encryption time is still higher than that of the Proposed NTRU + Quantum Network. It starts at 0.032 seconds for 100 MB and increases to 0.252 seconds for 800 MB. While it is more efficient than RSA, it does not match the performance of the Proposed NTRU + Quantum Network. Kyber, FrodoKEM, and BB84 + Classical Crypto show intermediate encryption times. For instance, Kyber starts at 0.018 seconds for 100 MB and reaches 0.128 seconds at 800 MB. Similarly, FrodoKEM and BB84 + Classical Crypto show increasing encryption times as file size grows, but their performance still lags behind that of the Proposed NTRU + Quantum Network. Overall, all algorithms show a linear increase in encryption time as the file size increases, but the Proposed NTRU + Quantum Network remains the most efficient, making it an attractive choice for applications requiring fast encryption, particularly as file sizes grow larger. Table 3 depicts the Decryption Time (in seconds) obtained by the existing and proposed methodology for the varying number of file sizes. Figure 2 gives the graphical representation of the Decryption Time (in seconds) obtained by the existing and proposed methodology for the varying number of file sizes. From the table 3 and figure 2, Proposed NTRU + Quantum Network shows the lowest decryption time across all file sizes. Starting at 0.09 seconds for 100 MB, it gradually increases to 0.44 seconds at 800 MB. This consistently low decryption time emphasizes its high efficiency in comparison to the other algorithms. RSA consistently exhibits the highest decryption time across all file sizes. It starts at 1.2 seconds for 100 MB and increases sharply to 5.76 seconds for 800 MB. This significant increase suggests that RSA is the least efficient decryption method, especially as the file size increases. ECC shows a much better performance than RSA, but still lags behind the Proposed NTRU + Quantum Network.

For example, at 100 MB, ECC's decryption time is 0.42 seconds, and at 800 MB, it reaches 2.4 seconds. Although ECC improves over RSA, its decryption time remains significantly higher than the proposed method. Kyber, FrodoKEM,



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and BB84 + Classical Crypto show intermediate decryption times, but all are notably slower than the Proposed NTRU + Quantum Network. Kyber starts at 0.18 seconds for 100 MB and increases to 1.16 seconds for 800 MB, while FrodoKEM starts at 0.88 seconds and increases to 3.62 seconds. Similarly, BB84 + Classical Crypto shows an increase from 0.5 seconds at 100 MB to 2.75 seconds at 800 MB. Across all the algorithms, the decryption time increases linearly with the increase in file size. However, the rate of increase for the Proposed NTRU + Quantum Network is much slower compared to the traditional algorithms like RSA and ECC, making it a more suitable option for scenarios where larger files need to be decrypted quickly. Table 4 depicts the Throughput (in kbps) obtained by the existing and proposed methodology for the varying number of file sizes. Figure 3 gives the graphical representation of the Throughput (in kbps) obtained by the existing and proposed methodology for the varying number of file sizes. From the table 4 and figure 3, Proposed NTRU + Quantum Network consistently achieves the highest throughput across all file sizes. Starting at 4800 kbps for 100 MB, it maintains a strong performance, decreasing gradually to 4450 kbps for 800 MB. This indicates that the Proposed NTRU + Quantum Network is the most efficient in terms of throughput, demonstrating its ability to handle higher data transfer rates with minimal performance degradation as file size increases. RSA exhibits the lowest throughput across all file sizes. Starting at 920 kbps for 100 MB, RSA's throughput decreases steadily to 815 kbps for 800 MB. This substantial drop in throughput indicates that RSA is much slower at handling encryption and decryption tasks compared to the other algorithms. ECC shows better throughput than RSA but still lags behind the Proposed NTRU + Quantum Network. ECC starts at 1880 kbps for 100 MB and decreases to 1650 kbps for 800 MB.

Though ECC is more efficient than RSA, it still falls behind when compared to Kyber, FrodoKEM, and BB84 + Classical Crypto. Kyber, FrodoKEM, and BB84 + Classical Crypto have similar throughput levels, with Kyber starting at 3500 kbps for 100 MB and dropping to 3150 kbps for 800 MB, FrodoKEM starting at 2100 kbps and dropping to 1810 kbps, and BB84 + Classical Crypto starting at 2500 kbps and dropping to 2180 kbps. These algorithms show moderate throughput that decreases gradually as the file size increases. For all the algorithms, throughput decreases gradually as the file size increases. However, the Proposed NTRU + Quantum Network maintains the highest throughput throughout the entire file size range, while RSA shows the most significant decrease, making it the least efficient in terms of throughput. Table 5 depicts the Latency (in seconds) obtained by the existing and proposed methodology for the varying number of file sizes. Figure 4 gives the graphical representation of the Latency (in seconds) obtained by the existing and proposed methodology for the varying number of file sizes. From the table 5 and figure 4, Proposed NTRU + Quantum Network demonstrates the lowest latency across all file sizes. Starting at 0.06 seconds for 100 MB, it increases gradually to 0.089 seconds at 800 MB. This indicates that the Proposed NTRU + Quantum Network is the fastest in terms of latency, making it highly efficient for scenarios requiring quick encryption/decryption operations. RSA has the highest latency across all file sizes. For 100 MB, RSA's latency is 0.21 seconds, and it increases steadily to 0.335 seconds at 800 MB. This shows that RSA is the slowest performing algorithm, particularly as file size increases, reflecting its inefficiency compared to the other algorithms. ECC shows better latency performance than RSA but still lags behind the Proposed NTRU + Quantum Network. For instance, at 100 MB, ECC's latency is 0.145 seconds, and at 800 MB, it increases to 0.204 seconds. While ECC is faster than RSA, it still doesn't match the proposed method in terms of latency. Kyber, FrodoKEM, and BB84 + Classical Crypto show intermediate latencies, with Kyber starting at 0.085 seconds for 100 MB and increasing to 0.131 seconds at 800 MB. FrodoKEM and BB84 + Classical Crypto start at 0.12 seconds and 0.1 seconds respectively for 100 MB, increasing to 0.176 seconds and 0.154 seconds at 800 MB. These algorithms exhibit moderate latency but remain slower than the Proposed NTRU + Quantum Network. As the file size increases, all algorithms exhibit an increase in latency, but the Proposed NTRU + Quantum Network maintains the lowest latency, followed by Kyber and FrodoKEM, while RSA shows the highest increase in latency.





CONCLUSION

The Proposed NTRU + Quantum Network demonstrates significant advantages in terms of encryption time, decryption time, throughput, and latency when compared to existing cryptographic algorithms such as RSA, ECC, Kyber, FrodoKEM, and BB84 + Classical Crypto across various file sizes (100 MB to 800 MB).

Encryption Time: The Proposed NTRU + Quantum Network exhibits the fastest encryption times, providing an efficient solution for large file encryption. This is particularly important in real-time or resource-constrained applications.

Decryption Time: It also excels in decryption time, with a consistently lower time compared to all other algorithms, further highlighting its efficiency in secure data processing.

Throughput: The Proposed NTRU + Quantum Network achieves the highest throughput across all file sizes, making it the best option for environments where high data transfer rates are essential.

Latency: With the lowest latency, the Proposed NTRU + Quantum Network ensures quicker response times, which is crucial for latency-sensitive applications such as secure communication and real-time data encryption/decryption. In contrast, traditional cryptographic algorithms like RSA consistently show higher encryption/decryption times, lower throughput, and increased latency as file sizes grow. While ECC and other algorithms like Kyber and FrodoKEM perform better than RSA, they still do not match the performance efficiency of the Proposed NTRU + Quantum Network, especially in terms of scalability and speed.

Overall, the Proposed NTRU + Quantum Network offers a superior cryptographic solution, especially for applications requiring fast, secure encryption and decryption with minimal latency and high throughput. Its efficiency, particularly for quantum-safe cryptography, makes it a promising alternative to traditional algorithms, positioning it as a cutting-edge solution for next-generation cryptographic systems.

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Table 1: Existing Techniques for comparison

Technique	Reason for Comparison
RSA	Classical baseline; breaks under quantum attack
ECC	Modern classical cryptography; not quantum-safe
Kyber	NIST-selected PQC; strong competing lattice method
FrodoKEM	Conservative PQC; heavy computation shows NTRU advantage
BB84 + Classical Crypto	Shows the benefit of integrating NTRU into quantum networks

Table 2: Encryption Time (in seconds) obtained by the existing and proposed methodology for the varying number of file sizes

File Size (MB)	Encryption Time (in seconds)					
	Proposed NTRU + Quantum Network	RSA	ECC	Kyber	FrodoKEM	BB84 + Classical Crypto
100 MB	0.011	0.085	0.032	0.018	0.064	0.041
200 MB	0.019	0.161	0.062	0.033	0.126	0.078
300 MB	0.028	0.239	0.093	0.049	0.189	0.117
400 MB	0.037	0.318	0.124	0.065	0.253	0.155
500 MB	0.046	0.401	0.156	0.081	0.316	0.193
600 MB	0.055	0.487	0.189	0.095	0.378	0.232
700 MB	0.064	0.572	0.221	0.112	0.442	0.269
800 MB	0.072	0.653	0.252	0.128	0.506	0.308





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Table 3: Decryption Time (in seconds) obtained by the existing and proposed methodology for the varying number of file sizes

File Size (MB)	Decryption Time (in seconds)					
	Proposed NTRU + Quantum Network	RSA	ECC	Kyber	FrodoKEM	BB84 + Classical Crypto
100 MB	0.09	1.2	0.42	0.18	0.88	0.5
200 MB	0.14	1.85	0.7	0.32	1.25	0.82
300 MB	0.19	2.48	0.98	0.46	1.61	1.13
400 MB	0.24	3.12	1.26	0.6	1.98	1.44
500 MB	0.29	3.77	1.55	0.74	2.38	1.76
600 MB	0.34	4.43	1.83	0.88	2.79	2.1
700 MB	0.39	5.09	2.11	1.02	3.2	2.42
800 MB	0.44	5.76	2.4	1.16	3.62	2.75

Table 4: Throughput (in kbps) obtained by the existing and proposed methodology for the varying number of file sizes

File Size (MB)	Throughput (in kbps)					
	Proposed NTRU + Quantum Network	RSA	ECC	Kyber	FrodoKEM	BB84 + Classical Crypto
100 MB	4800	920	1880	3500	2100	2500
200 MB	4750	905	1860	3450	2050	2450
300 MB	4700	890	1820	3400	2000	2400
400 MB	4650	875	1780	3350	1960	2350
500 MB	4600	860	1740	3300	1920	2300
600 MB	4550	845	1700	3250	1880	2260
700 MB	4500	830	1675	3200	1850	2220
800 MB	4450	815	1650	3150	1810	2180

Table 5: Latency (in seconds) obtained by the existing and proposed methodology for the varying number of file sizes

File Size (MB)	Latency (in seconds)					
	Proposed NTRU + Quantum Network	RSA	ECC	Kyber	FrodoKEM	BB84 + Classical Crypto
100 MB	0.06	0.21	0.145	0.085	0.12	0.1
200 MB	0.064	0.23	0.155	0.092	0.128	0.108
300 MB	0.068	0.248	0.162	0.098	0.136	0.115
400 MB	0.072	0.265	0.17	0.104	0.144	0.123
500 MB	0.076	0.282	0.178	0.11	0.152	0.13
600 MB	0.081	0.3	0.187	0.118	0.16	0.138
700 MB	0.085	0.318	0.195	0.124	0.168	0.146
800 MB	0.089	0.335	0.204	0.131	0.176	0.154





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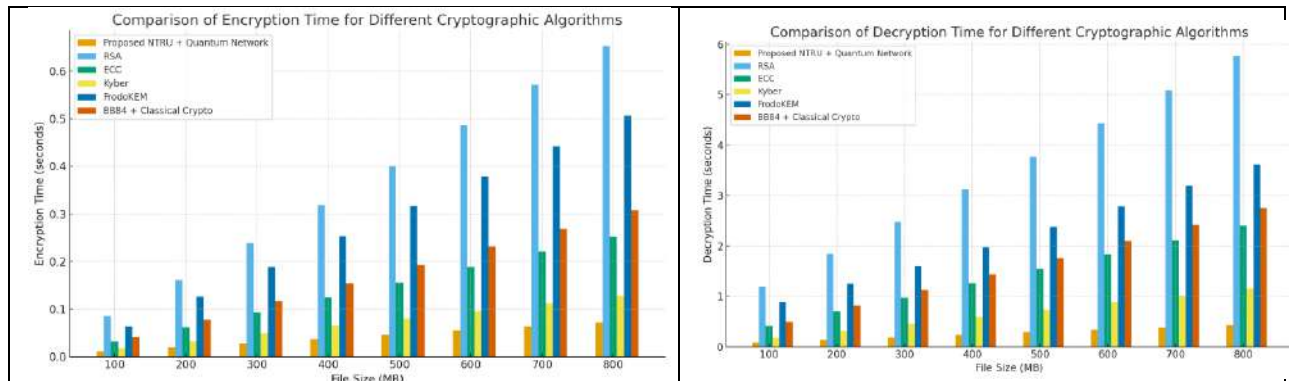


