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Contemporary Trends in Chemical, Pharmaceutical and Life Sciences Volume V

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Dr. Bassa Satyannarayana
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Volume V

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PREFACE

Scientific advancements in the fields of chemistry, pharmaceuticals, and life sciences continue to play a crucial role in shaping modern research and applications. The convergence of these disciplines has led to groundbreaking discoveries that impact healthcare, industry, and environmental sustainability. Contemporary Trends in Chemical, Pharmaceutical, and Life Sciences – Volume V serves as a comprehensive collection of the latest research contributions, highlighting innovative approaches, emerging technologies, and significant developments in these fields.

This volume brings together contributions from esteemed researchers and scholars, presenting diverse topics ranging from drug development, nanotechnology, green chemistry, and biotechnological advancements to novel therapeutic strategies and environmental science. The interdisciplinary nature of these studies underscores the significance of collaboration in addressing global challenges and driving scientific progress.

A special emphasis is placed on sustainable and eco-friendly solutions in pharmaceutical and chemical research, aligning with the growing need for responsible scientific practices. Additionally, this volume explores cutting-edge methodologies in life sciences, offering new perspectives on biological processes, disease mechanisms, and medical innovations.

We extend our sincere gratitude to all the authors, researchers, and contributors who have enriched this edition with their valuable insights and findings. Our appreciation also goes to the editorial team and reviewers for their dedication in ensuring the quality and integrity of this publication.

We hope that Contemporary Trends in Chemical, Pharmaceutical, and Life Sciences – Volume V will serve as a valuable resource for researchers, academicians, and industry professionals, inspiring further advancements in these dynamic fields.

- Editors

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HEMALAKSHMI P, NITHIYAPRABA S, SANTHIYA G, SHALINI R, SOWNDHARYADURGA M AND ABARNA. T

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ABSTRACT

The *Musa paradisiaca* (banana tree) is more than a staple food source; it has been recognized for centuries in traditional medicine due to its diverse therapeutic properties. This chapter explores the medicinal values of various parts of the banana tree, including the fruit, leaves, stem, flowers, and roots. These components have demonstrated potential in treating a range of ailments, from digestive disorders and skin conditions to more severe diseases, such as diabetes and cancer. Through phytochemical analysis and scientific studies, the bioactive compounds within the banana tree reveal anti-inflammatory, antioxidant, and antimicrobial properties. This chapter also discusses how traditional practices and modern research can converge to harness the banana tree's medicinal potential for healthcare applications.

KEYWORDS: *Musa paradisiaca,* Phytochemicals, Antioxidant, Bioactive Compounds, Antiseptic.

INTRODUCTION

The *Musa paradisiacal* belonging to the *Musaceae* family, is widely cultivated in tropical and subtropical regions around the world. While commonly known for its nutritious fruit, every part of the banana tree holds significance in various traditional and modern medicinal practices. Ancient cultures in Asia, Africa, and Latin America have utilized banana tree components for health and wellness, creating remedies that address a broad spectrum of ailments.

Banana leaves, for example, have been used as natural wrappers for food and medicinal applications due to their antimicrobial properties. The flower, often consumed as a vegetable, is known to help manage diabetes and menstrual disorders. The stem and roots are rich in bioactive compounds like polyphenols and flavonoids, which have demonstrated antioxidant and anti-inflammatory properties (Choudhury H *et al.,* 2015).

In recent years, scientific studies have substantiated many traditional uses of the banana tree, identifying compounds with potential pharmaceutical applications. These findings not only validate ancient medicinal practices but also open avenues for integrating banana tree extracts into modern healthcare products. This chapter aims to provide a comprehensive overview of the banana tree's medicinal properties, examining each part's unique contributions to health and well-being.

ANCIENT AND TRADITIONAL SYSTEMS OF MEDICINE

In the Indian Ayurvedic system, *Musa paradisiaca* is considered a sacred plant with all parts viewed as having medicinal properties. Ayurvedic texts mention the use of banana fruits, flowers, stems, and roots to treat a variety of ailments. The ripe banana is recommended for digestive health and is said to help balance the doshas (energetic forces in the body). Banana flowers are used in treatments for diabetes and ulcers, while the stem juice is employed as a diuretic, aiding in kidney health and the treatment of urinary issues.

In traditional Chinese medicine bananas are believed to possess "cooling" properties, making them suitable for reducing internal heat. They are used to alleviate symptoms of excessive heat, such as fever and inflammation. The banana fruit is used as a natural laxative and is thought to help moisturize the intestines, making it valuable for those with constipation. The stem and flowers are also utilized for their purported ability to regulate blood sugar and treat infections and wounds.

THERAPEUTIC BENEFITS OFVARIOUS PARTS OF *MUSA PARADISIACA*

The *Musa paradisiaca* is considered a "whole-plant remedy," with every part from its fruit to its roots offering therapeutic benefits. The plant's parts have been used in traditional medicine to address ailments ranging from digestive issues to skin infections, and even as general health tonics. The *Musa paradisiaca* is rich in diverse bioactive compounds that contribute to its therapeutic effects. These compounds include polyphenols, flavonoids, alkaloids, and other phytochemicals that provide anti-inflammatory, antioxidant, antimicrobial, and anti-diabetic benefits. Scientific studies have identified specific compounds in the banana tree's fruit, leaves, flowers, stem, and roots, each contributing to the plant's medicinal value.

MEDICINIAL VALUE OFMUSA PARADISIACA FRUIT

Known for its high fiber and pectin content, the banana fruit is frequently used in traditional medicine as a gentle laxative and remedy for constipation. The fruit is also recommended to soothe the stomach lining, protect against ulcers, and reduce gastric acidity. Its ability to normalize bowel movements makes it a staple in traditional diets for promoting gut health. Rich in natural sugars, potassium, and vitamins like B6 and C, the banana is often used as a quick energy booster in traditional diets, especially for the elderly and children. It is also given to people recovering from illness to help restore energy levels. Due to its potassium content, the banana fruit is traditionally considered beneficial for heart health. The high potassium helps regulate blood pressure, while magnesium supports proper muscle function, including the heart. In traditional medicine, both green and ripe bananas are used to manage diarrhea. Green bananas, in particular, contain resistant starch, which is beneficial for gut health and helps absorb excess water in the intestines, reducing symptoms of diarrhoea (AliM *et al.,* 2020). In some traditional practices, bananas are recommended to alleviate symptoms of depression or low mood due to their tryptophan content, which the body converts to serotonin, a mood-regulating neurotransmitter.

The banana fruit, especially the pulp and peel, contains a range of compounds that promote health and prevent disease. Dopamine, which is present in high concentrations in both the pulp and peel, dopamine acts as an antioxidant, protecting cells from oxidative damage. It is also thought to play a role in brain health by supporting neurotransmitter functions. A potent antioxidant, vitamin C in

bananas helps reduce inflammation and supports immune function. It also plays a role in collagen synthesis, benefiting skin and wound healing (JahanF *et al.,* 2019). Catecholamine including norepinephrine and epinephrine has a role in regulating blood pressure and promoting heart health. Catecholamine also improves mood and alertness, making bananas a natural energy booster. Bananas are rich in tryptophan, an amino acid that the body converts into serotonin, a neurotransmitter linked to mood stabilization, sleep, and relaxation. Bananas are a great source of dietary fibre, including pectin, which aids digestion, improves bowel health, and helps regulate blood sugar. Found in higher levels in green bananas, resistant starch acts as a prebiotic, promoting gut health by feeding beneficial gut bacteria.

MEDICINIAL VALUE OF MUSA PARADISIACA FLOWERS

Banana flowers have been traditionally used in many cultures, particularly in Southeast Asia and India, as a natural remedy to help manage blood sugar levels. Their high fiber and low glycemic index make them beneficial for individuals with diabetes. In Ayurveda and other traditional practices, banana flowers are used to manage menstrual discomfort, including heavy bleeding and cramps. They are believed to help balance hormonal levels and are commonly consumed by women experiencing menstrual irregularities. The flowers are known for their anti-inflammatory and antimicrobial properties, making them effective in treating infections, especially in the respiratory and digestive systems. Traditional remedies often use flower extracts in teas or decoctions to alleviate symptoms of infections and inflammation. Banana flowers are traditionally consumed as a source of dietary fiber, which supports digestive health and helps alleviate symptoms of gastrointestinal disorders. In some cultures, banana flower soups or teas are consumed as a remedy for stomach discomfort.

Banana flowers are known for their health-promoting properties and are used traditionally for their anti-diabetic and anti-inflammatory effects. Banana flowers contain flavonoids like myricetin, quercetin, and kaempferol, which have strong antioxidant and anti-inflammatory properties (Saxena SC *et al.,* 2016). Flavonoids help protect cells from oxidative stress, reduce inflammation, and support heart health. Phenolic compounds such as gallic acid, ferulic acid, and chlorogenic acid, which contribute to the flowers' antioxidant properties. Phenolic acids are known to reduce inflammation, promote cell health, and improve metabolic function. The astringent nature of tannins in banana flowers makes them useful for treating infections and digestive issues. Tannins have antimicrobial and antiviral properties, which help in fighting off infections. High in dietary fiber, banana flowers help regulate blood sugar and are beneficial for gut health, making them suitable for individuals managing diabetes.

MEDICINAL VALUE OF MUSA PARADISIACAL LEAVES

Banana leaves are traditionally used as natural dressings for cuts, burns, and wounds due to their antiseptic and anti-inflammatory properties. The leaves are often wrapped around the affected area, helping to cool and soothe the skin while protecting it from infections. In some cultures, mashed or ground banana leaves are applied directly to insect bites to reduce itching and swelling. In regions with hot climates, banana leaves are employed as a cooling agent to reduce body temperature. The leaves are sometimes wrapped around the body to help bring down fever, particularly in traditional

settings where other cooling measures are not available. While primarily used for cooking, the use of banana leaves in wrapping food is believed to provide health benefits, as they release beneficial antioxidants, polyphenols, and other compounds when heated. This traditional practice is thought to enhance the nutritional value of foods and aid digestion. Banana leaves are sometimes used in steam treatments or compresses to help relieve respiratory conditions. In traditional Southeast Asian remedies, for example, the leaves may be boiled, and the steam inhaled to soothe symptoms of coughs and congestion.

Banana leaves, though mainly used as topical treatments, contain several compounds with medicinal properties (NascimentoD F *et al.,* 2020). Banana leaves are a rich source of polyphenols, particularly catechins, which exhibit antioxidant, anti-inflammatory, and antimicrobial activities. Catechins protect skin health and support wound healing when used topically. Allantoin is known for its skin-soothing and healing properties. It helps reduce skin irritation, promotes cell regeneration, and is often found in natural skin-care treatments for burns and wounds. Terpenoids are bioactive compounds that have anti-inflammatory, antimicrobial, and antiviral properties. Terpenoids in banana leaves are thought to protect the skin from infections and reduce swelling. Lignin found in the fibrous tissue of banana leaves, lignin has antioxidant properties and plays a role in supporting wound healing. It acts as a barrier, helping to protect wounds from microbial contamination.

MEDICINAL VALUE OF MUSA PARADISIACAL STEM AND PSEUDOSTEM

The juice extracted from the banana stem is widely used in traditional medicine as a diuretic, helping to flush out toxins and support kidney function. It is commonly recommended in Ayurvedic practices to prevent and treat kidney stones, as it aids in breaking down and passing stones from the urinary tract. Due to its high fiber and low-calorie content, banana stem juice is traditionally consumed to promote satiety and support weight management. It is often included in diets aimed at reducing body weight or managing obesity. The stem juice, particularly when taken fresh, is believed to have a regulatory effect on blood sugar levels. Some traditional healers prescribe it to individuals with diabetes, as it can help manage insulin response and control glucose levels in the body. In tropical regions, banana stem juice is consumed to maintain hydration and aid in detoxifying the body. It is rich in water and nutrients, making it beneficial for flushing out impurities and replenishing electrolytes in the body. The stem is used in traditional medicine to treat inflammatory conditions, particularly those affecting the digestive and urinary systems. Some cultures use stem extract to alleviate joint pain and other inflammatory conditions.

The stem and pseudo stem (the fleshy part supporting the leaves) are known for their diuretic, anti-inflammatory, and detoxifying effects. Potassium and Magnesium are abundant in the banana stem, contributing to its diuretic properties and making it helpful in managing kidney health and reducing blood pressure. Banana stem contains lignans, which are phytoestrogens with antioxidant and anti-inflammatory effects. Lignans are believed to reduce the risk of certain cancers, particularly hormone-related cancers (Sujatha S et al2023). As a rich source of fiber, cellulose in the banana stem aids digestion and promotes a feeling of fullness, making it helpful for weight management. Saponins in banana stem possess antimicrobial and anti-inflammatory properties, and they support

the body's immune function. Saponins in the stem are thought to promote detoxification and help in the management of inflammation. The stem is a good source of plant sterols, which are beneficial for heart health as they help lower cholesterol levels. Sterols also have anti-inflammatory properties and contribute to metabolic health

MEDICINAL VALUE OF MUSA PARADISIACA ROOTS AND RHIZOME

In some folk medicine systems, banana roots are used as a remedy for fever and infections. The roots are boiled to create a decoction, which is believed to have mild antipyretic (fever-reducing) properties. In certain regions, this decoction is also used to treat minor infections and soothe sore throats. Banana roots are occasionally used to treat joint pain and inflammation. Root paste or extracts may be applied topically to alleviate arthritis symptoms or muscle soreness in some traditional practices. In Southeast Asia, the rhizome or roots are used in traditional medicine to support respiratory health. They are often included in decoctions or syrups aimed at alleviating symptoms of bronchitis, asthma, and persistent cough (Mikkelsen A *et al.,* 2016). The roots, though less frequently used than other parts, are known in some traditional systems to promote digestion and relieve bloating. They are believed to enhance digestive enzyme activity, thereby aiding in the breakdown and absorption of food. Some folk remedies use banana root extracts as a natural antibiotic to treat minor infections. The roots are sometimes applied directly to the skin to prevent infection in small wounds and scrapes.

The roots and rhizome, although less commonly used, contain powerful compounds with anti-inflammatory and antiviral properties. Banana roots contain various alkaloids, which have been shown to possess antimicrobial, analgesic, and anti-inflammatory effects. These compounds contribute to the roots' use in traditional medicine for pain relief and treating infections (SaxenaSC *et al.,* 2016). Glycosides in the banana root exhibit antioxidant properties and have been traditionally used to treat infections and support heart health. Similar to other parts of the banana tree, the roots contain polyphenols, which provide antioxidant benefits and contribute to overall cell health and longevity. Triterpenoids exhibit anti-inflammatory, antiviral, and antimicrobial properties. Triterpenoids are beneficial in treating skin infections and reducing inflammation when the roots are applied topically or taken in decoctions. Known for their anticoagulant properties, coumarins in banana roots are believed to aid in blood circulation. Coumarins also have anti-inflammatory and antioxidant effects, contributing to the medicinal use of roots for inflammation-related conditions.

MODERN PHARMACEUTICAL APPLICATIONS OF MUSA PARADISIACA

Musa paradisiaca fruit, rich in vitamins, minerals, and dietary fiber, is used in nutraceutical formulations. These supplements are marketed for their health benefits, including improved digestion, energy enhancement, and heart health.The resistant starch found in green bananas acts as a prebiotic, promoting the growth of beneficial gut bacteria. Products formulated with banana extracts may be used to enhance gut health and support the microbiome. Compounds such as flavonoids, phenolic acids, and vitamins from banana fruits and flowers are isolated for use in antioxidant formulations (Asif M *et al.,* 2013). These extracts can be found in products aimed at reducing oxidative stress and inflammation, which are implicated in various chronic diseases, including cancer and cardiovascular diseases.

Bioactive compounds in banana flowers and stems, including flavonoids and dietary fibers, are being investigated for their potential in managing blood sugar levels. Extracts from these parts are explored for inclusion in diabetes management supplements and functional foods designed for glycaemic control. The antimicrobial properties of banana flowers, leaves, and roots have led to their use in developing topical and oral formulations. Extracts are investigated for their effectiveness against various pathogens, and products may be marketed for wound care and infection prevention.
Some studies have explored the antiviral properties of banana compounds, particularly against viruses like HIV and herpes. Extracts may be utilized in developing antiviral medications or supplements. Banana leaf extracts, known for their soothing and healing properties due to compounds like allantoin, are increasingly used in skincare products (Chowdhury S H *et al.*, 2018). These include creams, ointments, and masks that aim to hydrate, soothe irritation, and promote wound healing.
The application of banana leaves as a natural dressing for wounds is gaining interest in modern wound care management. Research is being conducted on their efficacy in promoting healing and preventing infections.
The nutritional profile of bananas is being leveraged in the development of functional foods—products fortified with additional nutrients to provide health benefits beyond basic nutrition. Examples include banana-flavored protein bars, smoothies, and energy snacks. Banana-based health drinks are formulated to provide a quick source of energy and nutrition, especially for athletes and individuals with high physical demands.
The protective effects of banana compounds on the gastrointestinal tract are explored for formulations aimed at promoting digestive health, preventing ulcers, and managing conditions like gastritis. The potassium-rich nature of bananas supports cardiovascular health (LimT. K. 2013). Modern supplements are formulated to help maintain healthy blood pressure and heart function, leveraging banana extracts alongside other heart-healthy ingredients.