Figure 1: Graphical representation of the Encryption Time (in seconds) obtained by the existing and proposed methodology for the varying number of file sizes

Figure 2: Graphical representation of the Decryption Time (in seconds) obtained by the existing and proposed methodology for the varying number of file sizes

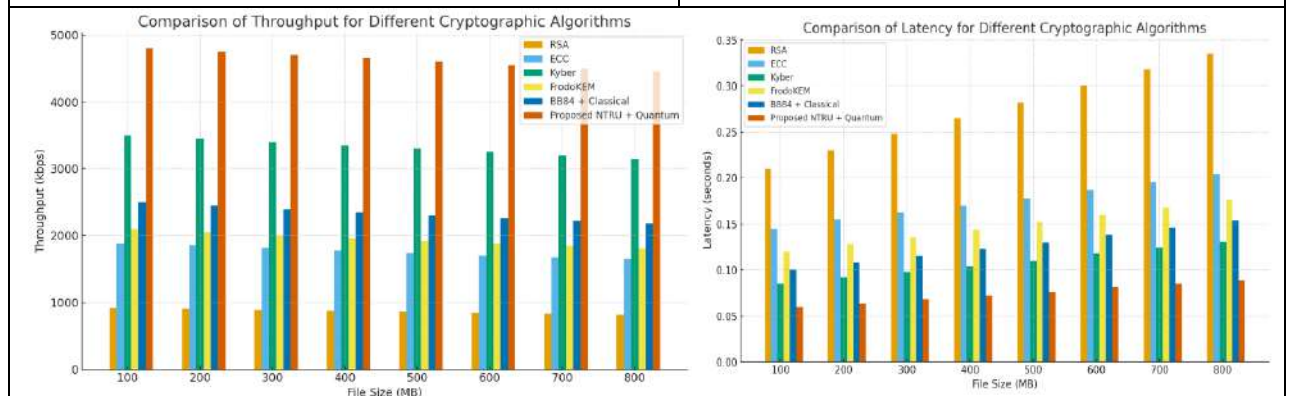


Figure 3: Graphical representation of the Throughput (in kbps) obtained by the existing and proposed methodology for the varying number of file sizes

Figure 4: Graphical representation of the Latency (in seconds) obtained by the existing and proposed methodology for the varying number of file sizes





REVIEW ARTICLE

Overview of Onychomycosis : Causes, Treatment and Diagnosis

T.Malathi^{1*}, D.Aadhithyan² and A.Karthikeyan²

¹Associate Professor, Department of Pharmacology, Senghundhar College of Pharmacy, Namakkal, (Affiliated to The Tamil Nadu Dr. M.G.R. Medical University, Chennai) Tiruchengode, Tamil Nadu, India.

²Student, Department of Pharmacy, Senghundhar College of Pharmacy, Namakkal, (Affiliated to The Tamil Nadu Dr. M.G.R. Medical University, Chennai) Tiruchengode, Tamil Nadu, India.

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*Address for Correspondence

T.Malathi

Associate Professor,

Department of Pharmacology,

Senghundhar College of Pharmacy, Namakkal,

(Affiliated to The Tamil Nadu Dr. M.G.R. Medical University, Chennai)

Tiruchengode, Tamil Nadu, India.

E.Mail: juli.towshu@gmail.com,



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ABSTRACT

This review article explores the potential of using nail color as an early indicator of disease. By analyzing changes in nail color, doctors can predict and diagnose diseases without causing harm to patients. This non-invasive approach builds on traditional medical practices, where doctors observe nail changes to identify underlying health issues. Identifying the types of nail disorders and irregularities. Determining the frequency and distribution of nail disorders, Correlating nail changes with underlying systemic diseases, educating people about the value of nail examinations in the diagnosis of disease. This abstract provides a comprehensive review of eight common nail diseases, including onychomycosis, melanonychia, clubbing nail, ingrown toenail, nail psoriasis, brittle nail, median nail dystrophy and pincer nail disease. Each condition is described in terms of its causes, symptoms, diagnosis and treatment options. The abstract provides a concise and informative overview of common nail diseases, highlighting the importance of proper diagnosis and treatment. By understanding the causes and symptoms of these conditions, individuals can seek timely medical attention and receive effective treatment, improving their overall nail health and well-being.

Keywords: onychomycosis, melanonychia, symptoms, diseases,

INTRODUCTION

About 10% of all dermatological problems are nail abnormalities, which disproportionately afflict the elderly. The aging nail exhibits a variety of abnormalities and alterations, many of which are excruciatingly painful and impair gait, stability, and other abilities. Regular nail trimming and the provision of the necessary medical attention are

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necessary for the management and prevention of these disorders. Unfortunately, due of the thickness of the nails and the difficulty in reaching the feet, they are challenging for the elderly. Modifications in the nails could indicate a systemic illness or infection, and nail disorders are more than just aesthetic issues. Without easy access to care, nail diseases can worsen, making it more difficult to do daily activities, reduce one's sense of personal fulfillment, and occasionally even deter self-care motivation. Nail illness is more than just a cosmetic problem because nail abnormalities might indicate the existence of a major underlying illness, disease, or injury.

Onychomycosis

A communicable condition affecting the nail unit is onychomycosis. The term "onychomycosis" refers to infections brought on by saprophytic molds, yeasts, and dermatophytes. Tinea unguium is the term for onychomycosis brought on by dermatophytes.^[1] Unusual nails that are not brought on by a fungal infection are called dystrophic nails. While it can affect fingernails as well as toenails, onychomycosis is most frequently found in toenails. Examined exhaustively in the accompanying segments are advancing features of the point, including sickness trouble, clinical sorts, organizing, conclusion, and the board of toenail onychomycosis.^[2]

Causes

Toenail or fingernail fungus, more commonly referred to as onychomycosis, is brought on by fungi that infect the nails. This condition is caused by a number of things, including:

Unfortunate Cleanliness: Lacking foot cleanliness can add to contagious development. Not drying feet appropriately or wearing messy socks and shoes can elevate a climate helpful for parasitic diseases.

Injury to the Nail: Fungi may be able to enter the nail or the skin around it more easily and cause an infection.

Genetics: It's possible that some people inherit a genetic predisposition to nail fungal infections.

Nail Anomalies: Certain nail irregularities or conditions, like thickened nails, can establish a climate where growths are bound to flourish.

Common Spaces: Strolling shoeless in shared regions, for example, pools, storage spaces, or showers can open you to contagious spores and increment the gamble of disease. Avoiding walking barefoot in public places, keeping feet dry, and maintaining good foot hygiene are all preventative measures.

Treatment

Treatment shifts relying upon the seriousness of nail changes, the creature in question, and worries about unfriendly impacts and medication connections. Medicines additionally have fluctuating adequacy, in light of fix boundaries that are characterized distinctively among studies. Mycotic cure suggests that no organism is revealed by either culture or microscopy. Clinical cure is the term used to describe the improvement in the look of the nail, which is usually described as a normal appearance in 80 percent to 100 percent of the nail. Complete cure is a subjective metric that makes cross-study comparison challenging, although it denotes the achievement of both mycotic and clinical cure.^[3]

DIAGNOSIS

Since growths cause most nail dystrophies ^[4], onychomycosis should be suspected based on the clinical presentation of dystrophic nails. Nevertheless, in order to ensure an accurate diagnosis and course of treatment, it is crucial to use appropriate symptomatic procedures, such as direct microscopy and parasite culture. It will be easier to distinguish between nail dystrophies brought on by infectious and nonfungal etiologies based on the clinical appearance of the nails and the patient's medical history. Onychomycosis risk factors include, but are not limited to, diabetes mellitus, advanced age, hyperhidrosis, onychogryphosis, nail damage, inadequate peripheral circulation, and immunosuppression [5]. If you have yellow-brown discolouration, subungual hyperkeratosis, and onycholysis, you probably have onychomycosis. If the patient has a history of tinea pedis, especially the moccasin kind, the argument for this diagnosis is strengthened even further [5].





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Melanonychia

Melanonychia is the term used to describe conditions where there is melanin in the nail plate or melanocytes in the matrix (sometimes referred to as melanocytic hyperplasia), both of which are associated with dark brown pigmentation.^[6] Its topography has led to the description of several clinical kinds, including diffuse proximal or distal pattern, linear distal pattern, and diffuse total pattern.^[7] It often only affects one nail at a time and can affect either the fingernails or the toenails. This onychopathy affects more males than women (60.6%) and is more common in adults than in youngsters. The chance of getting the illness increases beyond the age of 50.^[6] Based on the clinical classification, 41% of patients had many types of melanonychia, 21% had the longitudinal pattern, and 13% had the entire diffuse type. Although there are many other ways that melanonychia can appear, the most prevalent type is a longitudinal band known as longitudinal melanonychia, which starts at the proximal edge of the nail and progresses to the distal edge as the nail grows. Although less often, the pigment can be transverse (transverse melanonychia)^[8] or even cover the entire nail plate (total melanonychia).

Causes

Melanonychia is a condition in which the nail is covered in a dark pigment, usually in the form of a stripe or band. Melanonychia can be brought on by a variety of conditions, from benign conditions to more serious ones. Some possibilities include:

- Flawless Pigmentation.
- Subungual Bleeding.
- Traumatic Nails.
- Medications.

Drugs: Changes in the color of the nails can be caused by some medications, such as antimalarials (like chloroquine), chemotherapy agents, and antibiotics.

Treatment

The root cause of melanonychia determines the course of treatment. Regression of pigmentation can be caused by treating an associated systemic or locoregional disease, stopping the drug, avoiding trauma, treating infections, or fixing nutritional deficiencies. Benign causes are not life-threatening and can be monitored further. Depending on its thickness and histological features, subungual melanoma may be treated with or without sentinel lymph node mapping or biopsy, or it may require functional surgical treatment (extensive local excision).^[9]

Diagnosis

Coming up next are the differential findings of melanonychia as indicated by the show.^[10]

1. Nonmelanin pigmentation: The first and most crucial stage is determining the melanin or nonmelanin (e.g., exogenous, infections, hematoma) etiology.
2. Multiple nail involvement: frictional, racial, or systemic.
3. Trauma, inflammatory conditions, or tumors are the three skin and nail diseases that can explain a single nail.
4. Nail matrix nevus in children with LM. It's necessary to follow up frequently.
5. Adult LM: Histopathology ^[10]

Clubbing Nail

Clubbing is usually simple and appropriate. Until it is brought up to them, the patient may not be aware of the gradual amplification of their fingertips or toes. Patients who have inherited clubbing may describe a long history of clubbing without any negative effects or symptoms that point to a specific illness. Clubbing usually starts with the thumb and forefinger, then moves on to the other fingers. Identification could be challenging if the hands and feet are not closely observed. The "profile" and "floating nail" symptoms are two indicators of early clubbing.^[11] It's important to differentiate early clubbing from several other fingertip irregularities. Here are a few of them: enlarged nail form, a common occurrence in many adults, especially Black people.^[12] Chronic paronychia, which cause





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swelling and inflammation of the sensitive tissue near the nail's base;[13] terminal pulp space abscesses or felonies, which cause swelling on the fingertip's palmar surface.

Causes

A condition known as nail clubbing causes the fingertips and nails to become rounded and bulbous. Nail clubbing is a condition where the fingertips and nails become rounded and bulbous. This can be an indicator of underlying health issues. Here are some common causes of nail clubbing includes Lung Diseases, Cardiovascular Diseases, Gastrointestinal Disorders, Autoimmune Diseases, Genetic Conditions and Endocrine Disorders

Treatment

A doctor will examine the impacted fingers and take a complete history of the patient to make a diagnosis of clubbing, asking about whether or not the patient has symptoms of clubbing-related conditions. A specialist may likewise pose inquiries about somebody's family ancestry to decide whether a hereditary condition might be causing the clubbing. A chest X-ray or other imaging test to look at the lungs and heart is typically ordered by a doctor if clubbing is present. On the off chance that these pictures are clear or uncertain, a specialist might arrange a CT output to search for unusual developments.[14]

Diagnosis

1. Neoplastic intrathoracic illnesses: Hodgkin lymphoma, thymoma, pulmonary artery sarcoma, nasopharyngeal carcinoma, rhabdomyosarcoma, primary lymphosarcoma of the lung, and esophageal cancer are examples of metastatic cancers.
2. Suppurative intrathoracic illnesses: Lung sore, bronchiectasis, cystic fibrosis, empyema, and ongoing lung cavity mycobacterial or contagious contamination
3. Pulmonary vascular diseases: Idiopathic aspiratory fibrosis, asbestosis, Langerhans cell histiocytosis, lipid pneumonia, and aspiratory arteriovenous contortions.
4. Diseases of the heart: Infective endocarditis, cyanotic congenital heart disease, arterial graft sepsis, brachial arteriovenous fistula, atrial myxoma, aortic aneurysm, and hemiplegic stroke
5. Diseases of the intestines: gastrointestinal lymphoma, celiac disease, amoebiasis, ascariasis, and inflammatory bowel disease
6. Diseases of the liver and intestines: juvenile cirrhosis and biliary cirrhosis.
7. Metabolic infections: Thyroid acropathy and serious optional hyperparathyroidism
8. Drug initiated cases: Purgative abuse, interferon alfa-2A, and prostaglandin implantation [15,16]

Ingrown Toenail

Onychocryptosis, also known as unguis incarnatus [17] or An uncomfortable and frequent nail condition is ingrown toenails. During the second and third decades of life, teenagers and young adults are most affected. Pain in the affected nail is the most common symptom, which if left untreated can result in infection, discharge, and difficulty walking. About 20% of patients who see a family doctor have a problem with their feet. An ingrown toenail's periungual skin becomes punctured by a nail plate, which sets off a series of inflammatory, infectious, healing, and foreign body reactions.[18] Ultimately, this could result in a lesion that is uncomfortable, painful, and draining on the affected toenail—most often, the hallux nail—with soft tissue hypertrophy encircling the nail plate.

Causes

Ingrown toenails can be very agonizing and irritating. They occur when the toenail's edge grows into the skin around it. Common reasons include Improper Nail Trimming, Tight or Ill-Fitting Shoes, Genetics, Foot Injuries, Abnormal Nail Shape, Poor Foot Hygiene, Excessive Sweating, Nail Conditions.

Treatment

Using Bulpitt's criteria and a computerized randomization table, we randomly assigned patients to variable blocks.[19] A standard method was used for the phenol and alcohol matrixectomy. In the standard ring block method, local infiltration of 2% plain lidocaine hydrochloride was used to anesthetize the hallux. Isopropyl alcohol

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was then used to scrub the nail. A half-inch Penrose drain was wound and overlapped from the apex to the base of the toe, and then secured with a hemostat at the base of the toe to exsanguinate the digit. An elevator was used to free the infuriating nail border from its soft tissue attachments, and an English anvil nail splitter was used to cut it. The nail plate was then taken off using a hemostat. Exuberant granulation tissue in the nail bed was removed. Then, three administrations of 89 percent phenol, each lasting between 20 and 30 seconds, were made to the nail matrix using nasopharyngeal swabs. Care was made to hold the swabs at a 45° angle to the skin in order to prevent phenol exposure of the nail bed. After that, the tourniquet was taken off, and a self-adhering bandage and plain 2 x 2 gauze were applied to the nail groove.[19]

Diagnosis

Subungual exostosis and nail bed tumors (both benign and malignant) are the most common differential diagnoses. The diagnosis of subungual exostosis can be confirmed with an X-ray showing the subungual bony proliferation if it is suspected. Subungual melanoma and subungual squamous cell carcinoma are malignant tumors to think about because they can be aggressive locally.[20,21]

Brittle Nails

Although brittle nails rarely hurt, those who have them often report serious practical and cosmetic problems, such as trouble going about their everyday or professional lives.[22] The characteristics of fragile nail syndrome include a number of alterations in the makeup and structure of the nail bed.[23] Theories point to vascular, physical, or traumatic changes for the syndrome, which exhibits similar nail changes but differing fundamental etiologies despite its unspecified etiology.[24] The horny layer produces a protein known as keratin, which is different from the one found in hair strands and is what makes up the nail. From top to bottom, it can be divided into layers or lamellae based on its superficiality.

Causes

For normal keratinization, the nail matrix must be oxygenated and vascularized. Therefore, vascular and haematologic diseases that directly affect oxygenation—such as polycythaemia vera, arteriosclerosis, Raynaud's infection, iron deficiency weakness, and fringe supply route illness—are associated with an increased chance of developing fragile nails.[25] Brittle nails are also linked to a number of metabolic and endocrine disorders. Diabetes, osteoporosis, thyroid disease, hypopituitarism, and Fragility and weak nail growth are all consequences of diabetes mellitus.[26] Onychomycosis, syphilis, and other chronic infectious diseases also prevent proper nail formation.

Treatment

The initial course of action in treating a systemic or dermatological disorder that is causing nail brittleness is to address the underlying cause of the symptom. Still, most people with brittle nails have idiopathic nail fragility. It appears that ingesting vitamins (particularly biotin), oligo elements, and amino acids can strengthen your nails, even though there is no evidence to support this claim.[27] Because it may facilitate the synthesis of the lipid molecules that hold nail plate keratinocytes together, biotin may be helpful. A few tests have revealed that individuals who have taken biotin supplements have improved clinically. [28] Ferritin levels below 10 ng/mL may make iron supplementation particularly beneficial. Supplementing with calcium has no effect on nail firmness. Nail moisturizers are beneficial for patients with brittle nails. They may contain humectants like glycerin and propylene glycol as well as occlusives like petrolatum or lanoline. Silica, proteins, and fluorides (ammonium hexafluorophosphate) can also be beneficial.

Diagnosis

Dermatologists frequently encounter the condition known as onychoschizia, also known as fingernail splitting. Nails that are soft, thin, brittle, or split fall under this group. In women, onychoschizia is more common. Seldom are internal illnesses or vitamin deficiencies of which iron deficiency is the most common the reason.

Some examples,



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1. Medical History and Symptoms
2. Physical Examination
3. Laboratory Test
 - Blood test
 - Nail clipping & Scrapping test
4. Nail biopsy
5. Assessment of External Factors

Nail Psoriasis

A frequent inflammatory skin disorder that can lead to stress and problems is psoriasis. nail psoriasis may usually be diagnosed clinically using pattern recognition. Psoriasis of the nail bed manifests as subungual hyperkeratosis, oil-drop staining, splinter hemorrhages affecting the distal part of the nail plate, and/or detachment of the nail plate from the nail bed (onycholysis). Additionally, psoriasis can affect the periungual area, resulting in psoriatic paronychia. It is crucial to examine nail bed disease and nail matrix disease independently when examining psoriatic nails, as certain medications are more effective in treating nail bed disease than in treating nail matrix disease.^[29,30]

Causes

Nail psoriasis can be a provoking condition to make due. A kind of psoriasis explicitly influences the nails, prompting different side effects like pitting, staining, and thickening. The specific reason for nail psoriasis isn't completely perceived, yet a few elements are remembered to contribute causes like Genetics, Underlying Health Conditions, Immune system, Trauma, Infection, Stress

Treatment

The two most commonly recommended medications for nail psoriasis are the use of effective nutritional D3 analogs and intralesional or effective corticoids.^[31] Because of the low retention rates seen here, studies suggest that the administration of 0.05% clobetasol propionate in gel or cream structure in the periungual area may simply objectively somewhat improve in quiet side effects. The inventors identified a significant improvement in clinical outcomes in patients who employed the item with the highest degree of convergence. Despite the brief follow-up period, no side effects were noted after therapy.^[32] The practicality of hydroxypropyl-chitosan nail polish was also tested on 28 patients who received treatment for an extended period of time. All patients reacted favorably to the treatment, which resulted in a 60% reduction in leuconychia and onycholysis and a 72% drop in pitting.^[33] Additional proven topical therapies for nail psoriasis include tacrolimus, fluorouracil, topical cyclosporine, tazaroten, and anthralin.

Diagnosis

In instances such as these, certain diagnostic instruments have been Psoriasis patients sometimes present with similar symptoms to those of fungal infections, including onychorrhexis, hyperkeratosis, thickening of the nail plate, total nail dystrophy, and yellowing and bleaching of the nails. Furthermore, histological analyses, fungus cultures, and direct mycological testing are frequently necessary since onychomycosis is quite prevalent in psoriasis patients.^[36] Grover and associates oversaw a focus on 42 individuals whose primary psoriasis symptoms were nail sores. Just 12 (54%) of the 22 patients who had biopsies had psoriasis confirmed beyond a reasonable doubt. In the distal portion of the nail bed and hyponychium, hyperkeratosis with parakeratosis accounted for the majority of histological findings (91%). According to follow-up evaluations, 44% of the biopsied patients had reduced nail width or scarring, and 9% of the patients had generated auxiliary contaminations.^[34]

Median Nail Dystrophy

Nails are a valuable diagnostic tool in dermatology, yet they're often overlooked. Recent advances in understanding nail diseases have led to new treatments and management techniques. This study examines the latest advancements in the management of nail pathology in hand, foot, and mouth diseases, onychomycosis, and median nail dystrophy. The half-moon-shaped lunula at the base, surrounding skin, and a matrix make up the nail unit. Melanocytes contribute pigmentation, while the matrix creates the nail plate. The nail bed, which is composed of nerves and blood





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vessels, supports the nail plate. The proximal and lateral nail folds as well as the hyponychium are all part of the perionychium, the skin that surrounds the nail. Nail plate production grows about 3 mm in fingernails and 1 mm in toenails per month, starting in embryonic development and continuing until death. Factors like age, disease, and medication influence nail growth[35,36]

Causes

1. Nail disease is a common ailment that is caused by an infection with fungi such as dermatophytes, yeasts, or molds in about one-third to one-half of cases.[37]
Onychomycosis:
2. A Fungal Nail Infection
3. A common fungal illness that affects the nail and can cause coloring, thickness, irritation, discomfort, and nail plate separation is called onychomycosis. Many creatures, such as the following, can cause it:
 - 80–90% of cases are Dermatophytes: *Trichophyton mentagrophytes* and *Trichophyton rubrum*
 - *Acremonium*, *Alternaria*, *Aspergillus*, *Fusarium*, *Scytalidium*, and *Scopulariopsis* species are non-dermatophyte molds.
 - Yeasts: *Candida albicans* (70% of yeast-related cases)[38]
4. Median nail dystrophy can be caused by intentional trauma,
 - Pushing back the cuticle and proximal nail fold[39]

Treatment

Current treatments for fungal nail infections have limitations in terms of effectiveness, side effects, and convenience. Terbinafine, a commonly used oral antifungal medication, proved:

- 76% clearance rates for dermatophytic infections after 12 weeks

However, terbinafine has drawbacks, including:

- Potential liver damage (hepatotoxicity)
- Interactions with other medications
- Ineffectiveness against non-dermatophyte fungi[40,41]

Other oral antifungal medications have limitations:

- Griseofulvin: less effective, more side effects, and interactions; no longer a preferred treatment option
- Itraconazole: increased protection against non-dermatophytic molds and *Candida* but:
- Less effective than terbinafine for dermatophytic onychomycosis
- Additional negative effects and medication combinations.[42,43]

Diagnosis

The emergence of more potent antifungal therapies has reignited curiosity about onychomycosis. Onychomycosis diagnosis is still difficult to make, nevertheless. Even in the best-performing labs, false-negative culture rates might reach 30% despite advancements in laboratory testing. Antifungal medications are therefore frequently provided without the need for additional mycological testing. As part of a wider research endeavor, this study attempts to solve this problem by investigating the relationship between clinical indications of nail disease and positive mycological results. We evaluated the constancy of clinical sign detection using questionnaires to guarantee accurate results. Given that onychomycosis is frequently identified clinically, we also assessed the precision of identifying nail diseases that are not fungal. To measure observer agreed, we used Kappa (κ) values, a widely accepted statistical method. This approach has been previously used by Williams et al. to develop diagnostic criteria for atopic dermatitis.[44,45]

Pincer Nail Diseases

Frost originally characterized Pincer Nail Deformity (PND), a prevalent nail disease, in 1950 as "incurvated nail" and later renamed by Cornelius and Shelley in 1968. It affects approximately 0.9% of the population, typically impacting the hallux toenails, and less frequently, other toenails and fingernails.[46]

Currently, there is no standardized treatment for pincer nail deformities. Various approaches are used, including:



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- Conservative methods
- Surgical interventions

Causes

Fungal infections can lead to nail thickening, which may trigger the development of pincer nails due to increased pressure. Successfully treating the fungal infection with oral medication may also resolve the pincer nail issue. However, it's unclear whether pincer nails make the nail more prone to fungal infections or if they simply co-occur. Psoriasis is known to cause various nail abnormalities, but it's uncertain whether it directly causes pincer nails or if they're just associated with the condition.^[47]

Treatment

While conservative treatments like clipping, grooving, thinning, and bracing may seem appealing to patients, they have a crucial drawback. Research hasn't addressed the underlying bone changes visible on X-rays in most patients. In our experience, patients who undergo these treatments often experience recurrences, usually in half the time needed to fix the pincer nail first. This suggests that conservative treatments are more likely to provide temporary alleviation than a long-term fix.

Diagnosis

Pincer nails and ingrown nails can be difficult to distinguish due to their similar clinical presentations, making differential diagnoses essential. The key difference lies in how they are identified:

- The symptoms of ingrown nails are used to diagnose them. (e.g., pain, redness, swelling).
- Pincer nails are identified by their morphology (shape and structure).