ENVIRONMENTAL IMPLICATIONS OF *MUSA PARADISIACA*

Large-scale banana plantations often require the clearing of forests, leading to habitat destruction and loss of biodiversity. This deforestation can displace local flora and fauna, disrupt ecosystems, and contribute to soil erosion. The predominance of monoculture in banana farming reduces genetic diversity, making crops more susceptible to diseases and pests. This practice can lead to over-reliance on chemical inputs and increase vulnerability to crop failures. The removal of vegetation for banana cultivation can lead to soil erosion, reducing soil fertility and altering local hydrology. Eroded soils can result in sedimentation in nearby water bodies, impacting water quality and aquatic ecosystems. Continuous cultivation of bananas can deplete soil nutrients, requiring the use of fertilizers to maintain yield. Over time, this can lead to soil degradation and reduced agricultural productivity. Banana plantations require significant amounts of water, which can strain local water resources, especially in regions prone to drought. Over-extraction of water for irrigation can lead to groundwater depletion and affect nearby ecosystems. Runoff from banana farms treated with fertilizers and pesticides can contaminate local water bodies, harming aquatic life and potentially affecting human health (Mohiuddin A K M *et al.*, 2014).

The reliance on chemical inputs in conventional banana farming poses risks to both environmental health and human safety. Pesticides can lead to the decline of non-target species, including pollinators and beneficial insects, and can contaminate soil and water. The overuse of certain chemicals can lead to resistance in pests and diseases, necessitating the use of more potent and potentially harmful chemicals (Kamoldeen Abiodun Ajijlakewu *et al.,* 2021). The transportation and distribution of bananas contribute to greenhouse gas emissions. Additionally, deforestation associated with banana production releases stored carbon, exacerbating climate change. Banana crops are sensitive to changes in climate conditions, including increased temperatures, altered precipitation patterns, and extreme weather events. These changes can impact yields and the viability of banana farming in certain regions.

ECONOMIC IMPLICATIONS OF *MUSA PARADISIACA*

The banana industry is a significant source of income and employment for millions of people worldwide. Smallholder farmers often rely on bananas as a primary cash crop, providing them with essential income for their families.Bananas are one of the most traded fruits globally, generating substantial revenue for producing countries. Many tropical nations rely on banana exports for foreign exchange and economic stability. The banana market can be subject to price fluctuations due to factors such as supply and demand, weather conditions, and global market trends (Archit Kumar Nayak *et al.,* 2018). Price volatility can impact the income of farmers and the overall economic stability of banana-producing regions. There is growing consumer demand for sustainably sourced and fair-trade bananas. These initiatives can help improve farmers' livelihoods and promote environmentally friendly farming practices, though they may also require changes in production methods and supply chain management.

CONCLUSION

The *Musa paradisiaca* is an extraordinary plant that offers a wealth of medicinal values through its various parts, including the fruit, flowers, leaves, stem, and roots. Rich in bioactive compounds such as flavonoids, phenolic acids, vitamins, and dietary fiber, the banana tree plays a significant role in promoting health and preventing disease. Its traditional uses in folk medicine, supported by emerging scientific research, highlight its potential as a source of natural remedies for a range of ailments, including digestive disorders, inflammation, infections, and metabolic issues like diabetes.

Moreover, as the global interest in natural and holistic health solutions grows, the banana tree stands out as a versatile resource that can contribute to both nutrition and wellness. The integration of banana-derived products into modern healthcare, alongside sustainable cultivation practices, can enhance the health of communities while preserving the environment. By recognizing and harnessing the medicinal properties of the banana tree, we not only celebrate its cultural significance but also pave the way for innovative health solutions rooted in nature. Ultimately, the banana tree exemplifies the interconnectedness of agriculture, health, and sustainable development, underscoring its enduring value in both traditional and contemporary contexts.

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Chapter 2

TRADITIONAL MEDICINE

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ABSTRACT

Traditional medicine is an age-old set of prevalent practices ranging from herbalism, acupuncture, Ayurveda, to spiritual healing, being the ancient practice of all cultures. It addresses well-rounded health; that is, both physical and mental. The old history of traditional medicine is a worthy resource for learning how natural methods of healing affect humanity, many of which have influenced modern-day drugs. However, despite its benefits, lack of standardization and scientific validation are considerable challenges. Organizations such as the WHO promote integration of traditional medicine in modern health-care systems. Accessibility and more comprehensive health solutions are enhanced. Continued research and regulation of traditional practices will ensure safety, efficacy, and quality.

KEYWORDS: Traditional Medicine, Herbal Medicine, Acupuncture, Ayurveda.

INTRODUCTION

Traditional medicine refers to knowledge, skills, and practices accredited by theories, beliefs, and experiences that are original to the different cultures. Such health practices are used to maintain health, prevent, diagnose, or treat physical and mental illnesses. Some of these include the remedial use of herbs, acupuncture, massage, and spiritual therapies. The idea is to upgrade the condition with natural and holistic means. The technique further aids in the prevention of diseases by using natural remedies and changes in lifestyle. The correct diagnosis and treatment of diseases occur in a natural fashion using traditional techniques and natural resources. It is also important to maintain and bequeath the culture surrounding health and medicinal science. Such an approach deals with the physical, emotional, and spiritual spheres of health and thus creates an all-inclusive framework for treatment.

SIGNIFICANCE OF TRADITIONAL MEDECINE

Traditional medicine usually offers accessible health care resources, especially in remote and low-resource regions where modern health care is not readily available. Being part of a community's cultural and social life makes it more acceptable and comfortable for people to use. The holistic nature of traditional medicine is in how it views the entire human body, that is, for the body, mind, and spirit. Conventional medicine can complement modern medicine by offering supplementary or alternative medicine, especially useful in chronic diseases. It usually resorts to locally sourced resources, thus promoting sustainability and biodiversity conservation.

HISTORY

Traditional medicine has a rich and diverse history that spans thousands of years and various cultures around the world. The traditional medicine practices date back to ancient civilizations such as Egypt, China, India, and Greece. For example, the Egyptian Papyrus Ebers (about 1500 BC) mentions the use of medicinal plants.TCM also known as Traditional Chinese Medicine is thought to be one of the oldest systems of medicine and dates back at least 2,200 years. One of the earliest known written records of Chinese medicine is Huangdi Neijing, also called The Yellow Emperor's Inner Classic, dating back to the 3rd century BCE. Dating back around 1500 BCE in India, Ayurveda is another system of ancient medicine that focuses on balance within the body, mind, and spirit. In this era, the great personalities such as Hippocrates and Galen contributed to the widespread development of medical knowledge of ancient Greece. Medieval and Renaissance times, even during those times, primitive medicine was evolving itself, but the great scholars in the Islamic world canon of medicine, such as Avicenna (Ibn Sina), was fundamental for centuries. Both Native American medicine and European herbal remedies have been practiced in colonial America, blending different traditions and knowledge systems. Traditional medicine has experienced a renewal of interest, with many modern pharmaceuticals derived from the sources that traditionally were used-for example, aspirin from willow bark, artemisinin from sweet wormwood.

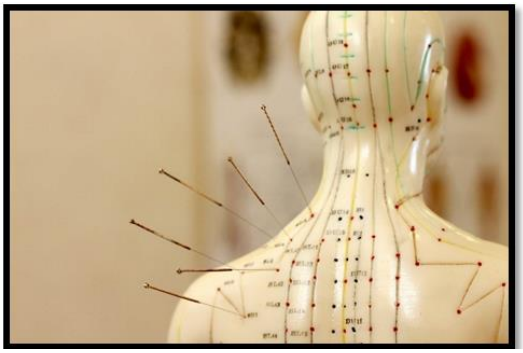
METHODOLOGY

Traditional medicine encompasses a wide range of practices and methodologies that vary across diff erent cultures and regions.

HERBAL MEDICINE

Herbal medicine, also known as phytotherapy, is the use of plants and plant extracts for the purpose of preventing, treating, and managing health-related conditions. The traditional method is founded from different parts of the world, such as Ancient Egypt, China, and India. Preparations of herbal medicines depend on the medicinal properties of the plant and can be made in such forms as teas, tinctures, capsules, and ointments. Many of the herbs such as chamomile, echinacea, and ginseng provide anti-inflammatory benefits and a healthy immune system. For example, resources like "The Green Pharmacy" by James A. Duke and "The Encyclopedia of Medicinal Plants" by Andrew Chevallier come as mega collections to find, process, and apply herbal remedies properly. Herbal medicine takes a more natural holistic approach toward health; for example, herbal medicine yields fewer side effects than synthetic drugs. This method has been quite trendy in recent years with the wide need for more natural and holistic health solutions.

ACUPUNCTURE



Acupuncture is the technique in the practice of traditional Chinese medicine, through inserting quite thin needles in several defined points in the body to balance the flow of energy, or "qi." This practice, more than 2,500 years old, has been used for healing and relief from the various health conditions, such as chronic pain, migraine, and even insomnia. The needles stimulate the nerve-rich areas to enhance circulation, immune response, and pain modulation. Some interested readers will also find "The Web That Has No Weaver: Understanding Chinese Medicine" by Ted Kaptchuk and "A Manual of Acupuncture" by Peter Deadman helpful to read for a greater appreciation.

AYURVEDA

Originating more than 5,000 years ago in the Indian subcontinent, it essentially constitutes a holistic system of medicine, which focuses on restoring balance between body, mind, and spirit. Diet, along with herbal treatments and yogic breathing, is used to maintain health and prevent diseases. There are a number of key texts, such as "Charaka Samhita" and "Sushruta Samhita". Modern books include Dr. Vasant Lad, "The Complete Book of Ayurvedic Home Remedies", using modern applications of Ayurvedic principles to diseases and health issues in contemporary practice. It is this holistic approach of Ayurveda that influences global health practices today by seeking natural, tailored care.

MASSAGE THERAPY

Massage therapy could thus be described as a manipulation of muscles, connective tissues, and other body parts in an effort to improve health and well-being. Techniques include soft stroking, kneading, friction, pulling, percussion and deep pressure on muscles, tendons, and ligaments. It may be Swedish massage, deep tissue massage, or sports massage. While giving a massage may bring comfort by promoting reduced pain and tension, it tends to reduce stress, improve circulation, promote relaxation, and generally enhance one's life. Other great books to read are "The Complete Guide to Modern Massage" by Ryan Jay Hoyme and "Trail Guide to the Body" by Andrew Biel. These books help you learn more about the techniques, advantages, and practical applications of massage therapy.

ENERGY HEALING

Energy healing, which is a holistic practice of healing channeling energy to promote health in the body physically, emotionally, and spiritually, is a new form of healing that balances the body's energy fields with techniques such as Reiki, Qi Gong, and Pranic Healing. Practitioners believe in removing any blockages of energy within the body to further enhance natural processes. For a greater understanding of this area, you could refer to books like "The Energy Codes: The 7-Step System to Awaken Your Spirit, Heal Your Body, and Live Your Best Life" by Dr. Sue Morter and "The Power of Energy Medicine" by Jill Mattson. These books give a more than adequate understanding of concepts about energy healing as well as its application.

MODERN VIEW ABOUT TRADITIONAL MEDICINE

The modern takes traditional medicine as a conscious welcome to the mainstream, with an emphasis on its tradition and modern use. As modernization takes hold, ancient medicinal practices like Ayurveda and acupuncture become a part of the newer health care systems. The mainstream interest is also for the reason that there is high demand for holistic and personalized care, along with high demand for natural treatment options. For instance, many modern pharmaceuticals have been identified as part of traditional knowledge, including aspirin and artemisinin. It can be said that organizations like WHO, through advocacy programs, are supporting the development of traditional medicine to integrate into mainstream primary healthcare systems to reinforce health promotion and well-being. Books like "Traditional Medicine for Modern Times" by Priya Shetty and Andrea Rinaldi is on the challenges and benefits of integrating modern medicine and other simple areas on regulation, quality control, and equity of access.

STUDIES DONE ON TRADITIONAL MEDICINE

Studies involving traditional medicine reveal its immense contributions to medical practice today. Studies have pointed out some contemporary medical treatments stemming from such ancient practices as herbal medicine and acupuncture. For example, the discovery of artemisinin in sweet wormwood by Tu You was a giant stride in the treatment of malaria, worthy of a Nobel Prize. The willow bark, traditionally used for pain relief, is the basis of aspirin. Several organizations, such as the World Health Organization, have recognized and endorsed the integration of traditional medicine into general practice. Studies also analyze the prevalence and utilization of traditional medicine in different cultures, which proves that it is applied universally. For example, the use of these practitioners was reported based on a national survey among middle-aged and elderly populations in India. Books such as "Traditional Medicine for Modern Times" by Priya Shetty and Andrea Rinaldi pose the issues and scopes of traditional medicine and modern medicine together as a means to be integrated in an effort to cause regulation, quality control, and fair access. These reports and available literature have established the fact that traditional medicine still has its relevance and further potential in modern times.

LIMITATIONS OF TRADITIONAL MEDICINES

Traditional medicine is of undeniablevalue but has several disadvantages. One of the most significant drawbacks is a problem with the lack of standardization, since traditional remedies have

had homogeneous dosages and preparation methods that often result in variability of effectiveness and safety. Scientific validation is also primarily lacking, since clinical trials that provide rigorous proof of the efficacy and safety of many traditional practices are often missing. Adverse effects may also result from the use of blends of traditional medicine with modern medicines or unprofessional use. Other challenges are also with regulatory oversight in that products of traditional medicine are subjected to limited regulation such as pharmaceuticals; therefore, it is a challenge on matters of quality control and contamination. Traditional medicine remains instrumental in health care despite these challenges, especially in regions where access to modern medical facilities is limited.

CONCLUSION

Traditional medicine, in its very long and rich history, is still an important part of health care. Indeed, it transcends ancient practices and time-honored traditions by bringing out the full holistic approach to health and well-being; that is, it speaks of "connectedness" of the mind, body, and spirit. Perhaps because it emphasizes these and does so in a profound manner, this perspective from traditional medicine is increasingly appreciated in today's healthcare practices-besides preventive care and personalized treatment, natural therapies must increasingly integrate with them.

Despite many such advantages, challenges do pose significant hurdles before traditional medicine develops adequately, and a few of them are: they need scientific validation, standardization, and regulation. All these very crucial steps have to be taken to ensure safe, effective, and quality practices and products of traditional medicine. A collaboration with respect for cultural heritage and embracing scientific advancement may serve to fill the gap between traditional and modern medicine.

It is obvious from the efforts made by the World Health Organization and other international organizations to integrate traditional medicine into the primary healthcare system in many areas of the world that such approaches hold great promise in this respect, particularly in regions with inaccessible conventional health services. Incorporation encourages a more inclusive and diverse healthcare system and raises knowledge on the approach of diversity cultures towards medicine.

Books such as "Traditional Medicine for Modern Times" by Priya Shetty and Andrea Rinaldi, and "The Green Pharmacy" by James A. Duke, provide helpful information on the way from old sense to modern times of traditional medicine. This resource underlines the need for saving knowledge, quality, and equal access toward traditional medicines.

Thus, traditional medicine is an essential part of the health system everywhere in the world. The combination of the two would give a holistic view of health by taking advantage of the merits of both systems. We will build the best health system for our future generations by embracing and improving on the wisdom of traditional medicine while addressing their weaknesses through scientific research and regulation. The very voyage that traditional medicine has taken, from its ancient roots to its more modern applications, speaks very strongly for the importance of holistic health practices-how they endure and their potential in enhancing global health and well-being.