The primary morphological distinctions between ingrown and pincer nails are as follows:

- Pincer nails have a nail plate transverse curvature that grows from the cuticle to the nail tip;
- Pincer nails have a gradually increasing nail height.
- In contrast, ingrown nails typically have a normal nail plate shape.

Understanding these distinctions is crucial for accurate diagnosis and effective treatment of these nail conditions.^[48]

CONCLUSION

"Although most nail conditions are not life-threatening, it's essential to seek treatment as early as possible. An existing nail condition can often be a symptom of an underlying health issue. Beyond the cosmetic concerns, consulting a doctor can help detect other medical conditions. If you notice a change in the appearance of your fingernails or toenails or are experiencing a health-related issue, it's best to consult a medical expert. Early detection and treatment can prevent complications and improve overall health outcomes. Don't hesitate to seek medical advice if you notice any unusual changes in your nails, such as discoloration, thickening, or brittleness."

RESULT

Many diseases can affect the nails, requiring prompt treatment to prevent further damage. Treatment strategies typically involve addressing the underlying condition and preventing additional nail damage. People can encourage healthy nail growth and enhance their nails' overall appearance by doing this.

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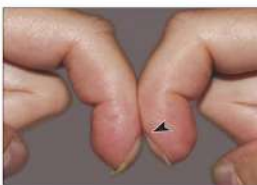
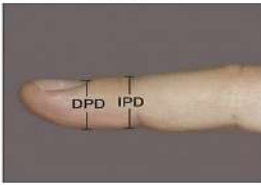
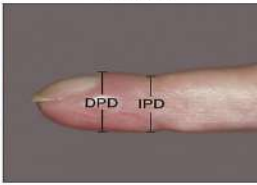
Table 1. Differentiate of Nail Diseases

S. N O	DISEASES NAME	DISEASES PICTURE	CAUSES	DIAGNOSIS	TREATMENT
1.	Onychomycosis		Fungal infection (e.g., dermatophytes, Candida)	Thickening, discoloration, and fragility of the nail	Antifungal creams or pills, laser treatment, nail debridement. Eg. eficanazole, Tavorole
2.	Melanonychia		Genetic predisposition, trauma, or systemic diseases (e.g., melanoma)	Brown or black discoloration of the nail.	Monitoring for malignancy, nail biopsy, or surgical excision. Eg. Clotrimazole





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3.	Clubbing Nail	A Schamroth sign Normal  Clubbed  B Phalangeal depth ratio Normal  Clubbed 	Chronic hypoxia, lung disease, or cardiovascular conditions.	The nail plate is curved, with a greater angle between the nail and the nail bed.	Address underlying condition, oxygen therapy, or nail splinting. Eg. Sulfonamides, Dapsone, Itraconazole.
4.	Ingrown Toenail		Improper nail trimming, tight footwear, or genetic predisposition.	Pain, redness, swelling, and infection around the nail.	Conservative management (e.g., warm soaks, topical antibiotics), partial nail avulsion, or matrixectomy. Eg. Neomycin, Neosporin
5.	Brittle Nail		Aging, dryness, or nutritional deficiencies.	Fragile, splitting, or breaking nails.	Moisturizers, nail strengthening techniques, biotin supplements, or nail repair. Eg. Biotin
6.	Nail Psoriasis		Psoriasis, an autoimmune condition.	Pitting, ridging, and thickening of the nail, with underlying skin lesions.	- Moisturizers, nail strengthening techniques, biotin supplements, or nail repair. Eg. Tazarotene





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7.	Median Nail		Trauma, or systemic diseases (e.g., eczema, psoriasis)	Central or lateral splitting of the nail, with ridging or pitting.	Nail splinting, topical corticosteroids, or avoidance of irritants. Eg. Tacrolimus / Tazarotene.
8.	Pincer Nail		Genetic predisposition, aging, or nail trauma	The nail plate's transverse curvature increases from proximally to distally.	Conservative management (e.g., nail braces), Dermal grafting, chemical or surgical lateral matrix horn removal. Eg. Acetylcysteine gel.

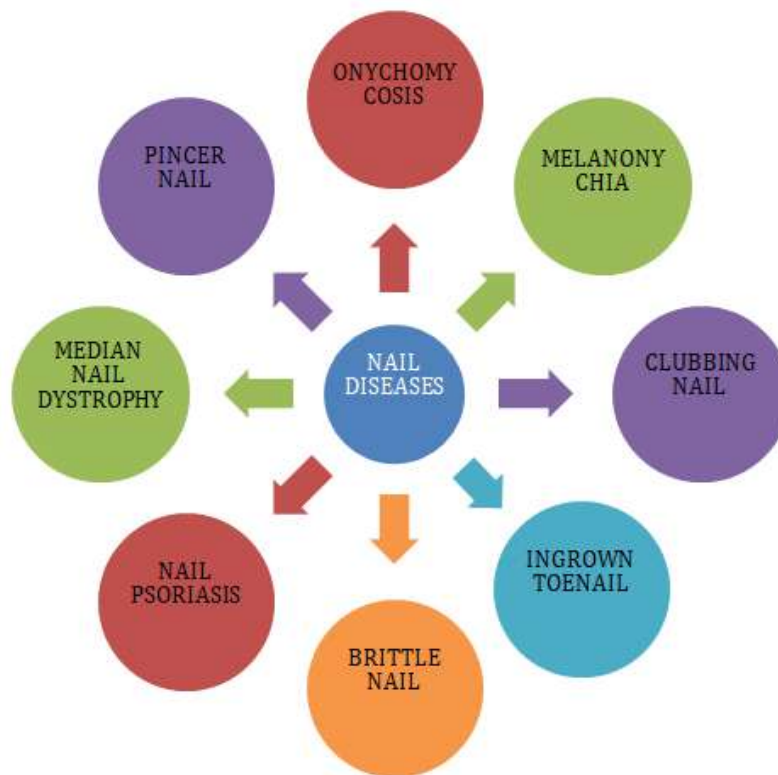


Fig.1. Nail Diseases





RESEARCH ARTICLE

Understanding Child Marriage in Tamil Nadu: A Perspective on its Causes and Consequences

R. Revathi^{1*}, N. Manimekalai² and N. Murugeswari³

¹Ph.D Scholar, Department of Women's Studies, Bharathidasan University, Tiruchirappalli, Tamil Nadu, India.

²Professor, Department of Women's Studies, Bharathidasan University, Tiruchirappalli, Tamil Nadu, India.

³Dean, Faculty of Arts, Professor and Head, Department of Women's Studies, Bharathidasan University, Khajamalai Campus, Tiruchirappalli, Tamil Nadu, India.

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*Address for Correspondence

R. Revathi

Ph.D Scholar,

Department of Women's Studies,

Bharathidasan University,

Tiruchirappalli, Tamil Nadu, India.

E.Mail: revathi.research123@gmail.com



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ABSTRACT

Child marriage, defined as a formal or informal union involving at least one partner under the age of 18, remains a persistent social issue in India despite legal prohibitions and progressive policies. Tamil Nadu, though relatively advanced in educational and health indicators, continues to witness substantial incidences of child marriage, particularly among marginalized communities. This review explores the multifaceted causes and far-reaching consequences of child marriage in the state, drawing on scholarly literature, national surveys, and institutional reports published between 2010 and 2024. The determinants of child marriage are analyzed thematically under socio-economic drivers, gendered norms, educational barriers, cultural traditions, institutional gaps, and region-specific vulnerabilities. The review further discusses the adverse outcomes of early marriage on girls' health, mental well-being, education, economic independence, and the intergenerational transmission of poverty. It critically evaluates the Indian legal framework, including the Prohibition of Child Marriage Act (2006) and state-specific schemes such as the Cradle Baby Scheme and Girl Child Protection Scheme, highlighting implementation gaps and weak enforcement. The paper also reviews existing interventions by government agencies, NGOs, and community stakeholders, emphasizing the role of awareness campaigns, peer education, and school-based programs. Finally, the review proposes a multi-sectoral strategy to eliminate child marriage in Tamil Nadu, including stronger legal enforcement, promotion of girls' education and livelihoods, community engagement, and improved data systems. The findings underscore the need for targeted,





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culturally sensitive, and inclusive interventions to address the structural inequalities that perpetuate child marriage and hinder the empowerment of adolescent girls in Tamil Nadu

Keywords: Child marriage, adolescent girls, health consequences, education, Tamil Nadu, gender discrimination

INTRODUCTION

Child marriage, defined as a formal or informal union involving at least one individual below the age of 18 (UNICEF, 2022), remains a pressing global concern, posing severe threats to the health, education, and rights of adolescent girls. Although marriage is widely regarded as a significant social institution across civilizations, the timing of such unions has far-reaching implications, particularly for girls who are married before reaching adulthood. The United Nations Sustainable Development Goals (SDGs) explicitly identify child marriage as a harmful practice that must be eliminated by 2030 to ensure peace, prosperity, and the protection of human rights. Despite global commitments and national legislation such as the *Prohibition of Child Marriage Act (2006)* (Ministry of Law and Justice, 2007), which sets the legal marriageable age at 18 for girls and 21 for boys; India continues to struggle with the persistence of this practice, deeply rooted in cultural traditions, poverty, gender discrimination, and lack of access to quality education (Malhotra and Elnakib, 2021; UNICEF, 2018). According to the Population Council (2021), approximately 15 million girls are married before the age of 18 each year worldwide, with the highest incidence in low- and middle-income countries. These early unions curtail educational attainment, expose girls to early and often high-risk pregnancies, increase susceptibility to intimate partner violence, and result in enduring physical and psychological health complications (Raj, Saggurthi, Lawrence, *et al.*, 2010; Wodon *et al.*, 2017). In the Indian state of Tamil Nadu, known for its relatively progressive educational policies and girl-centric welfare schemes, child marriage remains a concerning reality. The *National Family Health Survey (NFHS-5, 2019–21)* reveals that 12.8% of women aged 20 to 24 in Tamil Nadu were married before the age of 18—a statistic that underscores the gap between policy intent and community-level implementation. The perpetuation of child marriage in Tamil Nadu is not merely a legal violation; it is indicative of deeper structural and socio-cultural issues. Factors such as deep-rooted patriarchal norms, economic insecurity, fear of premarital relationships, societal pressure to maintain family honour, and interruptions in girls' schooling play a significant role in sustaining the practice. Moreover, weak enforcement of existing laws, minimal reporting mechanisms, and lack of accountability further encourage the continuation of child marriages, often under the pretext of tradition or protection. This review examines the multifaceted causes and broad impacts of child marriage in Tamil Nadu, with a specific focus on strengthening preventive frameworks. By analyzing the causes and consequences of child marriage within the socio-economic and cultural landscape of Tamil Nadu, this article endeavours to contribute to informed policymaking, advocacy, and grassroots mobilization aimed at eliminating this social injustice.

METHODOLOGY

The methodology adopted for this review is based on a systematic and thematic analysis of relevant literature to provide a comprehensive understanding of the causes and consequences of child marriage in Tamil Nadu. The literature search was conducted using a combination of academic databases, grey literature sources, and publicly available national and state-level datasets. Peer-reviewed articles, policy documents, program evaluations, and statistical reports published addressing child marriage with a focus on Indian or Tamil Nadu-specific contexts, discussing causal determinants or consequences, or presenting intervention models and legal frameworks were considered.



Revathi *et al.*,**Determinants of Child Marriage**

Child marriage in Tamil Nadu, as in other parts of India and the Global South, is not the result of a single factor but a web of interconnected drivers. These determinants operate at multiple levels: individual, household, community, and systemic; and are reinforced by socio-cultural, economic, and institutional factors. Understanding these drivers is critical for designing effective interventions.

Case Study

Meena, a 15-year-old girl from a financially disadvantaged family in a remote village of Tamil Nadu, had aspirations of continuing her education and one day becoming an IAS officer. However, her ambitions were cut short when her parents arranged her marriage to a man more than twice her age, in his forties. Despite her desire to study and build an independent future, economic pressures and deeply rooted social norms led to the early marriage, derailing her educational and personal goals (Rajeswari *et al.*, n.d.).

Socio-economic Drivers**Poverty and Urban-Rural Disparities**

Poverty is one of the most consistent and cross-cutting determinants of child marriage. Families struggling with financial instability often view daughters as economic burdens (OHCHR, n.d.). Early marriage is perceived as a way to reduce household costs—such as food, clothing, and education (Kumari and Shekhar, 2023)—and, in some cases, to secure economic gain through dowry or bride price. In Tamil Nadu, while rural poverty has declined, urban poverty has intensified, especially in peri-urban slums and informal settlements (Venkatesh, 2023). A UNICEF (2020) report noted that urban poor families are increasingly resorting to early marriage due to financial precarity, social insecurity, and lack of access to public welfare schemes.

Dowry Practices and Economic Insecurity

Despite legal prohibitions, dowry remains a pervasive social practice in many parts of India (Chiplunkar and Weaver, 2023). As dowry expectations rise with the age and education of girls, many families prefer to marry their daughters early to reduce financial demands (Fattah and Camellia, 2022; Kumari and Shekhar, 2023; Mahato, 2016). Economic insecurity—particularly among marginalized castes and tribal groups—compounds this pressure, with marriage seen as a transaction that can either provide temporary financial relief or serve as a means of forming strategic family alliances (Maertens and Chari, 2020).