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Chapter
3

ENERGY-RELATED APPLICATIONS OF METAL-ORGANIC FRAMEWORKS

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ABSTRACT

Metal-Organic frameworks (MOFs), also known as porous coordination polymers (PCPs), have attracted great interest because of their unique highly porous structures, synthetic advantages, organic-inorganic hybrid nature, and versatile applications. Recently, the applications of MOFs in energy fields such as fuel storage, photo-induced hydrogen evolution, fuel cells, batteries, and supercapacitors have experienced a new surge of interest in both the chemistry and materials science communities. Recently, the development of clean sustainable energy storage and conversion technologies to deal with environmental pollution and the forthcoming energy crisis has attracted much attention in the energy research community. It is critical to develop carriers to store energy or to facilitate mass and electron transportation in energy storage and conversion. Research on the various applications of MOFs has shown that they are promising porous materials for energy storage and conversion technologies because of their inherent advantages, including structural diversity, functionality, tailorability, and versatile applications. Current chapter describes the recent progress in the energy-related MOF applications. The most outstanding research papers and reviews, which report the application of Metal-Organic Frameworks for gas storage, adsorption heat transformation, solar cells, fuel cells, hydrogen evolution reaction and supercapacitors are highlighted.

KEYWORDS: Metal-Organic Frameworks. Gas Storage, Solar Cells, Fuel Cells.

INTRODUCTION

After the globalization and economic boom, the global demand for energy resources has increased continuously and dramatically, giving rise to urgent global concerns on the sustainability of fuel reserves and environmental problems, including climate change, melting glaciers, and rise in sea levels. The development of renewable, safe, clean, and sustainable energy storage and conversion technologies has thus become a hot research topic. Considerable efforts have been devoted to mitigating the strong reliance on fossil fuel and solving environmental issues [1-3]. Hydrogen is considered an ideal energy carrier, discharging no harmful chemicals while supplying energy [2]. In addition, methane has been suggested as a transition fuel for clean and renewable energy for the future, because it is abundant in nature and yields relatively environmentally friendly combustion products. In the proposed alternative energy cycle, the energy sources are generated by photo- and electro-driven management of water and CO_2 [3]. Meanwhile, a variety of technologies such as solar

cells, fuel cells, supercapacitors, and batteries have been proposed to address the foreseeable severe energy issues [4]. Therefore, confidence in overcoming the energy crisis and the environment pollution has been strengthened considerably.

Renewable energy sources, such as solar and wind power, are taking up a growing portion of total energy consumption of human society. Owing to the intermittent and fluctuating power output of these energy sources, electrochemical energy storage and conversion technologies, such as rechargeable batteries, electrochemical capacitors, electrolyzers, and fuel cells, are playing key roles toward efficient and sustainable energy utilization [5,6]. For example, electricity generated from solar and wind power can be efficiently stored in and released from rechargeable batteries and electrochemical capacitors, or converted into fuels by electrolyzers and further regenerated by fuel cells. Despite their different working principles, these electrochemical devices include the following key functional components [7]; two electrodes (cathode and anode), where the major electrochemical processes take place, such as charge storage in batteries/capacitors and electrocatalytic reactions in electrolyzers/fuel cells, and an electrolyte that allows the transport of ions and blocks electronic conduction to complete the electric circuit. In principle, the physical (for example, electronic and ionic conductivity) and electrochemical (for example, redox and catalytic activity) properties of functional materials used in these components govern the performance of devices. Therefore, seeking better materials has been a primary quest for the development of future electrochemical energy–related technologies.

During the development of innovative energy technologies, a porous material, which are able to store energy carriers or to facilitate fast mass and electron transportation for energy storage and conversion, have been explored extensively to identify the best materials for photo- and electrochemical energy applications. Suitable surface area, rational pore-size distribution, desired morphology, and superior functionality are the most important factors for mass and electron transportation and substance reaction kinetics, thus determining the performance of energy devices. In comparison with traditional inorganic porous materials, with metal-organic frameworks (MOFs) have a highly porous structure, uniform spatial dispersion of components, tunable pore sizes and topologies, a hybrid organic-inorganic nature, and multifunctionality [8-9], which enable them to outperform other porous materials in energy applications. Furthermore, the well-defined structure is helpful for the direct and exact rationalization of the related structure-property relationships, which is an important aspect for optimizing materials. In recent years, the spectacular development of MOFs has drawn wide attention

In recent years, the spectacular development of MOFs has drawn wide attention from many fields and is stimulating the emergence of an innovation wave of conventional energy applications. The excellent gas storage capacity of MOFs at ambient temperature has driven their rapid growth, providing a large number of new adsorbents with potential uses in vehicle gas tanks, fuel cells, and stationary power facilities. After more than few decans of exploration of the syntheses and fundamental properties of MOFs, their energy applications have become a hot topic. Development of MOF-related materials for electrochemical energy storage and conversion has been a rapidly expanding research area in the past decade. Several excellent reviews have summarized recent advances in this field mostly focusing on specific aspects, such as MOF-related materials for specific

applications (for example, photocatalysis/electrocatalysis and energy storage devices) or functional/nanostructured materials derived from MOFs [9-13]. We hope that this review and the cited articles will inspire chemists and material scientists to explore MOFs for energy applications.

PHYSICAL ADSORPTION STORAGE

HYDROGEN STORAGE

Hydrogen is an ideal clean-energy carrier, and hydrogen storage materials with high gravimetric and volumetric densities are prerequisites for practical on-board application. The first discovery of MOF-5 (Figure 1) with hydrogen storage capability was reported in 2003 [8]. Since then, porous MOFs have attracted increasing attention as hydrogen adsorbents, and the number of MOFs for high hydrogen storage has increased significantly. Thus far, the highest hydrogen storage capacity with total H2 gravimetric uptake of 17.6 wt % at 80 bar and 77 K is still exhibited by MOF-210 with the highest surface area [13]. Although the overall gravimetric H2 storage capacity (77 K and high pressure) has been estimated to be proportional to MOF surface areas [2], this cannot be enhanced infinitely because of the synthetic difficulty in achieving MOFs with much higher surface area. In addition, the hydrogen storage performance of MOFs can be boosted by introducing open metal sites (OMSs), alkaline or alkaline-earth metal ions (such as Li+ and Mg2+), metal nanoparticles, and small pores.

METHANE STORAGE

Methane, the main component of natural gas, has the highest hydrogen to carbon ratio with a high-octane number of 107. It is crucial to develop safe, cheap, and convenient technologies for high-capacity methane storage for implementation in natural-gas-fuelled vehicles. The emerging porous MOFs are promising candidates for adsorbed natural gas (ANG) technology. It is well known that the pore volume and Brunauer-Emmett-Teller (BET) surface area, in combination with pore size, play vital roles in the physical adsorption of methane [2]. The total gravimetric uptake of MOFs is proportional to the pore volume and BET surface area under high pressure, and the proper pore size will be significantly helpful for enhancing total methane storage capacity[14]. The introduction of OMSs and functional groups is able to improve methane binding affinity and thus increases the volumetric methane uptake [2,5]. There is an unexpected increase in the volumetric uptake when the benzene ring of NOTT-101 is replaced with the pyrimidine ring of UTSA-76[15]. This MOF exhibits an extraordinarily high volumetric uptake of 257 cm3 (STP) (298 K and 65 bar) and a high working capacity of 197 cm3 (STP).

CHEMICAL HYDROGEN STORAGE

Chemical hydrogen storage is defined as the storage of hydrogen in chemical bonds, which is promising for fuel-cell applications. It is also a safe and efficient alternative to physical hydrogen storage. The chemical storage of hydrogen in solid and liquid states has been extensively investigated in the past few decades. MOFs are able to confine chemical hydrides in their nanopores, releasing hydrogen under mild conditions with less undesirable volatile byproducts. Moreover, MOF-supported metal nanoparticle catalysts enhance the hydrogen liberation kinetics of liquid-phase chemical hydrides.

Nanoconfinement of chemical hydrides in the pores of MOFs is of great interest for chemical hydrogen storage, changing the thermodynamics of chemical hydrides and significantly enhancing

dehydrogenation kinetics with suppressed evolution of undesirable volatile byproducts[16-180. The nanoconfinement of chemical hydrides in MOFs was first attempted with HKUST-1 to confine solid NaAlH4.36 A comparative study on the H2 desorption behavior of NaAlH4@HKUST-1 and NaAlH4 revealed that the former species desorbs H2 at a much lower temperature (70 oC) than the latter (250 oC). With the aim of increasing the hydrogen release rate and suppressing volatile byproduct formation in the dehydrogenation process, a metal-nanoparticle-embedded MOF scaffold, Pt@MIL-101, was used to confine ammonia borane (AB). [18]

SOLAR CELLS

In the last decade the photovoltaic is considered as a prospective source of the green energy and alternative to nuclear and charcoal plants. Although the silicon-based solar panels are now widely commercialized, the search for a more efficient charge separation is still ongoing. Beside the organic perovskites with their record power conversion efficiency (PCE), MOFs, based on the red-ox active metals are also considered for this type of application. Following this idea, Vinogradov and coworkers used Ti-based MOF MIL-125 (MIL - Materials Institute Lavoisier) as a composite with TiO2 for the construction of the solar cell. As a result, authors succeed with increasing of PCE from 2.5 % for pure TiO2 to 6.4 % for the composite containing 3 % of MIL-125 in TiO2 [19]. Different strategy to introduce the red-oxcenter into the MOF-based solar cell was introduced by Morris and co-workers. RuDCBPY (RuDCBPY –ruthenium(II) bis-(2,20 -bipyridine)(2,20 -bipyridine-5,50 -dicarboxylic acid)) containing UiO-67 (UiO) type MOFs were grown as thin films on TiO2 as sensitizing materials[20].

CONCLUSIONS

Overall, the development of MOF-related materials for electrochemical energy storage and conversion has been an exciting interdisciplinary area, where opportunities and challenges coexist. One might expect rapid development of MOF-related functional materials from materials design and synthesis, evaluation of properties, fundamental understanding, and eventually to practical applications. In addition to fundamental research, low-cost and industrial production of MOFs has already been successfully demonstrated

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Chapter 4

SULPHONAMIDES WITH THEIR DERIVATIVES: A POTENTIAL ANTIBACTERIAL AGENTS

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ABSTRACT

The sulphonamide is an antibiotic which has provocative role in cure of the infections caused by gram positive and gram negative bacteria. The current topic has gained more attention in the treatment of various infections. The current article focuses on the comprehensive study of the sulphonamides with their derivative preparations as it includes the synthesis of sulphonamide from benzene, benzene derivatives, method of preparation of N-heteroaryl substituted benzene with their pharmacological activity furthermore it also states the methods intended for the synthesis of sulphonamide by adopting the synthetic approaches. Therefore the sulphonamides are costly but it has been used worldwide or could have the promising effect in the cure of infections.

KEYWORDS: Sulphonamides, Derivatives, Pharmacological Activity, Uses.

INTRODUCTION

Sulphonamide is a synthetic antibiotic. It is effective against the gram-positive and gram-negative microorganisms. Sulphonamides were discovered the first effective chemotherapeutic agent against different bacterial infections.

The structure of sulphonamide is resembles to Paraminosalicyclic acid. The sulphonamide drugs are derivatives of sulphanilamide.

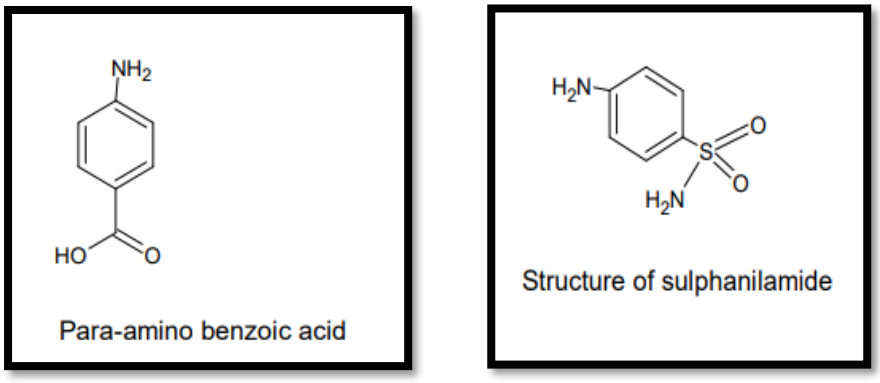


Fig 1: Structure of Para amino benzoic acid and sulphanilamide

Many adverse reactions such as haemopoietic disorders, hypersensitivity reactions, urinary tract disorders, and porphyria, can be brought on by sulfonamides. Large doses of these have the potential to trigger a severe allergic reaction. Toxic epidermal necrolysis, or Lyell disease, and Stevens-Johnson syndrome are two of the most dangerous. Sulphonamide antibiotic treatment causes adverse effects in about 3% of the general population[5]

Derivatives of sulfonamides the discoveries made by medical groups may resemble a thread of unique pearls. Although their bioactivities differ, they share the same primary core. The shared core structure of sulfonamide. Sulfonamides were classified in the literature as either non-anti-bacterial sulfonamides or anti-bacterial sulfonamides with or without an aromatic amine. The latter group consists of medications that have anti-inflammatory, anti-hyperglycemic, diuretic, serotonin antagonist, or other pharmacological properties. This activity is dependent, as we suppose in this article, on the replacements that the compound's chemical structure contains in addition to the sulfonamide group. Here, we attempted to gather the characteristics and molecular structures of sulfonamide medications so that we could compare them based on structural variations that correspond to their respective actions.

HISTORY OF SULPHONAMIDE

The prontosil may be prepared by the diazotization reaction of m-phenylenediamine with sulphanilamide. It was noticed that prontosil is inactive in-vitro and possesses the good antimicrobial activity in vivo.

In year 1937 the sulphapyridine was prepared which is analog of sulphanilamide.it is widely popular in treatment of pneumonia.

NOMENCLATURE OF SULPHONAMIDE

Sulphonamide is derivative of para amino benzene sulphonamide skeleton. The sulphonamide Consists of SO_2NH_2 group which is essential for antibacterial activity.

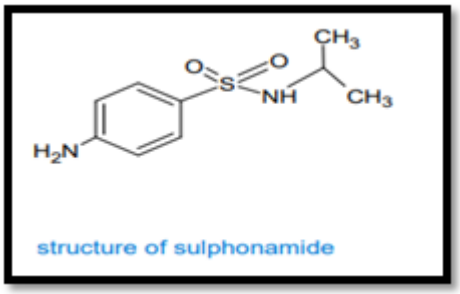


Fig 2: Structure of Sulphonamide

CLASSIFICATION OF SULPHONAMIDE

Based on pharmacokinetic activity it is classified as follows

- Absorbed and excreted rapidly: sulphisoxazole, sulphamethoxazole, sulphadiazine
- Poorly absorbed: sulphasalazine
- Topically used: Sulphacetamide, silver sulphadiazine
- Long acting: sulphadoxine
- On the basis of pharmacological activity it is classified as

- Long acting sulphonamide
- Intermediate acting sulphonamide[6]
- Short acting sulphonamide
- Ultra short acting sulphonamide

MECHANISM OF ACTION

Sulphonamide drug compete with paraminobenzoic acid and for the dihydrofolate synthase enzyme and block the synthesis of dihydrofolic acid, tetrahydrofolic acid. Hence the folic acid synthesis is stopped in bacteria.

SAR OF SULPHONAMIDE

- The structure consists of the SO2 group acts as an electron withdrawing group it acquiresa partial positive charge on adjacent nitrogen atoms hence it increases the acidity of hydrogen atoms present near to nitrogen atom which increases the antibacterial potency of drugs.
- The pka of sulfisoxazole is 5.0 and it has poor water solubility hence it is responsible for the crystalluria that leads to kidney damage moreover it is recommended that take plenty of water if you are taking medicines sulphonamide to avoid kidney damage.
- The sulphur atom should directly attach to the benzene ring.
- Replacement of benzene ring system by another ring it decreases the activity of drug.
- The amino group of the sulphonamide is essential for antibacterial activity.[6,7]

METHOD OF PREPARATION OF SULPHONAMIDE

Nitrobenzene is synthesized by using nitrating benzene. Tin and hydrochloric acid are used as reducing agents to further decrease the resulting anilinium ion to aniline, which is then further processed with sodium hydroxide. 4-acetamidobenzenesulfonyl chloride is the result of the reaction between acetanilide, which is created through acetylation in the aqueous medium, and chlorosulfonic acid. In the presence of ammonia, the resulting intermediate yields 4-acetamidobenzene sulphonamide. The last stage of the synthesis is hydrolyzing 4-aminobenzenesulfonamide (sulphanilamide) in an acidic medium.

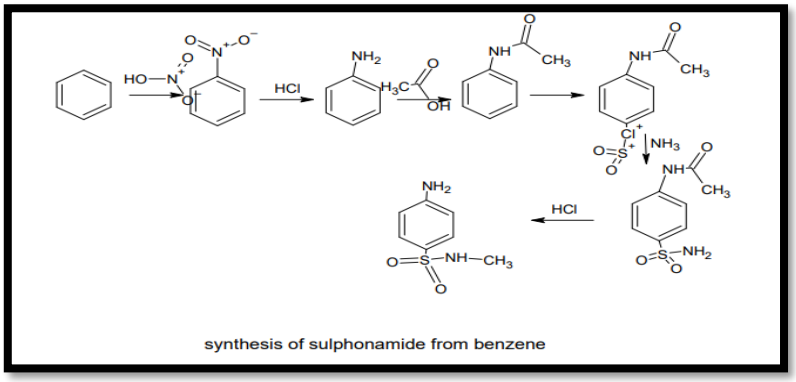


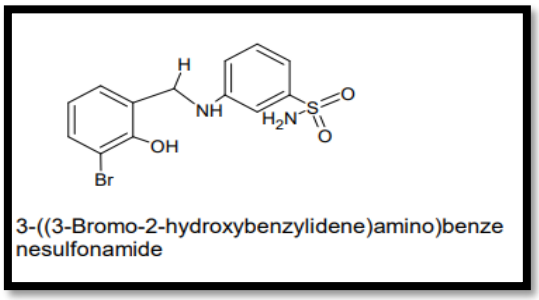
Fig 3: Synthesis of sulphonamide from benzene

GENERAL METHODS FOR THE DERIVATIVE PREPARATIONS

The general procedure for the derivative are imine, aromatic aldehyde solution was mixed with the methanol and prepare another solution the methanol with few drops of sulphonamide, add formic

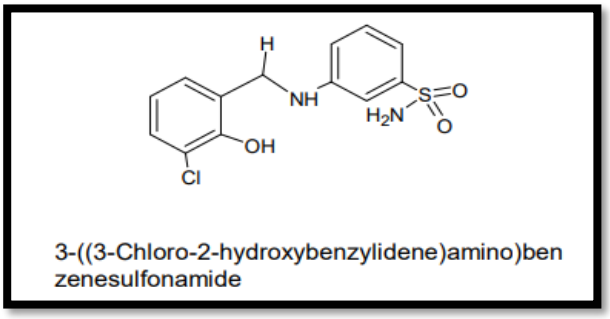
acid and stir the solution 3-5 hrs under reflux. The solutions were monitored by performing the thin layer chromatography and infrared spectroscopy. The solution was subjected to evaporation. The solid product washed with ice cold water and recrystallized by using methanol as a solvent.

3-((3-Bromo-2-hydroxybenzylidene)amino)benzene sulfonamide : The percentage yield of a product is 60%, Colour: White, Melting point: 121-122C, Infrared spectroscopy: 3344, 3324 (NH, NH_2), 3253 (OH), 3111, 3078 (Ar-C-H), 2860–2995 (Aliphatic –C–H), 1617 (–C=N–), 1325 and 1315 respectively.



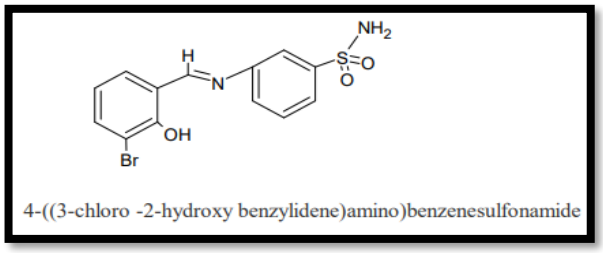
3-((3-Bromo-2-hydroxybenzylidene)amino)benze nesulfonamide

3-((3-chloro -2-hydroxy benzylidene)amino)benzenesulfonamide: The percentage yield of a product is 85% the Colour of the product is Dark Yellow, Melting point: is 205-207, Infrared spectroscopy: From the IR spectra the following functional group was found be NH2, Ar-H,3266, 3115–3410and 3085, 3061for function group of OH and –C=N respectively.



3-((3-Chloro-2-hydroxybenzylidene)amino)ben zenesulfonamide

4-((3-Chloro-2-hydroxybenzylidene)amino)benzenesulfonamide: The percentage yield of product is 60%.the physical appearance is white the melting point of product is 170-172^0 C, IR ranges were found to be in the following manner 3368, 3348 (NH, NH_2), 3254 (OH), 3116, 3066 (Ar-C-H), 2840–2985 (Aliphatic –C–H), *1616 (*–C=N–) (disappeared), 1338 (asymmetric), 1135 (symmetric) (S=O).



4-((3-chloro -2-hydroxy benzylidene)amino)benzenesulfonamide

Fig 4: 4-((3-Chloro-2-hydroxybenzylidene)amino)benzenesulfonamide

4-((3-Bromo-2-hydroxybenzylidene)amino)benzenesulfonamide: The percentage yield of the product is 60%.The physical appearance is white the melting point of the product is 180-182C, IR spectra were found to bein the following ranges 3362 3347 (NH, NH_2), 3254 (OH), 3125, 3075 (Ar-C-

H), 2880–2960 (Aliphatic -C-H), 1616 (–C=N–) (disappeared), 1308 (asymmetric), 1135 (symmetric) (S=O).[9]

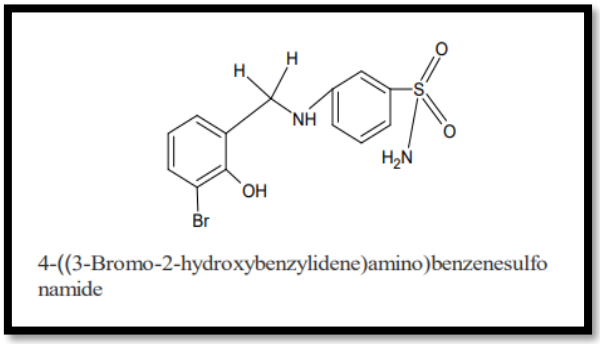


Fig 5: 4-((3-Bromo-2-hydroxybenzylidene)amino)benzene sulfonamide

BIOLOGICAL ACTIVITY OF SULPHONAMIDE DERIVATIVES

It was looked at how they affected the activities of carbonic anhydrase I and II and AChE. Several bio analytical assays, including metal-reducing capacities with CUPRAC and FRAP assays and radical scavenging tests with ABTS•+ and DPPH•+, were used to assess their antioxidant activity. At nanomolar doses, all drugs demonstrated adequate enzyme inhibitory activity against AChE and CA isoforms, with KI values ranging from 10.14 ± 0.03 to 100.58 ± 1.90 nM. High metal reduction activity and roughly 70% ABTS radical scavenging activity were demonstrated by the amine group-containing derivatives. Owing to their antioxidant properties and inhibition of AChE, these new compounds could be promising candidates for further research into neurodegenerative illnesses.

SYNTHESIS OF BENZENE SULPHONAMIDE

1 mmol of each corresponding amine (urea, thiourea, semicarbazide, and thiosemicarbazide) was dissolved in water in a 100 mL round-bottom flask. Subsequently, 1 mmol of 4-methylbenzenesulfonyl chloride and benzenesulfonyl chloride were weighed individually and added to the mixture with 1 mmol of amine mentioned earlier. The reaction's pH was kept between 6 and 8 by adding 0.05 M Na2CO3 drops-wise, and a digital pH meter (WTW, Germany) was used to track the pH. At room temperature, synthesis was completed in a round-bottom flask equipped with a magnetic stirrer. The decrease in pH brought on by the HCl production during the reaction served as a gauge for the reaction's advancement. Because the basic medium was aqueous, hydrogen was extracted with ease. The solvent was evaporated on a water bath to produce residues once the pH was stabilized. Remaining material was dissolved with acetone, and residue was filtered using filter paper (Whatmann no. 42). Pure crystals were obtained by evaporating the acetone present in the filtrate. After that, the crystals were repeatedly cleaned and let them dry. Crystals soluble in water were produced. Using pre-coated silica TLC plates, thin layer chromatography was used to confirm the product formation. Spots were observed under UV light by in the presence of a chloroform and methanol (8:2) mobile phase.

The following derivatives prepared from benzene sulphonamide : N-(aminocarbonyl)-4-methylbenzenesulfonamide (1, $C_8H_{10}N_2O_3S$), N-(aminocarbonothioyl)-4-methylbenzenesulfonamide (2, $C_8H_{10}N_2O_2S_2$), N-(aminocarbonyl)benzenesulfonamide (3, C7H8N2O3S), N-(aminocarbonothioyl)benzenesulfonamide (4, C7H8N2O2S2), N,N′-carbonylbis(4-

methylbenzenesulfonamide) (5, C15H16N2O5S2, Each derivative were characterized by using the ultra violet spectrophotometer, Infrared spectrophotometer and confirmed by using the thin layer chromatography as a methanol: chloroform solvent in ratio of 2:8, ^{1}HNMR and mass spectroscopy.

ANTIMICROBIAL STUDY OF BENZENE SULPHONAMIDE DERIVATIVES

Total sixteen derivatives were employed for the screening of antimicrobial activity against the gram positive and gram negative bacteria like *Staphylococcus aureous* and *E-Coli, Candida albicans.* From the observation of Minimum inhibitory concentration and IC50, all the compounds exhibited the excellent activity against the gram positive bacteria like *S. aureous* and the ineffective against the gram negative bacteria like *Candida albicans*.

MOLECULAR DOCKING OF BENZENE SULPHONAMIDE

From the Protein Databank (www.rcsb.org), the crystal structure of staphylococcus aureus's dihydropteroate synthase with PDB ID = 1AD4 was obtained. The Schrodinger software's "protein preparation wizard" was used to prepare it. This enzyme's side chains and missing residues were added using the Prime modeling tool included in the program as indicated in above. Following the removal of the co-crystallized chemicals, hydrogen atoms were introduced to the crystal structure. Additionally, water molecules were eliminated from the enzyme's active site. After that, steric conflicts were eliminated by limiting the prepared enzyme's minimization to a distance of 0.3 Å from the original structure using the OPLSA_2005 force field. The ChemDraw software was used to sketch all biologically active synthesized compounds, and the Schrodinger software package's lig-prep module was then used to prepare them. Along with their various conformations, these chemicals also produced distinct ionization and tautomeric states[10].

SYNTHESIS OF N-HETEROARYL SUBSTITUTED BENZENE SULPHONAMIDE

GENERAL PROCEDURE

The following describes the synthesis of N-heteroaryl-substituted benzenesulphonamide (3a–h). Anhydrous acetone (10.00 ml) was used to dissolve heteroaromatic compounds (2a–h) (10 mmol). Dry pyridine (3 ml) was added, and benzene sulphonyl chloride (1) (1.76 g, 10 mmol) was added. The mixture was stirred for approximately five minutes to aid in the dissolution process. After 24 hours, the reaction mixture gave rise to N-heteroaryl substituted benzene sulphonamide (3a–h) as a crystalline solid after suction filtering. The crude product was crystallized using dimethylformamide (DMF) and acetone. The goods were baked at 50∘C for six hours in a hot air oven to produces good to outstanding yields of the target molecule (67.8% to 85.5%). The derivatives of N-arybenzene substituted benzene were monitored by using infrared spectroscopy and thin-layer chromatography.

MINIMUM INHIBITORY TEST

The sulphonamides were synthesized by serial dilution starting with a 2 mg/mL solution and ending with 2.0–0.125 mg/mL. Following dilutions used, the test solutions were put to the matching molten agar cups, commencing at the lowest concentration (0.125–1.0 mg/mL). Incubation at the proper incubation temperature and time came next. The diameter of the inhibition zone (IZD) was obtained by subtracting the measured inhibition zone diameter (IZD) from the corkborer's diameter (8 mm).

The logarithm of IZD2 against concentration for each plate containing a certain drug and microbe was used to calculate the MIC. The intercepton *X*-axis's antilogarithm yields the MIC. Few of the derivatives were more effective than the standard compound[11].

SYNTHESIS OF SULPHONAMIDE DERIVATIVE BY SYNTHETIC SCHEME

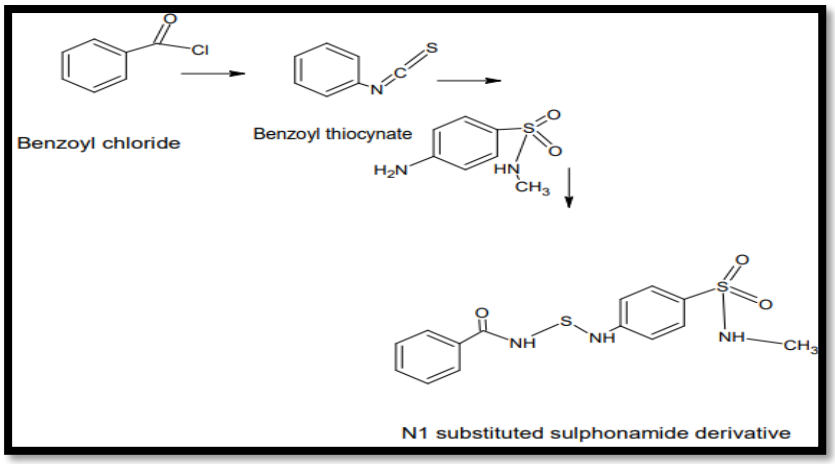
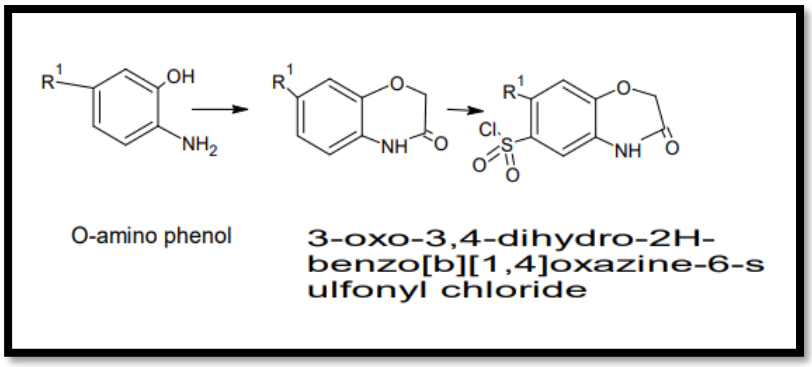


Fig 6: N-substituted sulphonamide derivative

Scheme-I

To obtain substituted benzoyl isothiocyanate, a suspension of potassium thiocyanate (1 mmol) in acetone (30 ml) was mixed dropwise with a solution of substituted benzoyl chloride (1 mmol) in acetone (20 ml). The reaction mixture was then refluxed for 1.5 hours. After the reaction was finished and the substituted sulphonamides (1 mmol) were added, the mixture was agitated under reflux for 4–8 hours, and the reaction was verified by TLC. When the reaction is finished (as determined by TLC), the precipitate that forms is collected through filtration and then recrystallized from ethanol, water, or dimethyl-form amide to produce a pure product.

Scheme –II



Substituted o-amino phenol 3a-b was treated with chloroacetyl chloride in the presence of benzyl triethyl ammonium chloride (TEBA), resulting in 2H-benzo[b][1,4] oxazin-3(4H)-one 4a-b. Compounds 5a-b were then obtained via chlorosulfonylation.The two-step synthesis approach led to the intermediate 3-oxo-3,4-dihydro-2H-benzo[b][1,4]oxazine-6-sulfonyl chloride 5a-b.

CONCLUSION

The present article highlighted the comprehensive study of sulphonamides and methods of derivatives. It stated the methods employed for the synthesis of derivatives by following the

synthetic scheme with their pharmacological activity. Therefore the sulphonamides and its derivatives could be therapeutically active in order to give its promising effect.

ACKNOWLEDGEMENT

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Chapter 5

INTERACTION OF COMMONLY USED COMMERCIAL PESTICIDES WITH NITROGEN-FIXING CYANOPHYTES

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ABSTRACT

The use of pesticides to manage pests in different crop field soil has resulted in a number of environmental issues and poses a serious risk to beneficial microorganisms. Pesticides are essential parts of contemporary agricultural operations. The impact of four commercial-grade pesticides viz. Carbamate, Furadan, and Sevin; Organophosphate, Rogor; and Organochlorine, Endotaf on the survival and qualitative occurrence of blue-green algae was examined in this study through taking into account 100% survival on the untreated control plate. According to the practical findings, soil blue-green algae exhibit varying degrees of pesticide treatment resistance. At 500 ppm of carbamate insecticides, Furadan and Sevin, the examined blue-green algae's survival percentage dropped by as much as 50%. However, at the 500 ppm dose level of Rogor and Endotaf, only 10.52% and 5.26% survivability has been recorded. Additionally, the carbamates Sevin and Furadan and the organophosphate Rogor were less harmful than the organochlorine insecticide Endotaf. In laboratory cultures, it was found that the qualitative and quantitative occurrence of heterocystous and non-heterocystous blue-green algae was significantly reduced at higher pesticide application doses i.e., more than 100 ppm of Furadan, Sevin, and Rogor, and even at 100 ppm of Endotaf. Sheathless heterocystous and unicellular forms of various blue-green algae were generally found to be more prone to pesticide application than heterocystous ensheathed and non-heterocystous ensheathed forms. This implies that the nitrogen-fixing blue-green algae in different crop fields could be impacted from the indiscriminate application of these pesticides, which directly affects overall productivity.