Gender and Patriarchy**Gender Roles, Norms, and Discrimination**

Deep-rooted gender discrimination and patriarchal norms devalue girls, controlling their sexuality and limiting their roles to marriage and motherhood (Ghomeshi *et al.*, 2020). They are socialized from an early age to accept subordinate roles as wives and mothers, with limited autonomy over their life choices. The 2021 Population Council study highlights how internalized gender norms among both parents and adolescent girls shape attitudes that support early marriage (Raj *et al.*, 2021).

Control of Female Sexuality and Family Honor

In many communities, female chastity is linked to family honor. Girls are often seen as liabilities, and marriage is viewed as a way to protect their "honor" and reduce household responsibilities (Melchior, 2022). Parents fear that adolescent girls may engage in premarital relationships or face harassment, which could tarnish family reputation. Consequently, early marriage is used as a strategy to regulate girls' sexuality and ensure social respectability. This dynamic is especially visible in caste-conscious rural regions of Tamil Nadu, where inter-caste interactions are closely monitored and marriage is tightly controlled by elders.



**Educational Barriers**

Limited access to quality education, particularly for girls, significantly increases vulnerability to child marriage. Education not only delays the age of marriage but also empowers girls with knowledge, skills, and aspirations (World Bank, 2017).

Access to Schooling and Dropout Rates

There is a well-documented inverse relationship between education and child marriage. Girls who complete secondary education are significantly less likely to be married before 18. In Tamil Nadu, despite high gross enrolment ratios in primary school, transition to secondary and higher secondary schooling remains low in economically disadvantaged and tribal belts. Issues such as inadequate transport, lack of separate toilets for girls, and safety concerns contribute to dropout, especially during menstruation or puberty (Kumar and Saikia, 2022).

Role of Parental Literacy

Parental education, especially maternal literacy, plays a crucial role in shaping children's educational outcomes and delaying marriage. Illiterate or semi-literate parents are less likely to value prolonged education for daughters and more likely to conform to traditional expectations. In tribal and first-generation learner households in Tamil Nadu, education is often undervalued for girls, who are seen as future homemakers rather than potential income-earners.

Cultural and Religious Norms**Traditional Customs and Caste / Community Beliefs**

Customary practices and collective community beliefs continue to legitimize early marriage in many rural and semi-urban areas. Among certain communities, child marriage is still celebrated as a marker of cultural identity or social responsibility. In Tamil Nadu, some caste groups uphold "marriage within puberty" as a norm, with girls expected to be married soon after menarche to avoid stigma and social scrutiny.

Role of Religion in Justifying Early Marriage

Religious interpretations can influence marriage norms. Although no major religion mandates child marriage, selective and conservative readings of religious texts have been used to justify the practice. Some communities invoke religion to validate early marriage as morally appropriate or spiritually rewarding. This is particularly difficult to counter when religious leaders or elders resist legal and social interventions.

Institutional and Legal Gaps**Weak Enforcement of Child Marriage Laws**

Although the Prohibition of Child Marriage Act (PCMA), 2006, is in effect across India, its enforcement in Tamil Nadu remains uneven. Local authorities, including police and child welfare committees, often face community resistance or lack sufficient training to handle child marriage cases.

Civil Registration Issues and Local Governance

Marriage registration in Tamil Nadu, especially in rural and tribal areas, remains incomplete or informal. Unregistered marriages enable families to bypass legal scrutiny. Panchayat officials sometimes overlook child marriages due to social pressures or personal involvement. Additionally, Childline or helpline services are not uniformly accessible or functional in remote regions, further weakening enforcement mechanisms.

Region-Specific Factors in Tamil Nadu**Urban Slum Vulnerabilities and Regional Variations**

Emerging data from Tamil Nadu indicate that child marriage is not confined to rural areas. Urban slums in cities like Chennai, Madurai, and Coimbatore report rising instances, driven by poverty, migration, lack of schooling, and social vulnerability. Girls in these areas are at heightened risk due to insecure living conditions, exposure to violence, and absence of strong support networks (Sivaram *et al.*, 1995; Venkatesh, 2023).



**Case Examples and Local Insights**

Local NGOs working in districts like Dharmapuri, Dindigul, and Salem have highlighted region-specific practices such as marriage fairs, child betrothals, and intra-family marriages that perpetuate early unions. For example, studies have reported the prevalence of cousin marriages and consanguineous marriages in certain communities, with girls being married off at 14–16 to family members to preserve property within the kinship network.

Consequences of Child Marriage

Child marriage has wide-ranging implications that extend far beyond the wedding ceremony. The practice exerts a detrimental influence on the physical, psychological, educational, and economic wellbeing of individuals, especially girls. Its repercussions are not only immediate but also ripple across generations, perpetuating cycles of disadvantage and deprivation. In Tamil Nadu, despite efforts to curb the practice, its consequences continue to impact thousands of adolescent girls, particularly from disadvantaged social groups and rural or urban poor settings.

Health Outcomes**Early Pregnancy Risks**

One of the most direct consequences of child marriage is early and repeated pregnancies, often within months of marriage. Adolescent girls face significantly higher risks during pregnancy and childbirth due to biological immaturity. Research notes that girls aged 10–19 are more likely to experience obstructed labor, preeclampsia, postpartum hemorrhage, and maternal mortality than adult women (Cavazos-Rehg *et al.*, 2015; Raj, *et al.*, 2010). In Tamil Nadu, while maternal health services are relatively accessible, early pregnancies among child brides continue to contribute to poor maternal nutrition, anemia (Narayan, 2019), and preterm deliveries (SPC, 2024).

Infant Mortality and Child Health Issues

Children born to adolescent mothers are at higher risk of low birth weight, neonatal mortality, stunting, and poor immunization coverage. This is due to the compounded effect of poor maternal nutrition, lack of antenatal care, and limited health knowledge among young mothers. Studies have consistently shown that child marriage is associated with higher rates of infant morbidity and mortality (Nguyen *et al.*, 2021).

Reproductive and Sexual Health Problems

Girls married early are often unprepared for sexual activity, both physically and emotionally. They face a higher prevalence of reproductive tract infections (RTIs), sexually transmitted infections (STIs), and HIV/AIDS, especially when married to older, sexually experienced men. The lack of sexual autonomy and reproductive decision-making further restricts access to contraception and family planning services.

Psychological and Social Impacts**Mental Health Disorders and Emotional Trauma**

Adolescent girls who are married early often experience feelings of fear, anxiety, depression, and hopelessness. Many suffer from post-traumatic stress disorder (PTSD) due to forced sexual initiation, marital rape, or domestic abuse. The sudden transition from childhood to marital responsibilities deprives them of a normal adolescence and contributes to long-term emotional distress (Davis *et al.*, 2013; Gupta *et al.*, 2020).

Domestic Violence and Gender-based Abuse

Studies from Tamil Nadu and other Indian states have shown a positive correlation between early marriage and intimate partner violence. Young brides are more likely to be subjected to physical and emotional abuse due to power imbalances in the relationship. They are often unable to seek help or exit abusive marriages due to social norms and financial dependence (Santhya *et al.*, 2010).

Loss of Autonomy and Social Isolation

Child marriage curtails personal freedom and often results in early withdrawal from peer groups, education, and family networks. Girls may be relocated to unfamiliar communities, where they are expected to conform to adult



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roles. Their lack of decision-making power further erodes their sense of self and personal agency, perpetuating a cycle of subjugation.

Educational and Economic Impacts

School Discontinuation and Skill Deficits

Marriage often leads to the immediate end of formal education for girls, especially in communities where education is seen as incompatible with marital responsibilities. The disruption in schooling reduces literacy, hinders skill development, and restricts opportunities for self-advancement (Harrison, 2023; Qureshi *et al.*, 2024). In Tamil Nadu, adolescent marriage is one of the leading causes of secondary school dropout among girls in certain districts (Saravanan, 2014; Vijayakumar, 2024).

Limited Employment and Financial Dependence

Girls who leave school early due to marriage often have limited access to employment, particularly in the formal sector. Without skills or qualifications, they are confined to informal work, domestic labour, or remain economically dependent on their spouses (Rahmani and Groot, 2023; Rose, 2021). This economic marginalization further diminishes their bargaining power within the household and increases their vulnerability to exploitation and abuse.

Intergenerational Effects

Perpetuation of the Cycle of Poverty and Marriage

Child marriage is both a cause and consequence of poverty. Daughters of child brides are more likely to be married early, replicating the cycle across generations. This intergenerational transmission is particularly persistent in socio-economically backward communities, where limited access to education and healthcare reinforce traditional norms.

Poor Development Outcomes for Children Born to Child Brides

Children born to young mothers tend to have worse health, educational, and cognitive outcomes than those born to older mothers. This includes a higher risk of malnutrition, incomplete vaccination, poor school attendance, and limited psychosocial development. These effects not only impact individual children but also contribute to wider societal burdens in the form of lost productivity, increased healthcare costs, and reduced human capital. Overall, the consequences of child marriage in Tamil Nadu are far-reaching and multifaceted. Beyond the violation of child rights, it hampers the achievement of broader development goals—such as gender equality, improved maternal and child health, universal education, and poverty reduction. Addressing these consequences requires a coordinated effort that not only prevents early marriage but also mitigates its adverse outcomes through targeted policy and programmatic interventions.

Legal and Policy Framework

Legal and policy frameworks play a pivotal role in combating child marriage by establishing minimum age standards, protecting children's rights, and enabling punitive and preventive mechanisms. While India has enacted robust national legislation and Tamil Nadu has introduced targeted welfare schemes, challenges in enforcement, awareness, and systemic coordination continue to hinder effectiveness.

National Legal Measures against Child Marriage

Prohibition of Child Marriage Act (PCMA), 2006

The PCMA is India's principal legislation to prevent and penalize child marriage. It defines child marriage as a union where either the girl is under 18 or the boy under 21 years of age. Key provisions include: declaring child marriages voidable at the option of the minor, Punishments for those promoting or solemnizing such marriages, including parents, priests, and community leaders, and appointment of Child Marriage Prohibition Officers (CMPOs) to prevent, investigate, and report violations. Despite its progressive intent, the PCMA suffers from limited enforcement, weak monitoring, and social acceptance of early marriage, particularly in rural and marginalized communities (PIB Delhi, 2023; The Prohibition of Child Marriage Act, 2006, 2007).



**The Protection of Children from Sexual Offences (POCSO) Act, 2012**

POCSO criminalizes all sexual activity involving minors under the age of 18, irrespective of consent or marital status. Since many child marriages involve non-consensual and unprotected sex, the POCSO Act intersects with the PCMA by providing avenues to prosecute sexual abuse within child marriages. However, judicial ambiguity and cultural reluctance to prosecute within marriages often dilute the law's application (NHRC, 2021).

The Right to Education (RTE) Act, 2009

By mandating free and compulsory education for all children aged 6 to 14, the RTE Act aims to delay marriage by encouraging school retention (RTE, n.d.). However, its enforcement weakens during secondary schooling, a critical stage when many girls are withdrawn from school for marriage preparations.

Juvenile Justice (Care and Protection of Children) Act, 2015

This act addresses the broader welfare of children in need of care and protection, including those subjected to early marriage. It empowers Child Welfare Committees (CWCs) to intervene in cases where child rights are violated, though such interventions remain limited in cases of child marriage due to familial complicity and societal pressure (The Juvenile Justice (Care and Protection of Children) Act, 2015, 2016).

Marriage Registration

Pilot programs that promote mandatory marriage registration to prevent illegal child marriages and document age proof (UNFPA India, 2021)

State-Specific Schemes in Tamil Nadu

Tamil Nadu has introduced several innovative schemes to delay marriage, improve the status of the girl child, and provide financial security to families.

Girl Child Protection Scheme

Launched to prevent female infanticide and promote the survival and education of girls, the scheme provides financial deposits and scholarships to girl children from poor families (annual income less than ₹ 72,000), contingent upon delayed marriage (after age 18) and continued schooling (Social Welfare and Women Empowerment Department, n.d.-a). There are two variants, ₹50,000 deposit in the child's name is made to families with one-girl child and ₹25,000 for each child in a two-girl child family (Monalisa, 2025).

Cradle Baby Scheme

Originally introduced in response to female infanticide in districts like Salem, the scheme allows unwanted female infants to be anonymously placed in cradle baby centers (Social Welfare and Women Empowerment Department, n.d.-b). While not directly linked to child marriage, it reflects efforts to improve the perceived value of the girl child, thereby indirectly contributing to delayed marriage. However, civil society activists have raised concerns about the scheme, arguing that it may unintentionally promote the neglect or abandonment of female infants, rather than addressing the root issues of sex-selective practices and female foeticide. Nevertheless, they acknowledge that such interventions may remain necessary until societal attitudes towards the girl child become more accepting (Srinivasan and Bedi, 2010).