KEYWORDS: Pesticides, Blue-Green Algae, Survivability, Occurrence.

INTRODUCTION

India's largest economic sector, agriculture plays a vital part in the nation's economic development in a number of ways. In the 1967, green revolution has significantly improved agricultural output and to some extent, resolved India's over-exploited population's food crisis. India has recently promoted and embraced the use of blue-green algae as an effective source of biofertilizer for a variety of crops. According to Majumdar (2015) and Singh *et al.,* (2016), biofertilizers are essentially soil-friendly microbial inoculants that are grown under controlled conditions to improve crop output and soil fertility. Utilizing biofertilizers derived from indigenous cyanobacteria strains has

the potential to improve rice and other crops' nitrogen use efficiency (Pereira *et al.,* 2009). Cyanobacteria are a diversified group of photosynthetic prokaryotes with a wide range of metabolic activities and exceptional biosynthetic potential.

Blue-green algae (Cyanophytes) are special prokaryotic organisms that can carry out complementary tasks including photosynthesis and nitrogen fixation within specialized cell heterocysts makes them unique (Kulasooriya and Magana-Arachchi 2016). By fixing nitrogen from the atmosphere, these photosynthetic cyanobacteria contribute significantly to the nitrogenous fertility of soil (Ahmed 2001; Tiwari *et al.,* 2011). In addition to their capacity to fix nitrogen, they also release ascorbic acid, auxins, and vitamin B_{12}, all of which may improve agricultural plant growth and productivity (Venkataraman & Neelkantan, 1967: Stewart, 1977). As animal feed, protein supplements, soil conditioners, biofertilizers, and biomonitors of soil fertility and water quality, they hold great promise for environmental management (Whitton and Pots, 2000). Since the previous two to three decades, cyanobacteria have gained significant practical significance as a biofertilizer.

Destroying blue-green algae populations through the use of pesticides meant to manage insects and other pests of different crops is one issue that has been observed in the crop field. Because these agrochemicals stay in the environment for a long time, they also harm a wide range of beneficial microorganisms (Islam *et al.,* 2007). Therefore, in addition to their intended uses, pesticides used in agriculture fields on a regular basis have significant ecological repercussions. Large volumes of pesticides have been used in agriculture throughout production and storage as a result of the advent of crop varieties that respond to fertilizer. The usage of pesticides has increased dramatically over the past forty years, leading to a large crop output and a decrease in production costs (Gupta and Baruah, 2015).

Unfortunately, pesticides are often utilized without considering the risks they pose to the biosphere. Due to their extended environmental persistence, these agrochemicals also harm a wide range of beneficial microorganisms (Subramanian, 1988). The chemical components of pesticides also affect their toxicity, in addition to the methods of application, duration of exposure and sensitivity of the organisms (Buch *et al.,* 2013; Yusoff *et al.,* 2016). Consequently, in addition to their intended uses, pesticides applied regularly in agricultural fields have significant ecological impacts (Aydinalp and Porca, 2004). Nowadays, a wide range of pesticides are used, including carbamates, organochlorines, organophosphates, and synthetic pyrethroids.

Although overuse of these agrochemicals had a negative impact on nitrogen fixation by blue-green algae, which reduced crop output. The current state of environmental issues brought about by the inconsiderate and excessive use of pesticide applications meant to manage pests in different types of crops. In this context, survivability of soil blue-green algae was studied by subjecting them to varying concentrations (ppm) of Carbamate, Organophosphate and Organochlorine pesticides for 28 days and compared with untreated control. These studies are helpful in encouraging farmers to implement improved agricultural management techniques, which will lessen the need for chemical pesticides and the issue of environmental deterioration.

MATERIALS AND METHODS

PESTICIDES USED

The impact of four widely used pesticides from the carbamate, organophosphate and organochlorine groups- Furadan (carbofuran, 3% G), Sevin (carbaryl, 50%) (Union Carbide Ltd.), Rogor (dimethoate, 30%), and Endotaf (endosulfan, 35%) (Rallis India Ltd.) on the Occurence and survival of soil blue-green algae was investigated. These pesticides are typically used to combat nematode, lepidopterous, and sucking pests and mites that affect the region's vegetable, oil, cotton, maize, wheat, sugarcane, and onion crops. While organochlorine, Endotaf attack the central nervous system and interfere with the pest's α-amino butyric acid receptor activity, carbamate and organophosphate pesticides are used as contact and stomach action pre-emergence systemic pesticides that disrupt the cholin esterage reversible activity.

CULTURE MEDIA USED

BG-11 Culture medium (Rippka *et al.,* 1979) was used for the present study and composition of BG-11 liquid medium per litre of glass-distilled water was 1.5g $NaNO_3$, 0.04 g K_2HPO_4, 0.075 g $MgSO_4.7H_2O$, 0.036 g $CaCl_2.2H_2O$, 0.006g Citric acid, 0.006 g Ferric ammonium citrate, 0.001 g EDTA, 0.02 g Na_2CO_3, 1.0 ml Trace metal mix.

Trace metal mix contained: 2.86 g H_3BO_3, 1.81 g $MnCl_2$-$4H_2O$, 0.222g $ZnSO_4$-$7H_2O$, 0.39 g Na_2MoO_4-$2H_2O$, 0.079 g $CuSO_4$-$5H_2O$, 0.0494 g $Co(NO_3)_2$-$6H_2O$.

The pH of the medium was adjusted to 7.5 and volume was made to 1000 ml with distilled water and it was then sterilized in autoclave for 20 minutes at 121^0 C and 15 lbs pressure.

STUDIES ON OCCURRENCE AND SURVIVABILITY OF BLUE-GREEN ALGAE

The sterilized BG-11 growth medium was mixed with freshly made stock solutions of Furadan, Sevin, Rogor, and Endotaf pesticides to get the required concentrations of 100, 250, 500, and 1000 ppm. The pH of the medium was brought to 7.5.

Following Singh (1961), soil samples were taken from a range of sampling locations in riverbank and rainfed regions. Ten grams of air-dried soil were taken in sterile conical flasks and each culture flask was aseptically filled with 50 ml of BG-11 culture media that contained varying pesticide dosages (100, 250, 500, and 1000 ppm). Triplicates of each pesticide treatment were prepared and incubated at 28 °C for 16/8 hours of light/dark cycles with light intensity of 2-5 K Lux from white fluorescent tubes. After 30 days of incubation, the blue-green algal forms that occurred in the culture flask were identified using monographs (Prescott, 1951; Desikachary, 1959 and Anand, 1990). By considering 100% survival in the untreated control flask, the survival percentage of the blue-green algae in the lab cultures was determined based on the number of species present in the corresponding treatments.

RESULTS AND DISCUSSION

The abundance of beneficial blue-green algal species in the soils of the study areas was suggested by the presence of *Nostoc punctiforme, Anabaena fertilissima, Hapalosiphon welwitschii* and *Westiellopsis prolifica,* which have been reported to fix atmospheric nitrogen in pure culture (Fogg *et al.,* 1973;

Nayak *et al.,* 1997). Twelve of the 19 blue-green algae species that were present in the control flask were heterocystous, while seven were non-heterocystous.

In total, 19 blue-green algae species from 14 genera and 6 families were found in the composite soils of the control flasks. They were taxonomically characterized using standard literature following Desikachary (1959). These species were representatives of three distinct orders: Stigonematales, Nostocales, and Chroococcales. Three genera and three species constitute the order Chroococcales, which includes *Chroococcus minutus, Gloeocapsa kuetzingiana* and *Aphanothece pallida*. There are currently nine genera in the order Nostocales, among which the family Oscillatoriaceae includes three genera and four species: *Oscillatoria okeni, O. animalis, Phormidium fragile* and *Lyngbya polysiphoniae*. The four genera and eight species that constitute the Nostocaceae family are *Cylindrospermum musicola, Nostoc punctiforme, N. paludosum, N. Linckia, N. calcicola, Anabaena oryzae, A. fertilissima* and *Aulosira aenigmatica*. There is only one genus in each of the families Scytonemataceae and Rivulariaceae, which are *Scytonema subtile* and *Calothrix javanica*, respectively. While the single family Stigonemataceae includes two genera and their species, *Hapalosiphon welwitschii* and *Westiellopsis prolifica*, in the order Stigonematales.

The data shown in Tables 1a and b revealed that, even when Furadan, Sevin, and Rogor insecticides were present in the test soil at a concentration of 100 ppm, the occurrence of blue-green algae was almost unaffected. However, there was a significant drop in their quantitative occurrence. A corresponding decline in their occurrence was seen with each increase in the pesticide dose level. The majority of the unicellular and filamentous forms of blue-green algae were unable to grow in the test soils at 500 ppm dose levels of the carbamate pesticides Furadan and Sevin. The blue-green algae species *Gloeocapsa kuetzingiana, Lyngbya polysiphoniae, Scytonema subtile* and *Calothrix javanica* are an exception to this, as they have distinct trichomes or well-defined sheaths around their cells. However, none of the other blue-green algae species that were examined were able to withstand 1000 ppm of the carbamate pesticides Furadan and Sevin. (Table 1a; Figures 1 and 2)

The occurrence of blue-green algal forms was specifically impacted by the organochlorine Endotaf and the organophosphate pesticide Rogor. Both the qualitative and quantitative occurrence of heterocystous and non-heterocystous blue-green algae was significantly reduced, even at 100 ppm of Rogor and Endotaf. When Rogor and Endotaf pesticides were present in soils at 500 ppm, these algae were totally eliminated. Nearly every blue-green algal form failed to survive in the culture as the concentration of the pesticides increased. Only *Calothrix javanica* and *Lyngbya polysiphoniae* were able to withstand up to 500 ppm of Rogor. However, the soils added with 500 ppm of Endotaf showed very few filaments of *Lyngbya polysiphoniae*. No blue-green algae species were able to grow when the quantity of Rogor and Endotaf insecticides was increased to 1000 ppm. (Table 1b; Figures 2 and 3)

Soil blue-green algae exhibit varying resistance to pesticide treatments, according to the data obtained about the total number of different blue-green algal species that occurred in the culture and their survival percentage in the presence of different pesticide dosages. At 500 ppm of the carbamate

insecticides Furadan and Sevin, the blue-green algae's survival rate dropped by as much as 50%. At the 500 ppm dose level, however, only 10.52% of Rogor and 5.26% of Endotaf showed survival.

Lal and Saxena (1980) state that exposure to organochlorine compounds can change the permeability and integrity of cell membranes, interfere with the synthesis of DNA, RNA, and proteins, and impede enzyme function and photosynthesis. According to this perspective, organochlorine pesticides are detrimental have been viewed as harmful because of their toxicity and extended environmental persistence. Previous researchers have observed a significant growth inhibition at higher pesticide concentrations, which is consistent with the findings of Kar and Singh (1978) and Adhikary *et al.,* (1984), Mohapatra and Mohanty (1992), Kapoor and Arora (2000), Ma et al.(2006), Kiran et al.(2006), Islam *et al.,* (2007), Das (2008), Crouzet *et al.,* (2010), Bodkhe and Tarar (2016), Gupta and Baruah (2020), Rajak *et al.,* (2023).

SUMMARY

Even when Furadan, Sevin, and Rogor pesticides were present in the test soil at a level of 100 ppm, the occurrence of blue-green algae was essentially remained unaffected. However, there was a substantial decline in their quantitative occurrence. It was observed that their occurrence decreased proportionately as the dose level increased. The most of the unicellular and filamentous blue-green algae species, with the exception of *Gloeocapsa kuetzingiana, Lyngbya polysiphoniae, Scytonema subtile* and *Calothrix javanica*, were unable to grow in the test soils when exposed 500 ppm dose level of the carbamate pesticides. However, none of the other blue-green algae taxa were able to withstand the Furadan and Sevin insecticides at concentrations of 1000 ppm.

The occurrence of blue-green algal forms was significantly impacted by the organophosphate and organochlorine pesticides, Rogor and Endotaf, respectively. When Rogor and Endotaf pesticides were present in soils at 500 ppm, these algae were almost exterminated. Only *Calothrix javanica* and *Lyngbya polysiphoniae* were able to withstand up to 500 ppm of Rogor. However, the soils added with 500 ppm of Endotaf showed very few filaments of *Lyngbya polysiphoniae*. None of the blue-green algal species were able to grow when the concentration of Rogor and Endotaf insecticides was increased to 1000 ppm level.

According to the findings, the organochlorine pesticide Endotaf was more harmful to the blue-green algae than the carbamates Sevin and Furadan and the organophosphate Rogor. However, the survival of blue-green algae with strong algicidal capability was significantly impacted by increased quantities of all these pesticides. In general, it has been demonstrated that unicellular and sheathless heterocystous blue-green algal forms shown to be more sensitive to pesticide application than heterocystous ensheathed and non-heterocystous ensheathed forms. This implies that the nitrogen-fixing blue-green algae in different crop fields could be detrimentally impacted from the indiscriminate application of these studied pesticides, which directly affects overall productivity.

Table 1a: Qualitative occurrence of soil blue-green algae at the end of 30 days after the treatment of Carbamate pesticides

Sr. No.	Blue-green algal species	Control 00 ppm	Concentration of Furadan ppm)				Concentration of Sevin (ppm)			
			100	250	500	1000	100	250	500	1000
1.	*Chroococcus minutus* (Kuetz.) Nag.	+	+	+	+	-	+	+	+	-
2.	*Gloeocapsa kuetzingiana* Nag.	+	+	+	+	+	+	+	+	+
3.	*Aphanothece pallida* (Kuetz.) Rabenh.	+	+	+	-	-	+	+	-	-
4.	*Oscillatoria okeni* Ag. ex Gomont	+	+	+	+	-	+	+	+	-
5.	*O. animalis* Ag. ex Gomont	+	+	+	+	-	+	+	+	-
6.	*Phormidium fragile* (Meneghini) Gomont	+	+	+	-	-	+	-	-	-
7.	*Lyngbya polysiphoniae* Fremy	+	+	+	+	+	+	+	+	+
8.	*Cylindrospermum musicola* Kuetz. ex Born.et Flah.	+	+	+	-	-	-	+	-	-
9.	*Nostoc punctiforme* (Kuetz.) Hariot.	+	+	+	-	-	+	+	-	-
10.	*N. paludosum* Kuetzing ex Born. et Flah.	+	+	+	+	-	+	+	+	-
11.	*N. linkia* (Roth) Bornet ex Born. et Flah.	+	+	+	-	-	+	+	-	-
12.	*N. calcicola* Brebisson ex Born. et Flah.	+	+	+	-	-	+	+	-	-
13.	*Anabaena oryzae* Fritsch	+	+	+	-	-	+	-	-	-
14.	*A. fertilissima* Rao, C. B.	+	+	+	+	-	+	+	-	-
15.	*Aulosira aenigmatica* Fremy	+	+	+	+	-	+	+	-	-
16.	*Scytonema subtile* Mobius	+	+	+	+	+	+	+	+	-
17.	*Calothrix javanica* de Wilde.	+	+	+	+	+	+	+	+	-
18.	*Hapalosiphon welwitschii* W. et G. S. West	+	+	-	-	-	-	-	-	-
19.	*Westiellopsis prolifica* Janet	+	+	+	-	-	+	+	+	-
Total number of blue-green algal species appeared		**19**	**19**	**18**	**10**	**04**	**17**	**16**	**09**	**02**
Percentage (%) survival		**100**	**100**	**94.73**	**52.63**	**21.05**	**89.47**	**84.21**	**47.36**	**10.52**

(+ Present, - absent)

Table 1b: Qualitative occurrence of soil blue-green algae at the end of 30 days after the treatment of Rogor and Endotaf