Moovalur Ramamirtham Ammaiyar Ninaivu Higher Education Assurance Scheme

Also known as "Pudhumai Penn Scheme", provides financial assistance to poor girls who complete education up to at least Class X, thereby preventing early marriage (Shanmugasundaram, 2024; Social Welfare and Women Empowerment Department, n.d.-c). This scheme incentivizes education-linked marriage and offer a positive reinforcement model. However, benefits are often claimed without fully meeting eligibility criteria, indicating gaps in verification and monitoring.



**Revathi et al.,****Sumangali Scheme**

The Sumangali scheme provides an opportunity to employ young women workers, who had few or almost no opportunities to find gainful employment in their respective villages, with the promise of a lump sum payment at the time of their marriage (Shadab and Koshy, 2012). In recent years, child marriage has increasingly been viewed through the lens of child labour, as both share similar root causes and harmful consequences. Both practices are more common in poor, rural communities and are linked to poverty, limited access to education, and gender-based discrimination. They expose children—especially girls—to health risks, psychological harm, school dropout, and further exploitation (Boender, 2021). This reinforces both labour exploitation and early marriage, as the end goal of the scheme is framed around preparing girls for marriage. Thus, child marriage and child labour are not only connected by shared socio-economic drivers but also intersect in schemes like Sumangali, where the lines between labour and marriage-related exploitation are blurred (Boender, 2021; Chandra, 2016; The New Indian Express, 2012).

Critical Review of Gaps in Implementation and Monitoring

Despite the existence of legal and policy safeguards, the persistence of child marriage in Tamil Nadu reflects serious gaps in execution

Lack of Awareness: Many families, especially in rural and tribal areas, remain unaware of legal age norms, penalties, and protective schemes.

Underreporting and Social Acceptance: Due to stigma, fear of backlash, and normalization of early marriage in some communities, violations are rarely reported or challenged.

Weak Enforcement Mechanisms: CMPOs and CWCs often face insufficient staffing, lack of training, and bureaucratic constraints, leading to delayed or no action.

Cultural Resistance: Legal interventions are often resisted by local leaders or families, citing tradition, religion, or economic necessity.

Fragmented Institutional Coordination: A lack of synergy between departments of education, health, social welfare, and police undermines comprehensive case management and tracking.

Inconsistent Data and Monitoring: Absence of a real-time state-level database to monitor at-risk adolescents or follow up on beneficiaries of incentive schemes limits early intervention.

While Tamil Nadu has demonstrated political commitment through various girl-focused welfare initiatives and law enforcement directives, systemic barriers persist. A multi-sectoral approach, integrating legal reform, educational support, community awareness, and real-time monitoring, is essential to close the gap between policy and practice. Strengthening grassroots enforcement, improving community trust in state institutions, and aligning legal and welfare frameworks can significantly enhance efforts to eradicate child marriage in the state.

Existing Interventions and Best Practices

Efforts to prevent child marriage in Tamil Nadu encompass a diverse range of strategies led by non-governmental organizations (NGOs), community-based groups, schools, and grassroots service providers. These interventions have been pivotal in delaying the age of marriage among girls, building awareness, and empowering young people to make informed choices.

NGO and Community-Level Initiatives**Community Mobilization and Dialogue**

Community mobilization remains one of the most effective tools in challenging the social norms that perpetuate child marriage. Several NGOs in Tamil Nadu—such as Evidence, Arunodhaya Centre for Street and Working Children (Le



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Borgne, 2014), and Child Rights and You (CRY) (CRY, 2020)—have led village-level campaigns engaging parents, religious leaders, and youth in structured dialogues (Rajeswari *et al.*, n.d.).

Children's Groups and Village Watch Committees: These are platforms for adolescents and community members to identify at-risk cases and intervene early.

Community monitoring mechanisms: Trained volunteers or NGO field workers track school attendance and flag potential dropouts, especially among girls, to prevent early marriages.

Peer Education and Youth Empowerment

Peer-led education initiatives have been instrumental in fostering awareness and confidence among adolescents, particularly girls. NGOs such as SAVE (Social Awareness and Voluntary Education) and Breakthrough India use adolescent girls and boys as peer educators to conduct sessions on: rights and entitlements, menstrual health and hygiene, dangers of early marriage and pregnancy, and life skills and vocational options. These interventions often lead to collective resistance to child marriage among youth and increased reporting of planned illegal marriages.

School-Based Programs and Awareness Campaigns

Schools serve as critical sites for early identification and prevention of child marriage. When children—especially girls—remain in school beyond the age of puberty, their risk of being married early is significantly reduced.

Awareness Programs in Schools

Initiatives supported by UNICEF, the Tamil Nadu Department of School Education, and NGOs have introduced school-based modules on gender equality, child rights, reproductive health, and legal literacy. Adolescent Education Programs (AEP), include discussions on early marriage, bodily autonomy, and safe relationships, embedded in the curriculum for Classes VIII–XII (CBSE, n.d.). Schools should provide gender-sensitive infrastructure (like separate toilets, sanitary pad vending machines) to reduce dropout rates among adolescent girls.

Safe Spaces and Mentorship

Creating safe spaces within or around schools has proven to be a protective factor. Trained teachers or counsellors act as mentors and first responders when a child is at risk of early marriage

Role of ASHAs, Teachers, and Local Leaders in Prevention

ASHAs and Anganwadi Workers

Accredited Social Health Activists (ASHAs), Anganwadi workers, and Auxiliary Nurse Midwives (ANMs) play a crucial role in tracking adolescent girls' health and school attendance. They conduct home visits to counsel parents, monitor menstrual health, and report early marriage risks to block-level officials. Through their participation in Village Health, Sanitation, and Nutrition Committees (VHSNCs), they integrate child marriage issues into discussions on adolescent health (Aggarwal *et al.*, 2023; Karol, 2014; Sandhyarani and Rao, 2013).

Teachers and School Administrators

Teachers are often the first to notice signs of withdrawal or marriage preparations among girl students. Incidents have been reported where teachers have reported to Social Welfare departments of child marriages (Express News Service, 2025). Teachers have the responsibility to alert child protection units, organize school-level campaigns and role-plays, and act as liaisons between schools and local Child Welfare Committees (CWCs) (Kirubakaran, 2025; Sivaguru, 2022; The Hindu Bureau, 2023, 2025)

Religious and Panchayat Leaders

Local influencers, such as priests, imams, and elected panchayat leaders, are critical in reshaping social norms. In Tamil Nadu, sensitization workshops and inter-faith dialogues have helped build consensus around discouraging child marriage. Collectively, these interventions highlight the importance of multi-stakeholder, grassroots-led, and



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adolescent-centered approaches in preventing child marriage. Sustainable change lies in fostering an enabling environment that encourages education, gender equality, legal awareness, and community accountability. Tamil Nadu's best practices can serve as models for replication and upscaling in other states and regions with similar challenges.

RECOMMENDATIONS

To effectively address the complex and entrenched issue of child marriage in Tamil Nadu, a multifaceted and context-sensitive strategy is essential. Strengthening the enforcement of existing child marriage laws—such as the Prohibition of Child Marriage Act (PCMA)—must be prioritized. This includes enhancing the capacity and accountability of local authorities, police, and child protection units to detect, intervene, and prosecute violations. The establishment of accessible and confidential reporting mechanisms at the village and block levels can empower community members, especially adolescents, to alert authorities without fear of retaliation. Incorporating legal awareness into school curricula and community workshops can further improve understanding and compliance.

The promotion of girls' education and livelihood opportunities is crucial to delaying marriage and fostering long-term empowerment. Educational incentives, scholarships, and infrastructure improvements (such as safe transport and sanitation facilities) that are already in action can reduce dropout rates, particularly among adolescent girls in rural and marginalized communities. In parallel, skills training and livelihood programs tailored to young women can increase their economic agency and decrease their dependency on early marriage as a survival strategy. The integration of vocational training into secondary school curricula, especially in regions with high child marriage prevalence, would offer girls tangible alternatives to early marriage. Integrated schemes like the Integrated Child Protection Scheme (ICPS), KGBV residential schools, and cash transfer programs must be scaled up in vulnerable regions.

Engaging community leaders, parents, and adolescents as allies in prevention efforts is equally important. Customizing outreach strategies to local social structures—such as involving panchayat leaders, faith-based organizations, and self-help groups—can create social pressure against child marriage and shift community norms. Dialogue-based programs that include both men and women can help dismantle patriarchal values and foster collective responsibility for protecting children's rights. Additionally, peer education models and adolescent clubs offer safe platforms for youth to gain knowledge, support each other, and assert their rights.

A significant challenge in addressing child marriage in Tamil Nadu remains the limited and fragmented data collection and monitoring systems. Robust and disaggregated data—by age, caste, region, education level, and socioeconomic status—are necessary to design targeted policies and measure progress effectively. Strengthening collaborations between government agencies, academic institutions, and civil society can ensure more systematic surveillance, case tracking, and evaluation of interventions. The integration of child marriage indicators into district-level health, education, and social welfare databases will help in identifying high-risk areas and vulnerable populations more accurately.

Finally, tailored interventions for specific vulnerable communities—such as tribal groups, urban slum dwellers, and migrant populations—must be developed with a nuanced understanding of local realities. In Tamil Nadu, region-specific factors such as the persistence of the Sumangali scheme, urban-rural disparities, and caste-based practices necessitate locally adapted solutions. Culturally responsive strategies, including the use of regional languages, local media, and community champions, can enhance outreach and acceptance. These localized interventions, combined with a strong political commitment and community ownership, are vital to achieving the long-term goal of eliminating child marriage across the state. Law enforcement agencies, including police and judiciary, require gender-sensitive training to handle such cases effectively.





CONCLUSION

Child marriage in Tamil Nadu remains a deeply rooted issue influenced by a complex interplay of socio-economic pressures, gender inequality, educational disparities, cultural norms, and institutional shortcomings. Despite various legal and policy efforts, the persistence of poverty, dowry practices, patriarchal beliefs, lack of access to quality education, and weak law enforcement mechanisms continue to drive early marriage among girls across the state. The consequences of child marriage are profound and multidimensional, impacting girls' health, mental well-being, educational attainment, and economic independence, while also perpetuating a cycle of poverty and disempowerment across generations.

To eliminate child marriage, there is an urgent need for integrated, multi-sectoral strategies that address both the root causes and the systemic enablers of the practice. This requires collaboration among legal, educational, health, and social sectors, along with active community engagement. Legal reforms must be coupled with effective enforcement, while educational access and quality must be prioritized to offer girls real alternatives to early marriage. Social norms that justify or tolerate child marriage must be challenged through sustained awareness efforts and community-driven change. Ultimately, the solution lies not only in legislation but in transforming the societal structures and attitudes that allow child marriage to persist. Promoting girls' rights, expanding their life choices, and fostering inclusive development must remain at the heart of all interventions. Tamil Nadu's progress toward ending child marriage will depend on how effectively it can implement comprehensive, rights-based, and locally contextualized strategies that ensure no girl is forced into marriage before she is physically, emotionally, and socially ready.

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RESEARCH ARTICLE

Development and Validation of Analytical Method for Simultaneous Estimation of Fluconazole and Cefixime in Synthetic Mixture by HPTLC Method

Mukesh B. Karhale¹, Manik S Pawde², Umesh S. Sapkal¹, S. L.Patwekar³ and Kalyankar T.M^{3*}

¹Research Scholar, Department of Quality Assurance, School of Pharmacy, Swami Ramanand Teerth Marathwada University, Vishnupuri, Nanded, Maharashtra, India.

²Research Scholar, Department of Pharmaceutics, School of Pharmacy, Swami Ramanand Teerth Marathwada University, Vishnupuri, Nanded, Maharashtra, India

³Associate Professor, Department of Pharmaceutics, School of Pharmacy, Swami Ramanand Teerth Marathwada University, Vishnupuri, Nanded, Maharashtra, India

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*Address for Correspondence

Kalyankar T.M

Associate Professor,

Department of Pharmaceutics, School of Pharmacy,

Swami Ramanand Teerth Marathwada University,

Vishnupuri, Nanded, Maharashtra, India.

E.Mail: dr.kalyankartm@gmail.com



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ABSTRACT

A simple, accurate, precise High Performance Thin Layer Chromatography method was developed for the simultaneous estimation of fluconazole and cefixime in synthetic mixture. Cefixime is broad spectrum cephalosporin antibiotic whereas, fluconazole is a first generation triazole antifungal medication. The separation was performed on silica gel 60 F₂₅₄ TLC plate using ethyl acetate: methanol (8:2 v/v) as mobile phase. The straight line calibration graphs were obtained in the concentration range 100-600 ng/band for cefixime and 75-450 ng/band for fluconazole. Wavelength used for detection and quantitation was 216 nm. The method was found to be accurate and precise, as it is indicated by recovery study, was close to 100% and % RSD not more than 2. The degradation studies revealed susceptibility of cefixime to hydrolysis, oxidative and thermal stress condition but it was found to be prone to hydrolysis, oxidative and thermal stress condition and stable under photolysis.

Keywords: Cefixime, Fluconazole, HPTLC, ICH guidelines.



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INTRODUCTION

Fluconazole (FLU) is chemically known as 2-(2, 4-Difluorophenyl)-1, 3-di (1H-1, 2, 4-triazol-1-yl) propan-2-ol [Figure 1(a)], is a first generation triazole antifungal medication. It differs from earlier azole antifungal (such as ketoconazole) in that its structure contains a triazole ring instead of an imidazole ring. Fluconazole and certain other triazole antifungal are preferred when systematic treatment is required because of their improved safety and predictable absorption. It inhibits the fungal cytochrome P450 enzyme 14 α -demethylase. Several methods have been described in the literature for the determination of fluconazole in pharmaceutical dosage form in single Cefixime (CEFI) is a [6R-[6 α ,7 β (Z)]]-7-[[[(2- Amino-4- thiazoyl)][(carboxymethoxy)imino] acetyl]amino]-3-ethenyl-8-oxo-5-thia-1-azabicyclo [4.2.0]oct-2-ene-2-Carboxylic acid. It exerts bacterial activity by interfering with bacterial cell wall synthesis and inhabiting cross- linking of the peptidoglycan. Several methods have been described in literature for the determination of cefixime in single and combination with other drug pharmaceutical dosage form.

METHODS AND MATERIALS

EXPERIMENTAL

Instrumental and Chromatographic conditions

The samples were spotted in the form of band with a Camag microliter syringe under nitrogen stream using a Camag Linomate V sample applicator. Precoated TLC silica gel 60 F₂₅₄ aluminium plates (20 cm x 20 cm x 250 μ m) were used. Development was performed in a Camag twin through glass chamber (20 x 20) saturated with mobile phase ethyl acetate: methanol (8:2 v/v). The optimal saturation time for mobile phase was 30 min at room temperature. Densitometric scanning was performed on Camag TLC scanner III operated with winCAT 1.4.2 software. The source of radiation utilised was deuterium lamp emitting a continuous UV spectrum between 190-400 nm. The obtained spot were scanned at 216 nm.

Material: Pharmaceutical grade of FLU and CEFI were kindly supplied by Bidwai chemical Pvt. Ltd. Nanded. Analytical grade of all ethyl acetate and methanol were obtained from Thomas Baker Pvt Ltd. (Mumbai, India).

Preparation of working standard solutions: Standard solution for FLU and CEFI was prepared by dissolving 15 mg and 20 mg in 10 ml to methanol to obtained 1500 ng μ L⁻¹ and 2000 ng μ L⁻¹, respectively. From these solutions 0.5 ml of solution were diluted further with same solvent to achieve working concentration 75 ng μ L⁻¹ and 100 ng μ L⁻¹.

Method development and optimization: The TLC method was optimized to establish suitable stability representative method for bulk drugs. Mobile phase composed of ethyl acetate: methanol (8: 2, v/v) gave better resolution and symmetrical peaks with R_f values of 0.42 $\pm$ 0.02 for cefixime and 0.70 $\pm$ 0.06 for fluconazole, respectively. Densitogram of cefixime (300 ng band⁻¹, R_f = 0.42 $\pm$ 0.02) and fluconazole (225 ng band⁻¹, R_f = 0.70 $\pm$ 0.06) are shown in figure 2.

Assay of laboratory prepared tablet sample: Twenty tablets, containing 150 mg FLU and 200 mg CEFI were finely powdered. A quantity of power equivalent to 15 mg FLU and 20 mg CEFI was weighed and transferred into volumetric flask, in that 5 ml methanol was added and stirred for 20 min then filtered into a 10ml volumetric flask. Then residue was washed with 5 ml methanol and transferred to flask to obtain the concentration 2000 ng/band for CEFI and 1500 ng/band for FLU. The working solution were prepared by diluting stock solution with methanol to produce 100-600 μ g/ml and 75-450 μ g/ml, for CEFI and FLU, respectively. 5 μ l portion were spotted as band on TLC plate for development of chromatogram using ethyl acetate: methanol (8: 2, v/v) as mobile phase. Recovery value was calculated. Six determinations were carried out for analysis of formulation. The % estimated (Mean $\pm$ R.S.D.) was 99.15 $\pm$ 1.25 and 99.20 $\pm$ 1.51 for CEFI and FLU, respectively.



**Mukesh B. Karhale et al.,****Method validation**

Linearity and range: Volume of 1, 2, 3, 4, 5 and 6 μL of standard solutions of CEFI (100 $\text{ng } \mu\text{L}^{-1}$) and FLU (75 $\text{ng } \mu\text{L}^{-1}$) were applied on the plates using sample applicator. The linearity study was performed by preparing standard solution of 100-600 ng band^{-1} for CEFI and 75-750 ng band^{-1} FLU.

Precision: The precision of the method was evaluated by intra-day and inter-day variation studies. It is calculated by standard deviation or relative standard deviation. Concentration of 300 ng band^{-1} , 400 ng band^{-1} , and 500 ng band^{-1} for CEFI and 225 ng band^{-1} , 300 ng band^{-1} , 375 ng band^{-1} for FLU were spotted in three replicate and analyzed thrice in a same day (intra-day) and in three consecutive days (inter-day) for precision study. % RSD was calculated.

Accuracy: Accuracy of analytical method is the closest of the test result to the true value. The accuracy is calculated as the percentage of recovery by the assay of a known added amount of the analyte in the sample. Recovery study was carried out at three different levels (80%, 100%, and 120%).

LOD and LOQ: The limit of detection and limit of quantification of developed method was calculated from calibration curve by following formula.

$$\text{LOD} = 3.3 \times \sigma / S \quad \text{LOQ} = 10 \times \sigma / S$$

Where, σ = standard deviation

S = Slope of the calibration curve

Robustness: Method robustness was evaluated by making intentional variation in optimized conditions. The parameters altered were wavelength ($\pm 1 \text{ nm}$), change in mobile phase composition ($\pm 1\%$ Methanol) and peak area were noted.

Forced degradation study: Stress degradation study was performed to check the stability of the drugs on different condition.

RESULT AND DISCUSSION

Validation of the proposed method: The proposed method was validated according to the ICH guidelines (ICH, 2005).

Linearity and concentration ranges: The linearity of the proposed HPTLC procedure was evaluated by analyzing a series of different concentrations for each of the two analyte. The linear regression equations were generated by least squares treatment of the calibration data. Linearity was detected in concentration range 100-600 ng band^{-1} (Figure 3) and 75-450 ng band^{-1} (Figure 4) for CEFI and FLU, respectively. Correlation coefficient for CEFI and FLU were found to be 0.998 and 0.999 respectively. Results of linearity study are shown in table 1.

Accuracy: The % mean recovery was found in the range of 99.54% - 100.47% and 99.67 - 100.06% for CEFI and FLU which shows that developed technique was accurate for the determination of drugs in combined formulation. Results of recovery are shown in table 2.

Precision: Peak area values were recorded upon application of three standard mixtures within linearity range. Precision was confirmed as % RSD as it was found to be below 2%. Results of precision studies are shown in table 3 for intraday and table 4 for interday precision.

Detection limit and Quantitation limit: The values of LOD were 24.26 ng band^{-1} and 18.28 ng band^{-1} while values of LOQ were 73.53 ng band^{-1} and 55.42 ng band^{-1} for CEFI and FLU respectively. These are based on standard deviation of y- intercept and slope of regression line.



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Specificity: The R_f value of peak in sample matches with R_f value of standard. No other peaks in a densitogram indicate the specificity of the method. Representative densitogram of formulation containing 200 mg of CEFI ($R_f = 0.42 \pm 0.03$) and 150 mg FLU ($R_f = 0.70 \pm 0.05$) are shown in figure 3.

Robustness: There was no significant change in the peak areas of the drugs after making the deliberate variations in the analytical parameters. The percentage relative standard deviation was within the limit as specified by ICH guidelines, which represent the method robustness. Robustness is shown in table 5. The validation parameters summaries by proposed method are given in table 6.

Stress degradation studies

Acid treatment: The densitogram of the acid degraded samples for CEFI shows additional peak of degradation at R_f 0.26 and FLU shows additional peak of degradation at R_f 0.57. Reduction in peak area of the drugs was seen when compared to the initial area demonstrating that both CEFI and FLU undergo degradation in acidic conditions. Representative densitogram are shown in figure 4 a and b, respectively.

Alkali treatment: The densitogram of the base degraded sample for CEFI shows peak for the products of degradant at R_f 0.30 while FLU showed 17.31% degradation without appearance of additional product of degradation. Representative densitogram are shown in figure 5 a and b, respectively.

Neutral hydrolysis: Densitogram of the drugs exposed to water shows that peak areas for both the drugs decrease significantly with time. Additional degradation peak was shown by FLU at R_f value 0.81, whereas there is no peak of degradation was found for CEFI. Representative densitogram are shown in figure 6 a (CEFI) and b (FLU).

Oxidative degradation: The densitogram of the drugs exposed to 30 % H_2O_2 shows susceptibility under oxidative conditions. CEFI undergo degradation with reduction in the peak area with appearance of degradation product at R_f 0.16. However 13.47 % degradation was observed for FLU without any additional peak of degradation. Representative densitogram are shown in figure 8 a (CEFI) and b (FLU).

Photo-degradation: The densitogram of the drugs exposed to photolysis show that there were no change in the peak areas of both drugs indicate that the both drugs are stable under photolytic stress conditions. Representative densitogram are shown in figure 7 a (CEFI) and b (FLU).

Degradation under dry heat: The densitogram of the CEFI exposed to dry heat at $105^\circ C$ for 12 hrs shows no additional peak of degradation but there was considerable change in peak area of the drug while FLU exhibited about 11.23 % degradation along with product of degradation at R_f 0.50. It indicates that CEFI and FLU undergo degradation under thermal stress condition. Representative densitogram are shown in figure 9 a (CEFI) and b (FLU). The results of stress degradation studies revealed that degradation products formed during the stability study were well separated from bulk drugs representing the method specificity. The results of stress degradation study are given in table 7.

CONCLUSION

A simple, selective and precise stability indicating HPTLC method for estimation of cefixime and fluconazole in multicomponent formulation has been established and validated. The outcome of stress degradation studies demonstrated that both the drugs were prone to hydrolysis, oxidative, thermal stress conditions and stable under photolytic stress conditions. All the analyzed validation parameters showed acceptable data with satisfactory correlation coefficient and lower % RSD. The developed procedure may be used to check potency during shelf life of the drugs. The developed method can be utilized by industry for simultaneous quantitative estimation of these drugs.





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Table 1: Linearity regression data for CEFI and FLU

CEFI		FLU	
Conc. spotted (ng band ⁻¹)	Peak Area*	Conc. Spotted (ng band ⁻¹)	Peak Area*
100	2100	75	1204
200	2760	150	1882
300	3603	225	2708
400	4366	300	3465
500	5049	375	4295
600	5738	450	4953

*n= Average of six determinations

Table 2: Results of recovery studies

Drug	Sample conc. (ng band ⁻¹)	Added conc. (ng band ⁻¹)	Total conc. found (ng band ⁻¹)	% Recovery	S.D.	% R.S.D.*
CEFI	200	160	361.71	100.47	1.336	1.33
	200	200	398.18	99.54	0.637	0.64
	200	240	439.08	99.78	0.598	0.6
FLU	150	120	269.12	99.67	0.936	0.94
	150	150	300.2	100.06	0.520	0.52
	150	180	332.22	100.66	0.815	0.81

*Average of three determinations





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Table 3: Intra-day precision for CEFI and FLU

Drug	Amount spotted (ng band ⁻¹)	Peak Area	% Assay	S.D.	% R.S.D.*
CEFI	300	3561	98.83	21.50	0.60
	400	4304	98.57	18.90	0.43
	500	5009	99.20	24.87	0.49
FLU	225	2694	99.48	19.13	0.71
	300	3462	99.91	24.55	0.70
	375	4231	98.50	25	0.59

*n= Average of three determinations

Table 4: Inter-day precision for CEFI and FLU

Drug name	Amount spotted (ng band ⁻¹)	Peak Area	% assay	S.D.	% R.S.D.*
CEFI	300	3552	98.58	22.27	0.62
	400	4284	98.12	34.51	0.80
	500	5021	99.44	24.54	0.48
FLU	225	2707	99.96	24.17	0.89
	300	3457	99.76	21.50	0.62
	375	4213	98.09	14.57	0.34

*n= Average of three determinations

Table 5: Robustness data

Parameters	% R.S.D.*	
	CEFI	FLU
Change in mobile phase composition ($\pm 1\%$ methanol)	0.85	1.29
Wavelength ($\pm 1\text{nm}$)	0.99	0.82