Sr. No.	Blue-green algal species	Control 00 ppm	Concentration of Rogor (ppm)				Concentration of Endotaf (ppm)			
			100	250	500	1000	100	250	500	1000
1.	*Chroococcus minutus* (Kuetz.) Nag.	+	+	+	-	-	+	-	-	-
2.	*Gloeocapsa kuetzingiana* Nag.	+	+	+	-	-	+	+	-	-
3.	*Aphanothece pallida* (Kuetz.) Rabenh.	+	+	-	-	-	-	-	-	-
4.	*Oscillatoria okeni* Ag. ex Gomont	+	+	+	-	-	+	-	-	-
5.	*O. animalis* Ag. ex Gomont	+	+	+	-	-	+	-	-	-
6.	*Phormidium fragile* (Meneghini) Gomont	+	+	-	-	-	+	-	-	-
7.	*Lyngbya polysiphoniae* Fremy	+	+	+	+	-	+	+	+	-
8.	*Cylindrospermum musicola* Kuetz. ex Born. et Flah.	+	+	-	-	-	-	-	-	-
9.	*Nostoc punctiforme* (Kuetz.) Hariot.	+	+	+	-	-	-	-	-	-
10.	*N. paludosum* Kuetzing ex Born. et Flah.	+	+	+	-	-	+	-	-	-
11.	*N. linkia* (Roth) Bornet ex Born. et Flah.	+	+	+	-	-	+	-	-	-
12.	*N. calcicola* Brebisson ex Born. et Flah.	+	+	+	-	-	+	-	-	-
13.	*Anabaena oryzae* Fritsch	+	+	-	-	-	-	-	-	-
14.	*A. fertilissima* Rao, C. B.	+	+	-	-	-	-	-	-	-
15.	*Aulosira aenigmatica* Fremy	+	+	+	-	-	+	-	-	-
16.	*Scytonema subtile* Mobius	+	+	+	-	-	+	-	-	-
17.	*Calothrix javanica* de Wilde.	+	+	+	+	-	+	-	-	-
18.	*Hapalosiphon welwitschii* W. et G. S. West	+	+	-	-	-	-	-	-	-
19.	*Westiellopsis prolifica* Janet	+	+	+	-	-	+	-	-	-
Total number of blue-green algal species appeared		**19**	**19**	**13**	**02**	**00**	**13**	**02**	**01**	**00**
Percentage (%) survival		**100**	**100**	**68.42**	**10.52**	**00**	**68.42**	**10.52**	**5.26**	**00**

(+ Present, - absent)

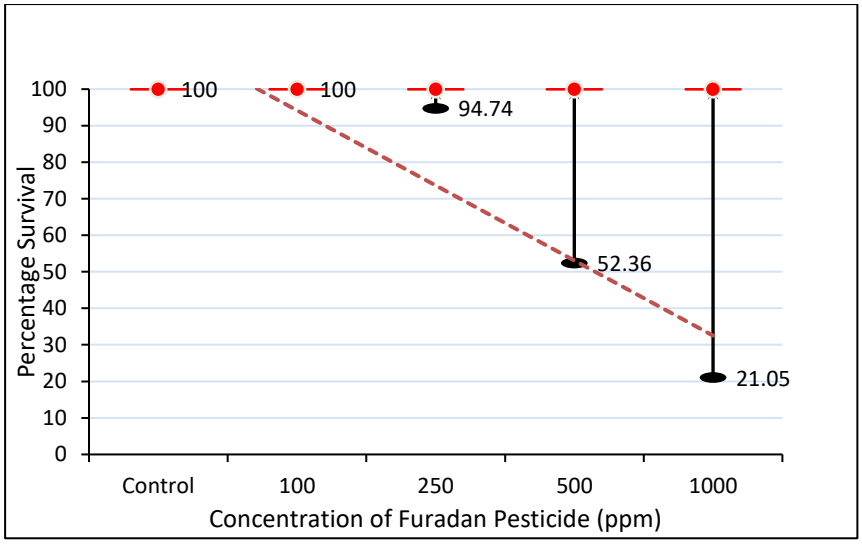

Fig 1: Effect of Furadan pesticide on percentage survival of soil blue-green algae

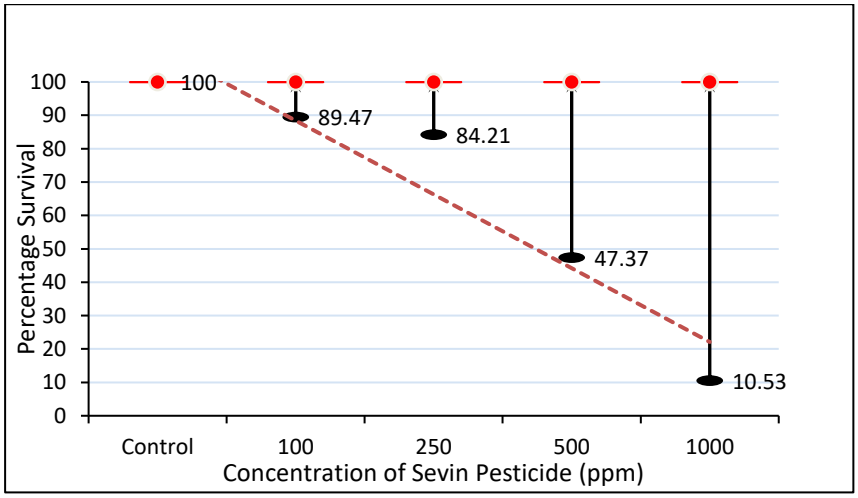

Fig 2: Effect of Sevin pesticide on percentage survival of soil blue-green algae

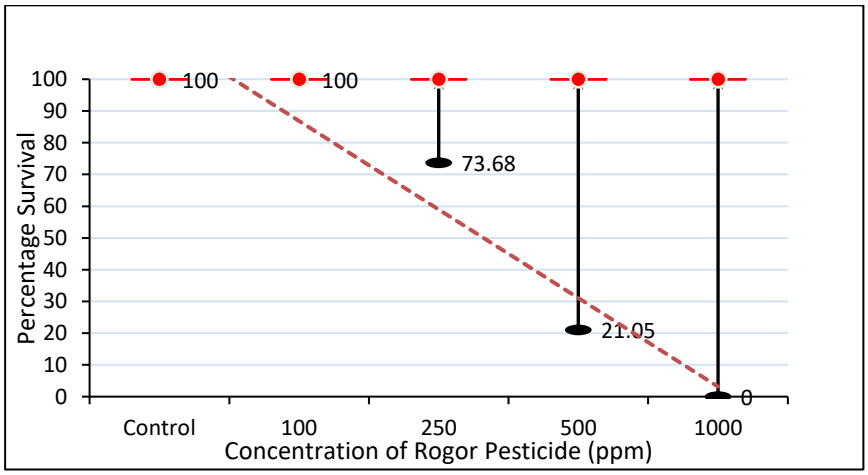

Fig 3: Effect of Rogor pesticide on percentage survival of soil blue-green algae

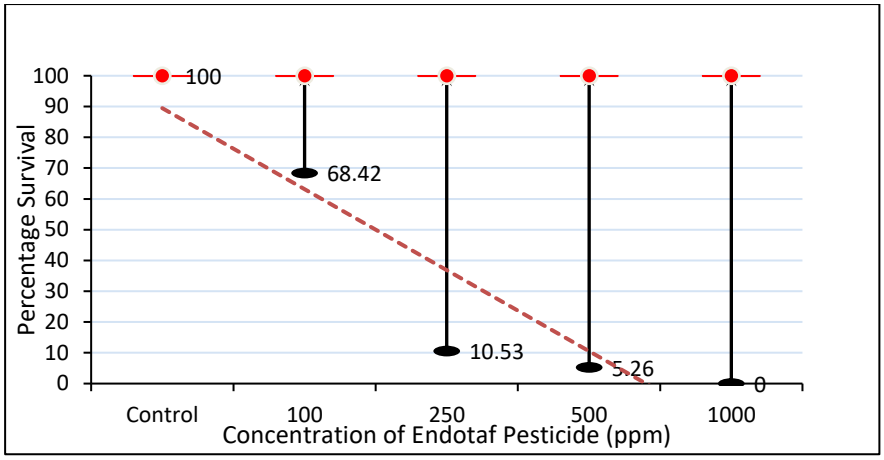

Fig 4: Effect of Endotaf pesticide on percentage survival of soil blue-green algae

CONCLUSION

The blue-green algae in the soil exhibited varying degrees of pesticide resistance. In the laboratory culture, it was seen that the occurrence and survival of blue-green algae was negatively impacted by greater pesticide application levels, such as more than 100 ppm of Furadan, Sevin, and Rogor and even at 100 ppm of Endotaf. This indicates that the indiscriminate use of pesticides may have a harmful impact on the blue-green algae's ability to survive and fix nitrogen. Before introducing these agrochemicals into the soil for crop cultivation, care should be taken to ascertain their proper dosage. Additionally, it was proposed that in order to properly analyze the data produced in the laboratory culture, field research on the blue-green algal population in pesticide-burdened soils is also required.

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Chapter 6

PLANT NATURAL PRODUCTS - AN OVERVIEW

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ABSTRACT

Numerous natural compounds with a wide range of structures are produced by plants. In contrast to the "primary metabolites," which are necessary for the growth and development of plants, these products are often referred to as "secondary metabolites." In the past, secondary metabolites were thought of as "waste products" that had no physiological significance for the plant

KEYWORDS: Primary Metabolites, Secondary Metabolites, Waste Products, Physiological Significance.

INTRODUCTION

The term "natural product" refers to anything that is created by life, including biotic materials (such as wood and silk), bio-based products (such as corn-starch and bioplastics), body fluids (such as milk and plant exudates), and other natural materials (such as soil and coal). Nature has been a source of medicinal ingredients for thousands of years, and a staggering number of modern treatments have been shown to have natural roots.

Plant Natural Products play an important role in life activities with their diverse and unique molecular structures.

Plants produce various signalling molecules (auxin, abscisic acid, cytokinin, gibberellic acid, salicylic acid, ethylene, jasmonate and brassinosteroid) and secondary metabolites (alkaloids, terpenoids and phenylpropanoids) which play a crucial role in various developmental and defence processes.

Since ancient times, natural products have been used to treat a wide range of illnesses and ailments, according to folklore. Numerous bioactive secondary metabolites from both terrestrial and marine sources have been found thanks to traditional natural product chemistry techniques.

According to the WHO, 80% of the world's population mainly those of developing countries depend on plant derivative medicines for their healthcare, which are mostly supplanted by pharmaceutical constituents in the Western world.

As we human race face the tremendous public health challenge posed by emerging infectious diseases, antibiotic resistance and surging drug prices etc., harnessing the healing power of medicinal plants gifted from mother nature is more urgent than ever in helpingus survive future challenge in a sustainable way.

For commercial purposes, the term "natural product" has also been expanded to include foods made from natural sources without the addition of artificial ingredients, dietary supplements, and cosmetics. An outstanding accomplishment in the field of medicine was the discovery of early pharmaceuticals derived from medicinal plants, including digitoxin, cocaine, pilocarpine, codeine, and quinine.

RESULT AND DISCUSSION

Products derived from plants include soaps, shampoos, perfumes, cosmetics, paint, varnish, turpentine, rubber, latex, lubricants, linoleum, plastics, inks, and gums. Renewable fuels from plants include firewood, peat and other biofuels. Alkaloids, flavonoids, terpenoids, and polyphenols are just a few of the many groups that make up these molecules, and they frequently have noteworthy medicinal properties. Alkaloids are compounds found in various plant species that contain nitrogen and may have important physiological effects.

These substances serve crucial ecological roles by offering defence against illnesses, pests, UV-B rays, and other environmental stressors. They are also used for a wide range of industrial biotechnology applications, including as agrochemicals, pharmaceutical drugs, and in the food and beverage sector.

These occasionally possess biological or pharmacological activity that may be therapeutically beneficial in the treatment of illness. Terpenoid, for instance, is a well-known natural product for essential oils that have a potent yet agreeable scent. These essential oils have long been used as perfumes because of their pleasant scent. Some essential oils are nearly exclusive mixtures of terpenoids, such as lemon, orange, and turpentine oil.

Plants are a source of a wide range of natural products that possess various therapeutic properties and are continuously explored to develop novel drugs. Many secondary metabolites are cytotoxic and have been selected and optimized through evolution for use as "chemical warfare" agents against prey, predators, and competing organisms.

Although bioactive natural products have been used for hundreds or even thousands of years as herbal drug preparations, it wasn't until the 19th century that they were used as isolated and characterized compounds in contemporary drug discovery and development.

The dependence on the natural products by more than 80% of the total population in the developing world, although there are some new approaches to drug discovery, such as combinatorial chemistry and computer-based molecular modelling design, and many drugs are made by synthetic chemistry

CONCLUSION

Plant-based natural compounds have long been and will remain extremely important sources of therapeutic agents and models for the design, semisynthesis, and synthesis of different medications for the treatment of human and animal diseases.

The development of medications to treat fatal human diseases will be made possible by natural products. To replace the allopathic medications, more research is required to find new natural products. Pharmacological activity in natural products can occasionally be therapeutically beneficial in the treatment of diseases.

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Chapter 7

LEVERAGING BRAIN ORGANOIDS TO REVOLUTIONIZE INSIGHTS INTO NEURO-DEVELOPMENTAL DISORDERS

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ABSTRACT

The relationship between human brain organoids and neurodevelopmental diseases is a burgeoning area of research that offers significant insights into the mechanisms underlying these complex conditions. Brain organoids, which are three-dimensional structures derived from human pluripotent stem cells, mimic key aspects of human brain development and architecture. This makes them invaluable for studying neurodevelopmental disorders such as autism spectrum disorder, schizophrenia, and intellectual disabilities.

By utilizing brain organoids, researchers can model specific genetic mutations and environmental factors associated with neurodevelopmental diseases. For instance, organoids can be engineered to carry mutations in genes known to be implicated in these disorders, allowing scientists to observe how these changes affect neuronal differentiation, connectivity, and overall brain function. This approach enables the exploration of critical developmental windows and the identification of disrupted pathways that may lead to abnormal brain development.

Moreover, brain organoids provide a platform for testing potential therapeutic interventions. Researchers can assess the effects of pharmacological agents or gene editing techniques on organoid development and function, offering insights into how these treatments might mitigate the effects of neurodevelopmental disorders in patients. Additionally, the ability to study organoids derived from individual patients allows for personalized medicine approaches, where therapies can be tailored to the specific genetic and phenotypic characteristics of a patient's condition.

Treatments might mitigate the effects of neurodevelopmental disorders in patients. Additionally, the ability to study organoids derived from individual patients allows for personalized medicine approaches, where therapies can be tailored to the specific genetic and phenotypic characteristics of a patient's condition.

KEYWORDS: Human Brain Organoids, Neurological Diseases, Pharmaceutical Agents.

INTRODUCTION

Brain organoids (BOs) are three-dimensional, miniaturized models of the human brain that are derived from pluripotent stem cells. Pluripotent stem cells are a unique class of stem cells characterized by their ability to differentiate into nearly all cell types of the body, making them a

vital resource in developmental biology and regenerative medicine. BOs derived from early embryos or induced from adult somatic cells through a process known as reprogramming, pluripotent stem cells possess the remarkable capacity to self-renew and proliferate indefinitely in culture. This versatility allows researchers to generate specific cell types, such as neurons (Lancaster, 2013).

These organoids mimic the complex architecture and cellular diversity of the brain, allowing researchers to study its development, function, and disease mechanisms in a controlled laboratory setting. By providing a more accurate representation of human brain tissue compared to traditional two-dimensional cell cultures, brain organoids enable the investigation of various neurological disorders, such as Alzheimer's disease, autism, and schizophrenia (Kim *et al.,* 2020). They serve as valuable tools for drug testing and the exploration of neurodevelopmental processes, offering insights into how genetic and environmental factors influence brain health. As research in this field advances, brain organoids hold the potential to revolutionize our understanding of the brain and pave the way for innovative therapeutic strategies (Kim and Chang 2023).

ORGANOIDS MIMIC THE COMPLEX ARCHITECTURE AND CELLULAR DIVERSITY OF HUMAN TISSUES, INCLUDING THE BRAIN, THROUGH SEVERAL KEY MECHANISMS

Stem Cell Differentiation: Organoids are typically derived from pluripotent stem cells, which have the ability to differentiate into various cell types. By manipulating the culture conditions, researchers can guide these stem cells to develop into specific cell types found in the target organ, such as neurons, glial cells, and other supporting cells in the brain (Tang, *et al*.,2022).

Three-Dimensional Culture: Unlike traditional two-dimensional cell cultures, organoids are grown in three-dimensional environments that allow cells to interact more naturally. This 3D structure facilitates the formation of complex tissue architectures, including the development of layers and spatial organization that resemble those found in vivo.

Unlike earlier systems, these new approaches established a stable platform capable of supporting the long-term culture of epithelial-like cells derived from sorted Lgr5+ stem cells or dissected crypts. This was achieved by incorporating in vivo intestinal stem cell niche components such as epidermal growth factor (EGF), Noggin, and R-spondin-1and embedding the cells in Matrigel to facilitate their expansion (Lancaster, 2013).

Cell-Cell Interactions: Organoids promote cell-cell interactions that are crucial for tissue development and function. These interactions help establish signalling pathways and communication networks that are essential for the maturation and specialization of cells, contributing to the overall complexity of the organoid (Yang*et al.,* 2023).

Extracellular Matrix (ECM): The presence of an extracellular matrix in organoid cultures provides structural support and biochemical cues that influence cell behaviour. The ECM mimics the natural environment of tissues, promoting cell adhesion, migration, and differentiation, which are vital for developing a diverse cellular composition (Chen*et al.,* 2024).

Self-Organization: Organoids exhibit self-organizing properties, where cells autonomously arrange themselves into functional structures. This self-organization is driven by intrinsic genetic and

epigenetic factors, allowing organoids to develop features such as cortical layers and regional specialization similar to those in the actual brain.

Mimicking Developmental Processes: By recapitulating key developmental stages, organoids can model processes such as neurogenesis, synaptogenesis, and the formation of neural circuits. This allows researchers to study how various factors influence brain development and the emergence of cellular diversity (Altinisik*et al.,* 2023).

Through these mechanisms, organoids provide a powerful platform for studying the complexities of human tissues, offering insights into development, disease, and potential therapeutic interventions.

BRAIN ORGANOIDS ARE PROVING TO BE INVALUABLE TOOLS IN THE STUDY AND UNDERSTANDING OF NEUROLOGICAL DISORDERS FOR SEVERAL REASONS

Modelling Disease Mechanisms: Brain organoids can be derived from patients' pluripotent stem cells, allowing researchers to create models that closely mimic the genetic and cellular characteristics of specific neurological disorders. This enables the investigation of disease mechanisms at a cellular level, providing insights into how genetic mutations and environmental factors contribute to conditions such as Alzheimer's disease, autism spectrum disorders, and schizophrenia (Qian*et al.,* 2019 and Adams*et al.,* 2019).

Studying Developmental Processes: Many neurological disorders have roots in developmental abnormalities. Brain organoids allow scientists to study the processes of neurogenesis, synaptogenesis, and the formation of neural circuits in a controlled environment. This can help identify critical periods during development when interventions might be most effective (Di Lullo and Kriegstein 2017).

Drug Testing and Screening: Brain organoids provide a platform for testing the efficacy and safety of new drugs. Researchers can expose organoids to various pharmacological agents to observe their effects on neuronal health, connectivity, and function. This can accelerate the drug discovery process and help identify potential treatments for neurological disorders (Van de Wetering 2015).

Understanding Cellular Interactions: The three-dimensional structure of brain organoids allows for the study of complex cellular interactions within the brain, including those between neurons and glial cells. This is crucial for understanding how these interactions may be disrupted in neurological disorders, leading to neuroinflammation or neurodegeneration (Zhang and Ming 2020).

Personalized Medicine: By using patient-derived stem cells, brain organoids can reflect individual genetic backgrounds and responses to treatments. This personalized approach can help tailor therapies to specific patient needs, improving the effectiveness of interventions for neurological disorders (Van Pel*et al.,* 2018).

Investigating Environmental Influences: Brain organoids can be used to study how environmental factors, such as toxins or stressors, impact brain development and function. This research can shed light on the role of environmental influences in the onset and progression of neurological disorders (Shakhbazau*et al.,* 2019).

Gene editing technologies- CRISPR-Cas9: Brain organoids serve as a powerful tool for studying the effects of gene editing technologies, such as CRISPR-Cas9, on human brain development and

function. By utilizing patient-derived pluripotent stem cells, researchers can create organoids that reflect the genetic makeup of individuals with specific neurological disorders. This allows for precise manipulation of genes associated with these conditions, enabling scientists to observe the consequences of targeted edits in a controlled, three-dimensional environment that closely mimics the human brain. Through gene editing, researchers can investigate the roles of particular genes in neurodevelopment, neuronal connectivity, and cellular behaviour, providing insights into the underlying mechanisms of diseases such as autism, schizophrenia, and neurodegenerative disorders. Additionally, brain organoids facilitate the assessment of potential off-target effects and the overall safety of gene editing approaches, paving the way for future therapeutic applications. As a result, brain organoids not only enhance our understanding of gene function but also hold promise for developing innovative treatments that could correct genetic abnormalities in neurological disorders (Wang*et al.,* 2017).

Investigating pharmacological agents: Researchers can utilize brain organoids to screen a wide range of pharmacological agents, assessing their effects on neuronal development, connectivity, and overall functionality. By applying specific drugs or compounds to organoids that model neurodevelopmental disorders, scientists can observe how these interventions influence disease-related pathways and cellular behaviours. This allows for the identification of promising candidates that may ameliorate symptoms or correct underlying dysfunctions associated with specific conditions (Dakic*et al.,* 2017 and Huang*et al.,* 2017).

TRANSFORMATIVE APPROACH IN NEUROSCIENCE RESEARCH

Investigating Autism Spectrum Disorder with Brain Organoids

Studying neurodevelopmental disorders such as autism spectrum disorder (ASD) using brain organoids has emerged as a transformative approach in neuroscience research. Brain organoids, which are three-dimensional structures derived from human pluripotent stem cells, replicate key aspects of human brain development and architecture, making them particularly valuable for investigating the complex biological underpinnings of autism.

Researchers can create brain organoids from the stem cells of individuals with autism, allowing for the examination of specific genetic mutations and environmental factors associated with the disorder. This enables scientists to model the neurodevelopmental trajectory of autism in a controlled laboratory setting. By analysing the organoids, researchers can observe alterations in neuronal differentiation, synaptic connectivity, and overall brain structure that may contribute to the symptoms of autism (Rabeling and Goolam 2023).

One significant advantage of using brain organoids is the ability to study the effects of specific genetic variants linked to autism. For instance, mutations in genes such as CHD8, SHANK3, and others can be introduced into the organoids to assess how these changes impact neuronal development and function. This research can reveal critical insights into the cellular and molecular mechanisms that underlie the disorder, including disruptions in neural circuit formation and neurotransmitter signalling. Additionally, brain organoids provide a platform for testing potential therapeutic interventions (Birnbaum and Weinberger 2017).

Researchers can evaluate the effects of pharmacological agents or gene editing techniques on organoid development and function, identifying compounds that may help mitigate the effects of autism-related genetic mutations. This approach not only aids in understanding the pathophysiology of autism but also paves the way for developing targeted treatments tailored to individual patients (Stoner*et al.*,2014).

Furthermore, the use of brain organoids allows for the exploration of environmental influences on neurodevelopment. By exposing organoids to various factors, such as toxins or stressors, researchers can investigate how these elements may interact with genetic predispositions to influence the development of autism (Lunden*et al.,* 2019 and Mariani*et al.,* 2015).

Investigating Schizophrenia with Brain Organoids

Investigating schizophrenia using brain organoids is a cutting-edge approach that allows researchers to explore the complex neurobiological mechanisms underlying this multifaceted disorder. Schizophrenia is characterized by a range of symptoms, including hallucinations, delusions, cognitive impairments, and social withdrawal, and its etiology is believed to involve a combination of genetic, environmental, and neurodevelopmental factors.

Modelling Genetic Variants: Researchers can create brain organoids from induced pluripotent stem cells (iPSCs) derived from individuals with schizophrenia. By incorporating specific genetic mutations associated with the disorder, scientists can study how these alterations affect neuronal development, connectivity, and function. This helps in understanding the role of genetic predispositions in the pathophysiology of schizophrenia (Stachowiak*et al.,* 2017).

Studying Neurodevelopmental Pathways: Brain organoids provide a platform to investigate critical neurodevelopmental processes that may be disrupted in schizophrenia. Researchers can examine how factors such as neuronal differentiation, synaptogenesis, and circuit formation are altered in organoids derived from patients. This can shed light on the timing and nature of developmental disruptions that may contribute to the onset of symptoms (Sachs*et al.,* 2005).

Investigating Environmental Influences: Environmental factors, such as prenatal stress or exposure to toxins, are believed to play a role in the development of schizophrenia. Brain organoids can be exposed to various environmental stressors to assess their impact on neuronal development and function. This research can help elucidate how these factors interact with genetic vulnerabilities to influence the risk of developing schizophrenia (Birnbaumand Weinberger2017).

Assessing Neurotransmitter Systems: Schizophrenia is associated with dysregulation of neurotransmitter systems, particularly dopamine and glutamate. Brain organoids can be used to study the expression and function of neurotransmitter receptors and signalling pathways, providing insights into how these systems may be altered in schizophrenia. This can also facilitate the testing of pharmacological agents aimed at restoring normal neurotransmitter function (Brandon*et al.,* 2009).

Evaluating Therapeutic Interventions: Brain organoids serve as a valuable tool for screening potential therapeutic compounds. Researchers can test various drugs or treatment strategies on organoids derived from individuals with schizophrenia to evaluate their effects on neuronal

function and connectivity. This approach can lead to the identification of novel treatments tailored to the specific biological characteristics of the disorder (Singh*et al.,* 2011).

Personalized Medicine: By using patient-derived organoids, researchers can explore personalized treatment options based on the unique genetic and phenotypic profiles of individuals with schizophrenia. This could lead to more effective and targeted therapeutic strategies that address the specific needs of patients

Investigating schizophrenia through brain organoids offers a promising avenue for advancing our understanding of the disorder's underlying mechanisms. This innovative approach not only enhances our knowledge of the neurodevelopmental aspects of schizophrenia but also holds the potential to inform the development of targeted therapies, ultimately improving outcomes for individuals affected by this complex condition. As research in this area continues to evolve, it may lead to significant breakthroughs in both the understanding and treatment of schizophrenia (Qian*et al.,*2020).

CONCLUSION

Brain organoids, three-dimensional structures derived from stem cells, mimic the architecture and functionality of the human brain on a miniature scale. These lab-grown models provide groundbreaking tools for studying the complex processes of brain development, offering unique opportunities to investigate neurodevelopmental disorders, such as autism spectrum disorder (ASD)and schizophrenia.

By replicating key developmental stages, brain organoids allow researchers to observe cellular interactions, genetic mutations, and molecular mechanisms in a controlled environment. This has led to significant advances in understanding the causes of neurodevelopmental disorders, particularly those linked to genetic or environmental factors. Additionally, organoids enable the testing of potential therapies and drugs without relying solely on animal models, bridging the gap between experimental studies and clinical applications.

The integration of technologies such as CRISPR gene editing, single-cell sequencing, and advanced imaging further enhances the utility of brain organoids. These tools allow precise manipulation and analysis, paving the way for personalized medicine approaches to treat neurodevelopmental disorders. As this field evolves, brain organoids hold transformative potential for unravelling the mysteries of the human brain and developing targeted interventions.

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Chapter 8

PHYTO-PHARMACOLOGICAL ACTIVITIES OF *TERMINALIA CATAPPA* LEAVES - A REVIEW

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ABSTRACT

Ancient medicine made use of a number of naturally occurring chemicals that served as the parental structure for the majority of active compounds and co-evolved to interact with one another. Although the structures and functions of these molecules vary, they have several evolutionary characteristics that make them superior ligands for human use in a variety of medical applications compared to randomly generated compounds. Crude herbs are the foundation of many traditional medicines; these are utilized all over the world, particularly in China, Japan, and Korea, as well as in a variety of homeopathic and Ayurvedic medications and for the treatment of physical therapy. The phyto-pharmacological properties of *Terminalia catappa* leaves are covered in this review.

KEYWORDS: *Terminalia catappa,* Phyto-Pharmacological Activity, Combretaceae Family.

INTRODUCTION

TERMINALIA CATAPPA(*T. CATAPPA*)

T. catappa is a member of the Combretaceae family. Southeast Asia is naturally endowed with it. The Latin word "terminalis," which describes the tendency of leaves to teem at the tips of shoots, is where the generic name comes from. It is a big tree that thrives in tropical and subtropical regions. It is frequently cultivated in tropical regions. This tree is being grown for its edible nuts as well as for aesthetic reasons. You can consume the nut kernel raw.

BOTANICAL DESCRIPTION

The tree has horizontal limbs and an upright, symmetrical crown, reaching a height of 35 meters. Its tier-like branch arrangement is a defining feature. The huge, ovoid, glossy, dark green, leathery leaves are 15–25 cm in length and 10–14 cm in width. With separate male and female flowers on the same tree, the trees are monoecius. Both have no petals, are inconspicuous, white to greenish, and have a diameter of 1 cm. The fruit is a drupe that is 5–7 cm long and 3–5.5 cm wide. It has a single seed and is initially green before turning yellow and red when ripe. When the fruit is completely mature, the seed within can be eaten.

ANTI-BACTERIAL ACTIVITY

Both Gram positive and Gram negative bacteria were effectively inhibited by the chloroform and methanolic extracts. While *T. catappa*'s petroleum root ether extract lacked antimicrobial action, its chloroform root extract shown antimicrobial activity against Escherichia coli and Staphylococcus aureus. While the chloroform extract showed a minimum inhibitory concentration of 0.4 mg/ml

against S. aureus, the methanolic root extract of *T. catappa* showed a minimum inhibitory concentration of 0.065 mg/ml against E. coli (Pawar and Pal, 2002). Different levels of action against 10 Gram positive, 12 Gram negative, and Candida tropicalis bacteria were demonstrated by aqueous and methanol extracts of *T. catappa* leaves. According to Nair and Chanda (2008), the methanolic extract inhibited the examined microbial strains far more effectively than the aqueous extract.

According to Taganna *et al.,* (2011), certain test strains' phenotypic expression of QS can be inhibited by the tannin-rich components of *T. catappa* leaves. The study on *T. catappa*'s antibacterial activity was carried out by Akharaiyi *et al.,* (2011). Water is used to remove different leaf stages and is utilized to combat a variety of dangerous germs. The findings demonstrated the ability of *T. catappa* leaves to act against a variety of species.

ANTI-INFLAMMATORY, ANALGESIC AND MODULATORY ACTIVITY

In animal models of acute and chronic ear edema caused by 12-O-tetradecanoylphorbol-13-acetate, ethanolic leaf extracts of *T. catappa* show an anti-inflammatory activity. The fraction of chloroform and its activity concentrates, according to a bioassay-based fractionation process, have ursolic acid (1) and 2alpha, 3beta, 23-trihydroxyurs-12-en-28-oic acid (2). They also have shown potent anti-inflammatory properties (Fan *et al.,* 2004).

Aimola *et al.,* (2014) identified new chemicals from *T. catappa* leaves that induce fetal hemoglobin. These compounds function in concert and suggest a dual modulatory action on erythropoiesis. Tender leaf extract has analgesic and anti-inflammatory properties without influencing the estrous cycle, according to Ratnasooriya *et al.,* (2002). They also discovered that the extract does not cause drowsiness.

ANTI-DIABETIC ACTIVITY

In alloxan-induced diabetes rat models, Nagappa *et al.,* (2003) assessed the anti-diabetic effects of *T. catappa* fruits with various extracts (aqueous, methanol, and petroleum ether) on fasting blood sugar levels and several serum biochemical markers. At dosage levels 1/5 of their lethal doses, all three extracts had a strong anti-diabetic effect. Histopathological examinations of these animals' pancreas showed a significant regeneration using methanolic and aqueous extracts that had previously been necrosed by alloxan. In animal models created by alloxan, an aqueous and cold extract of the tender, fresh leaves of *T. catappa* can lower lipids and elevated blood glucose levels. Its anti-diabetic properties are also supported by concurrent histological and pathological investigations (Ahmed 2005).

ANTI-OXIDANT AND RADICAL SCAVENGING ACTIVITY

Treatment with *T. catappa* aqueous extracts demonstrated anti-hepatotoxic efficacy against carbon tetrachloride (CCl4)-induced toxicity in the rat liver, according to Lin *et al.,* (1997).In the liver homogenate, the crude medication demonstrated antioxidant effects on lipid peroxidation caused by FeCl2-Ascorbic acid. Using electron spin resonance and spin trapping techniques, *T. catappa*'s superoxide radical scavenger actions further show that it has good anti-hepatotoxic and superoxide radical analytic activity.

According to Lin *et al.,* (2001), the tannin components from *T. catappa* have several anti-oxidant properties, including the ability to scavenge free radicals and inhibit lipid peroxidation and superoxide production. Effective antioxidant action was demonstrated by tannin. Of this group of tannins, punicalin and punicalagin were the most prevalent and exhibited the most potent anti-oxidative properties.

Ko *et al.,* (2002) used GC-MS and high-performance liquid chromatography (HPLC) spiking analyses in the supercritical CO to separate squalene from *T. catappa* leaves and seeds (2). Strong anti-oxidative and 2,2-diphenyl-1-picrylhydrazyl (DPPH) scavenging properties were demonstrated by *T. catappa* leaf extracts, and these activities grew as the leaves matured. On the other hand, the seed extracts only demonstrated very modest DPPH scavenging activity and substantial suppression of conjugated diene hydroperoxide production.