*Average of three determinations

Table 6: Summary of validation parameters of proposed method

Parameters	Result	
	CEFI	FLU
Linearity range (ng band ⁻¹)	100-600	75-450
Correlation coefficient (r)	0.998	0.999
Limit of detection (ng band ⁻¹)	24.26	18.28
Limit of quantitation (ng band ⁻¹)	73.53	55.42
Accuracy	99.93 $\pm$ 0.86	100.13 $\pm$ 0.76
Precision (% R.S.D.)		
Intraday precision	0.64-0.97	0.65-0.83
Inter day precision	0.66-1.17	0.38-1.05
Robustness	Robust	Robust
Specificity	Specific	Specific

Table 7: Stress degradation summary for CEFI and FLU

Mode of degradation	% Recovery		% Degradation	
	CEFI	FLU	CEFI	FLU
Acid (0.1 N HCl, kept at RT for 2 h)	79.66	79.25	20.34	20.75
Alkali (0.1N NaOH, kept at RT for 4 h)	83.78	82.69	16.22	17.31



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Oxidation (30 % H ₂ O ₂ , at room temperature for 1 h)	80.94	86.52	19.06	13.48
Neutral (H ₂ O, reflux for 24 h)	99.73	75.51	0.27	24.49
Photolysis (sunlight for 24 h)	100.41	100.35	-	-
Dry heat at 105° C for 12 h			85.25	88.76

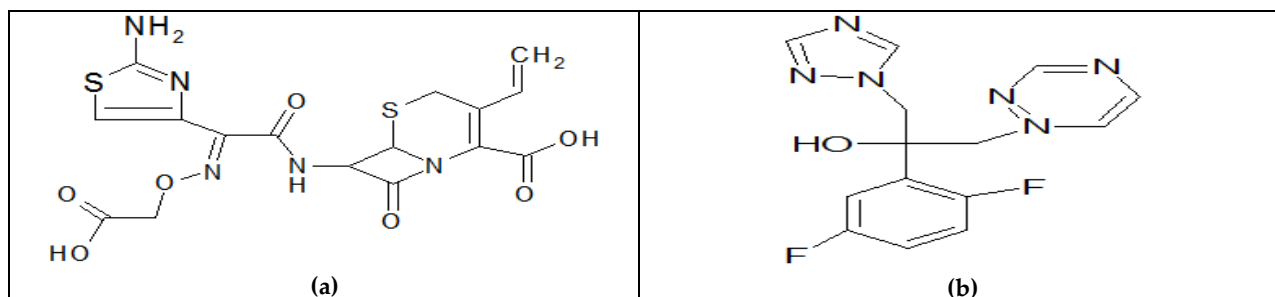


Fig 1. Structure of a) CEFI and b) FLU

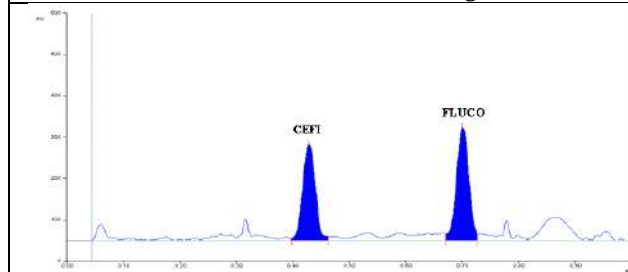


Figure 2. Densitogram of CEFI and FLU

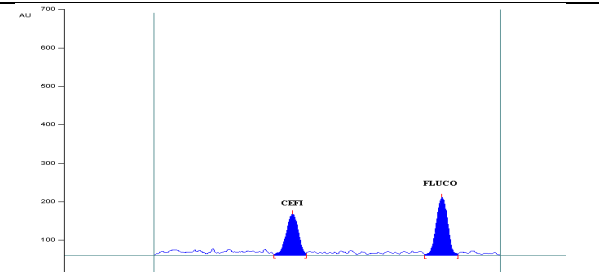
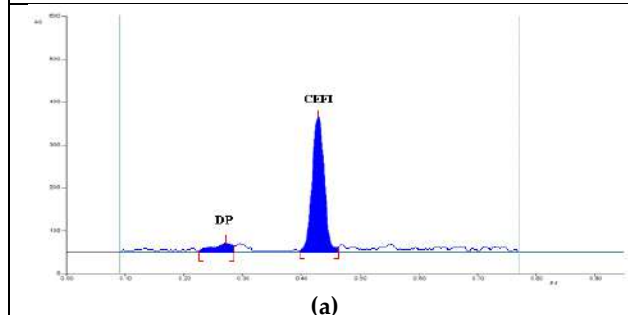
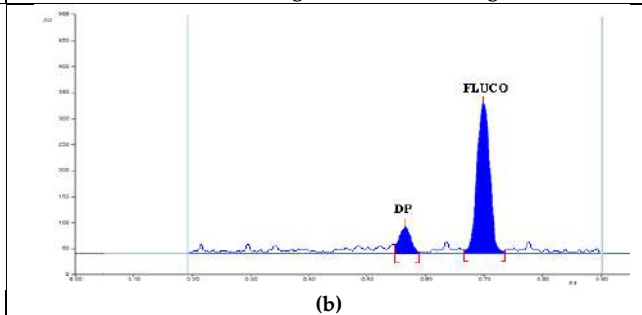


Figure 3. Representative Densitogram of formulation (200 mg of CEFI and 150 mg FLU)

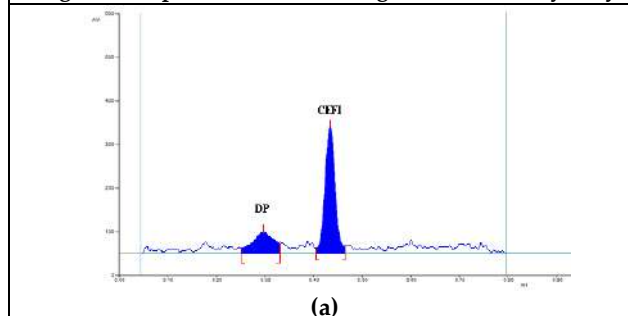


(a)

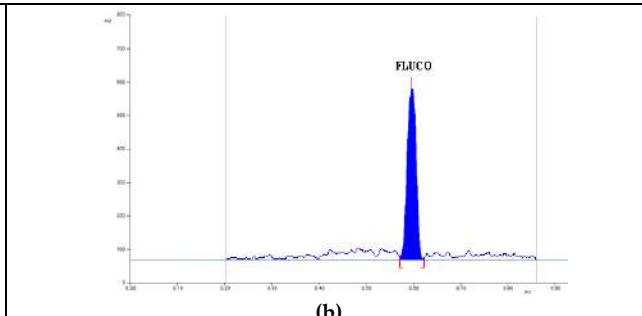


(b)

Figure 4. Representative Densitogram after acid hydrolysis for (a) CEFI with DP (Rf = 0.26) (b) FLU with DP (Rf = 0.57)



(a)



(b)

Fig 5. Representative Densitogram after alkali hydrolysis for (a) CEFI with DP (Rf = 0.30) and (b) FLU



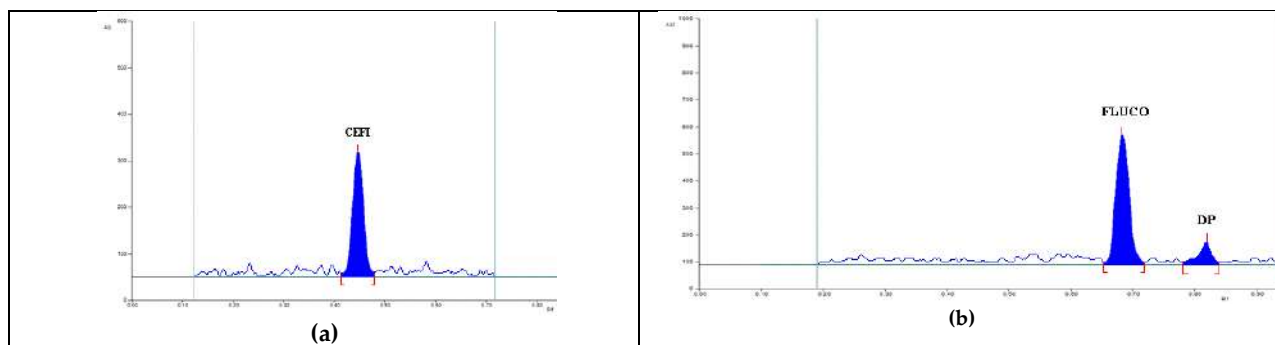
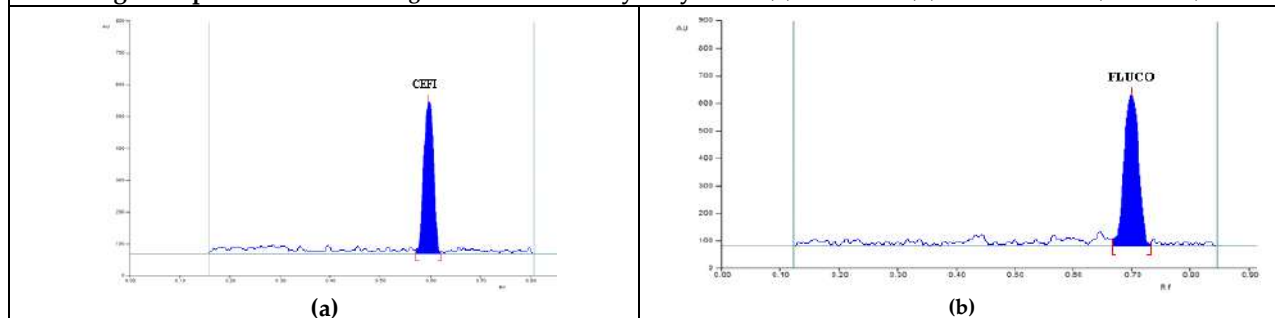
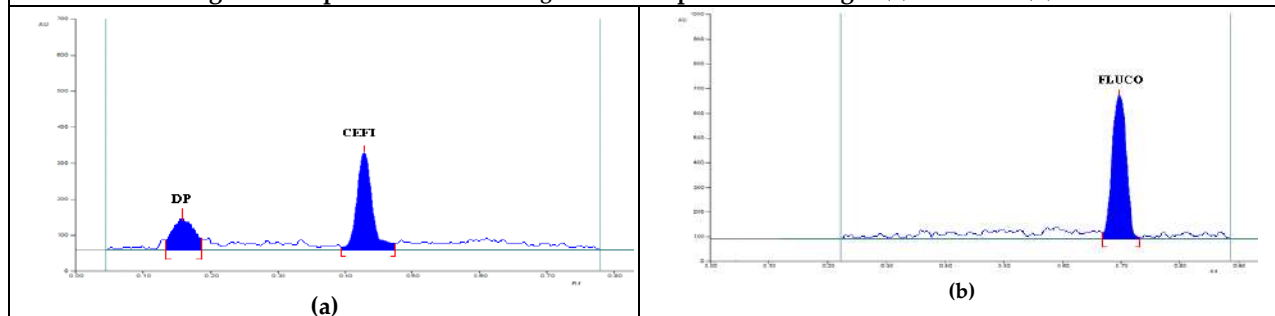
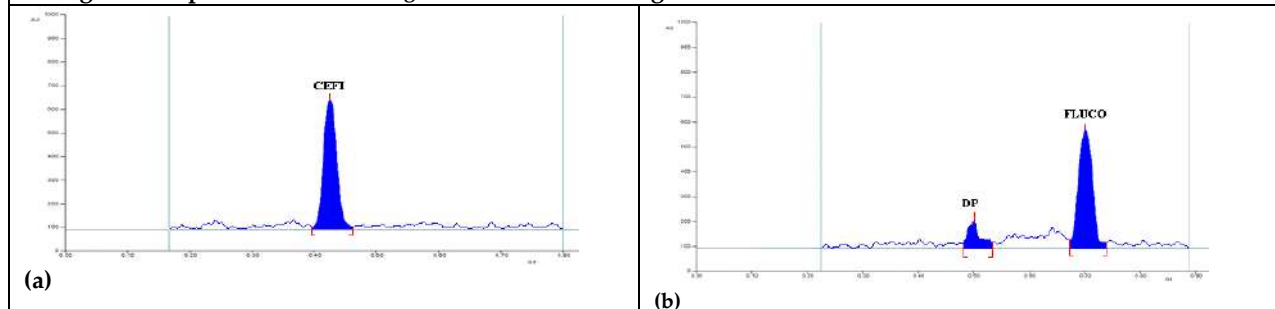
Mukesh B. Karhale *et al.*,Fig 6. Representative Densitogram after neutral hydrolysis for (a) CEFI and (b) FLU with DP ($R_f = 0.81$)

Figure 7. Representative Densitogram after exposure to sunlight (a) CEFI and (b) FLU

Figure 8. Representative Densitogram after oxidative degradation for (a) CEFI with DP ($R_f = 0.16$) and (b) FLUFigure 9. Representative Densitogram after exposure to dry heat for (a) CEFI and (b) FLU with DP ($R_f = 0.50$)