In contrast to 20 and 60 minutes of sonication and control, Annegowda *et al.,* (2010) discovered that the extract of *T. catappa* leaves obtained with 40 minutes of sonication had considerable polyphenolic contents. According to the antioxidant assays, the sonicated extract's vitamin C equivalent value was significantly higher after 40 minutes than it was at other sonication and control intervals. This activity might be caused by the polyphenolic content.

HEPATOPROTECTIVE ACTIVITY

In an animal model generated by D-galctosamine, oral pretreatment with *T. catappa* reversed leaves significantly reduced the substantial morphological alterations and raised levels of alanine amino transaminase (ALT) and aspartate amino transaminase (AST). Furthermore, the sensitivity of mitochondrial swelling to the foreign Ca2+ stimulation is reduced by *T. catappa* leaves. In mice's primary cultured hepatocytes, incubation with *T. catappa* leaf extract may be able to stop the decline in cell viability in a dose-dependent way. Additionally, it was discovered that the supernatant of primary cultured hepatocytes had both a 1.9-fold rise in AST and a 48% drop in superoxide dismutase (SOD) activity (Tang *et al.,* 2004).

Ursolic acid and Asiatic acid were separated from the chloroform extract of *T. catappa* leaves by Gao *et al.,* (2004). Pretreatment with 50 and 100 mg kg(-1) *T. catappa* leaf extract restored the elevated serum ALT and AST levels and prevented substantial morphological changes in the acute liver damage test. Pretreatment with 0.05, 0.1, and 0.5 g L(-1) *T. catappa* leaf extract prevented the rise in ALT and AST levels in the medium of primary cultured hepatocytes caused by D-galactosamine in the hepatocyte damage experiment. Furthermore, ursolic acid and Asiatic acid demonstrated dose-dependent hydroxyl radical and superoxide anion scavenging activities.

In patients with CCl4-induced liver damage, treatment with chloroform leaf extracts of *T. catappa* at concentrations of 20, 50, or 100 mg/kg dramatically lowers serum ALT, AST, and liver lipid peroxidation levels. The hepatoprotective benefits were also validated by morphological inspection. Furthermore, intramitochondrial Ca2+ overload (2.1-fold), inhibition of mitochondrial Ca2+-ATPase activity (42.0%), and disturbance of mitochondrial membrane potential (14.8%) are all successfully avoided by pretreatment with *T. catappa* leaf extracts. This might point to a novel mechanism for *T. catappa*'s hepatoprotective benefits (Tang *et al.,* 2006).

Chebulagic acid and corilagin were identified by Kinoshita *et al.,* (2007) as the active ingredients in *T. catappa* leaves. Both substances demonstrated potent scavenging capabilities for peroxyl and O (2)(.-) radicals, as well as preventing leukocytes from producing ROS, which is triggered by phorbol-12-myristate acetate. Serum ALT, AST, and glutathione-S-transferase (GST) activity were decreased when leaf extract or corilagin was administered intraperitoneally before galactosamin and lipopolysaccharide were administered. Additionally, this lessens lipid peroxidation and the production of free radicals in the mitochondria. In addition, apoptotic events in the liver caused by galactosamin and lipopolysaccharide included DNA fragmentation and an increase in caspase-3 activity.

ANTI-CANCER ACTIVITY

T. catappa leaf extracts reduced matrix MMP-9 production and activity based on hepatocellular carcinoma messenger ribo nucleic acid (mRNA) levels. To ensure this inhibition, tissue inhibitor of metalloproteinase-1 (TIMP-1) is upregulated. Additionally, nuclear translocation is suppressed, and nuclear factor-kappa B (NF-κB) and activating protein-1 (AP-1) DNA binding activity on the MMP-9 promoter in Huh7 cells is down regulated (Yeh in 2012).

In the long run, *T. catappa* treatment of Huh7 cells significantly reduced both the mRNA and protein levels of u-PA. *T. catappa* reduced the phosphorylation of the ERK1/2 pathway, which in turn reduced the effects of u-PA. It also decreased the transcription protein of nuclear factors SP-1 and NF-κB. According to Yeh *et al.,* (2014), these findings provide evidence that u-PA expression could be a useful therapeutic target in the *T. catappa*-mediated inhibition of hepatocellular carcinoma metastases.

T. catappa's ethanoic extract has 51.67 mg/g of flavonoids and 354.02 mg/g of total phenolics. When compared to mice with ehrlich ascites carcinoma (EAC) tumors, *T. catappa* extract at two different dosages (50 and 200 mg/kg) dramatically reduced solid tumor mass at 200 mg/kg and enhanced peritoneal cell count and life span. In mice given extract, the levels of protein, hemoglobin, white blood cells, and red blood cells were all within normal limits. *T. catappa* dramatically reduced lipid peroxides (LPO) and lowered glutathione (GSH) while increasing SOD and catalase (CAT) levels. Because of its phenolic and flavonoid components, *T. catappa* shown anti-tumor action by altering LPO and antioxidant defense (Pandya *et al.,* 2013). In a dose-dependent way, *T. catappa* leaves may decrease the expression of matrix MMP-2, MMP-9, urokinase plasminogen activator, and their endogenous inhibitors, particularly tissue inhibitor of MMP-2 and plasminogen activator inhibitor-1. Additionally, in vivo research demonstrated the inhibitory effect on LLC cell proliferation and metastasis (Chu *et al.,* 2007).

T. catappa leaf extracts in ethanol dramatically reduce SCC-4 cell movement and invasion potential. MMP-2, MMP-9, and u-PA protein levels and activity were all reduced by *T. catappa*. Moreover, *T. catappa* may also prevent JNK1/2, ERK1/2, and Akt from being phosphorylated, and it may also prevent the expression of nuclear proteins NF-κB, c-Fos, and c-Jun. Additionally, *T. catappa* decreased AP-1 and NF-κB's DNA-binding activity (Yang *et al.,* 2010).

CONCLUSION

The pharmacological studies conducted on *T. catappa* confirm the plant's enormous potential for treating a wide range of illnesses. To strengthen the usage of *T. catappa* for future generations, more research and clinical studies are required for product development.

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Chapter 9

AYURVEDA MEETS GENOMICS: PIONEERING THE FUTURE OF PERSONALIZED MEDICINE

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ABSTRACT

Ayurgenomics, the fusion of Ayurveda and genomics, presents a revolutionary framework for integrating traditional Indian medical wisdom with cutting-edge genetic science. This interdisciplinary approach promises significant breakthroughs in personalized medicine, disease prevention, and therapeutic efficacy. By correlating Ayurvedic Prakriti classifications with genetic markers, Ayurgenomics enhances our understanding of individual health profiles and responses to interventions. This comprehensive review explores the theoretical foundations of Ayurgenomics, its clinical applications, and its synergy with modern medicine.

KEYWORDS: Personalized Medicine, Ayurveda and Genomics, Ayurgenomics.

INTRODUCTION

Ayurveda, the ancient Indian system of medicine, has stood the test of time with its comprehensive, holistic approach to health and well-being(Patwardhan & Mashelkar, 2009). Dating back over 5,000 years, Ayurveda emphasizes the harmony of mind, body, and spirit, centering on the concept of *Prakriti*, or an individual's unique constitution(Chandran & Patwardhan, 2016). This foundational principle underscores Ayurveda's commitment to personalized care, which is achieved by tailoring lifestyle recommendations, dietary plans, and therapeutic interventions to each individual's constitution. Unlike the one-size-fits-all model seen in many modern practices, Ayurveda prioritizes prevention and balance as the cornerstone of health management.

In contrast, modern medicine has revolutionized healthcare with its reductionist approach, focusing on diagnosing and treating diseases through molecular-level insights (Prasher *et al.,* 2016). Genomics, a discipline that deciphers the role of genes in health and disease, has transformed medicine into a precision-based practice (Bhat, S *et al.,* 2021). This genomic lens has enabled significant breakthroughs in understanding genetic predispositions, developing targeted therapies, and predicting health outcomes.

The emergence of *Ayurgenomics* bridges these two paradigms, integrating the holistic wisdom of Ayurveda with the precision of genomic science (Chandran & Patwardhan, 2016). By combining

Prakriti-based frameworks with genomic data, Ayurgenomics enables a systems-based understanding of human health and disease (Huang, Z*et al.,* 2022). This interdisciplinary approach not only enriches the understanding of individual physiology but also provides insights into genetic variations, epigenetic modifications, and disease susceptibilities tied to different Prakriti types.

THE ALIGNMENT WITH P4 MEDICINE

Ayurgenomics aligns seamlessly with the principles of *P4 medicine*—predictive, preventive, personalized, and participatory:

Predictive: Ayurgenomics utilizes genetic markers and Prakriti-based assessments to predict disease risks. For example, Kapha-dominant individuals with specific genetic profiles can be identified as at risk for metabolic conditions like diabetes or cardiovascular diseases (Shalini *et al.,* 2021).

Preventive: The preventive ethos of Ayurveda, reinforced by genomic insights, encourages lifestyle and dietary modifications to mitigate disease risks. This is particularly effective in addressing chronic and lifestyle-related disorders (Prasher *et al.,* 2016).

Personalized: Prakriti-based frameworks in Ayurgenomics tailor interventions, from pharmacological therapies to dietary plans, to suit individual needs. This personalized approach ensures greater efficacy and fewer side effects (Bhalerao *et al.,* 2012).

Participatory: By involving patients in their health journey, Ayurgenomics fosters participatory care. Tools like wearable health monitors and digital platforms facilitate continuous tracking and empower individuals to make informed decisions about their health (Patel *et al.,* 2019).

GLOBAL RELEVANCE AND DEMAND

In the era of global health crises and the rising burden of chronic diseases, the demand for personalized and preventive healthcare solutions is at an all-time high. Ayurgenomics addresses this demand by offering:

A Holistic Perspective: Unlike reductionist approaches that treat isolated symptoms, Ayurgenomics provides a holistic view of health, considering the interconnectedness of the body, mind, and environment.

Cultural Relevance: For populations familiar with traditional systems like Ayurveda, Ayurgenomics offers a scientifically validated pathway that respects cultural heritage while embracing modern innovations.

Scalability: Advances in technology, such as artificial intelligence (AI) and big data analytics, enhance the scalability of Ayurgenomics, making personalized healthcare accessible on a larger scale.

FOUNDATIONS OF AYURGENOMICS

Ayurgenomics, as a discipline, builds on the ancient principles of Ayurveda while incorporating advancements in modern genomics. This synergy enables a scientific understanding of Prakriti, the core Ayurvedic concept that emphasizes individual constitution, and how it correlates with genetic and epigenetic mechanisms.

AYURVEDIC PRINCIPLES AND PRAKRITI

The concept of an individual's Prakriti reflects a unique combination of the three doshas—Vata, Pitta, and Kapha—each associated with distinct physiological, psychological, and behavioral traits(Chandran & Patwardhan, 2016).

DOSHA CHARACTERISTICS:

Vata: Governs movement and is associated with qualities like dryness, lightness, and variability. Individuals with Vata-dominant Prakriti often exhibit lean physiques, irregular digestion, and a predisposition to conditions like anxiety and neurological disorders.

Pitta: Controls metabolism and is linked to heat and intensity. Pitta types are characterized by sharp intellects, robust digestion, and a tendency toward inflammatory disorders such as gastritis or skin rashes.

Kapha: Regulates structure and lubrication, and is associated with heaviness and stability. Kapha-dominant individuals often have sturdy builds, slower metabolisms, and a predisposition to conditions like obesity and diabetes.

Classification of Prakriti: Ayurveda identifies seven primary Prakriti types: the three single dosha types (Vata, Pitta, Kapha), three dual-dosha types (Vata-Pitta, Pitta-Kapha, Kapha-Vata), and the rare tri-dosha type. This classification determines an individual's susceptibility to diseases, their response to environmental factors, and the most suitable therapeutic interventions.

Therapeutic Implications: The holistic nature of Prakriti-based medicine allows Ayurveda to offer tailored health strategies, encompassing diet, exercise, herbal remedies, and lifestyle adjustments. For example, a Kapha-dominant individual might benefit from warming spices and vigorous exercise, while a Pitta-dominant person may require cooling foods and stress-relief techniques.

GENOMIC INSIGHTS INTO PRAKRITI

Modern genomic studies provide scientific validation for the concept of Prakriti by identifying genetic and epigenetic markers that align with the physiological and psychological traits described in Ayurveda.

HLA Gene Associations: Research on human leukocyte antigen (HLA) genes has revealed distinct patterns across Prakriti types. For example, the HLA DRB1*02 allele is notably absent in Vata individuals, suggesting a unique immune system configuration that might influence susceptibility to autoimmune disorders and infections. Pitta types exhibit alleles associated with heightened inflammatory responses, while Kapha individuals show markers indicative of robust but slower immune activity.

Single Nucleotide Polymorphisms (SNPs): Genome-wide association studies have identified 52 SNPs significantly correlated with Prakriti types. These SNPs influence a variety of biological processes:

Kapha Types: SNPs linked to genes regulating lipid metabolism, such as APOA5 and LPL, correlate with Kapha's predisposition to obesity and cardiovascular diseases (Saha *et al.,* 2021).

Pitta Types: Variations in genes associated with cytokine activity, such as IL-6 and TNF-α, align with Pitta's susceptibility to inflammatory and metabolic disorders.

Vata Types: SNPs influencing neuronal function and oxidative stress pathways, such as those in the SOD2 gene, reflect Vata's vulnerability to neurological and degenerative diseases.

Epigenetic Mechanisms: Environmental factors, lifestyle practices, and diet, all core aspects of Ayurvedic therapy, significantly influence gene expression through epigenetic mechanisms:

DNA Methylation: Studies have shown distinct DNA methylation patterns among Prakriti types. For instance, Vata individuals' exhibit hypomethylation in genes related to neuronal pathways, while Kapha types show hypermethylation in metabolic genes.

Histone Modification: Ayurvedic interventions like yoga and meditation have been shown to modulate histone acetylation, impacting gene expression related to stress response and immune function.

MicroRNA Expression: Preliminary findings suggest that Prakriti types have unique microRNA expression profiles, potentially influencing disease pathways and therapeutic responses.

These findings demonstrating that Prakriti is not just a theoretical construct but a biologically and genetically grounded framework for understanding individuality in health and disease(Chandran & Patwardhan, 2016).

CLINICAL IMPLICATIONS OF AYURGENOMICS

Ayurgenomics plays a crucial role in understanding individual susceptibility to diseases, optimizing pharmacological interventions, and identifying physiological markers for preventive care. Its ability to integrate Prakriti-based profiling with genetic insights enables a personalized approach to managing health and disease.

DISEASE SUSCEPTIBILITY AND PRAKRITI

Prakriti-based stratification provides a unique perspective on genetic predispositions to various diseases. It highlights how constitutional differences influence vulnerability to metabolic, neurological, and inflammatory conditions.

Metabolic Disorders: Kapha-dominant individuals are genetically predisposed to metabolic disorders, including obesity, diabetes, and cardiovascular diseases. Elevated triglycerides, LDL cholesterol levels, and insulin resistance markers are common among Kapha types. Research has identified variations in genes like FTO and APOA5, which regulate lipid metabolism, contributing to these risks (Sahoo *et al.,* 2021). Preventive strategies such as low-fat diets, regular physical activity, and lipid-lowering therapies are especially effective in managing these conditions for Kapha individuals.

Neurological Conditions: Vata-dominant individuals are associated with oxidative stress and mitochondrial dysfunction, making them more vulnerable to neurodegenerative diseases such as Alzheimer's and Parkinson's. Elevated oxidative stress markers, including malondialdehyde (MDA) and superoxide dismutase (SOD), have been linked to Vata-dominant profiles. Lifestyle interventions like yoga, meditation, and antioxidant-rich diets are recommended for reducing oxidative damage and supporting neuronal health (H. Sharma *et al.,* 2007).

Inflammatory Disorders: Pitta-dominant individuals exhibit higher levels of pro-inflammatory cytokines, such as IL-6 and TNF-α, predisposing them to autoimmune and inflammatory diseases

like rheumatoid arthritis and Crohn's disease. Genomic studies have shown over expression of inflammatory pathways in Pitta individuals, making anti-inflammatory diets and Ayurvedic herbs like turmeric and ashwagandha particularly beneficial for managing inflammation.

DRUG METABOLISM

Prakriti-based pharmacogenomics offers personalized solutions by aligning drug therapy with an individual's genetic and constitutional profile. This approach minimizes adverse drug reactions and enhances efficacy (Ghodke *et al.,* 2009).

CYP2C19 Variations: Genetic polymorphisms in the CYP2C19 gene significantly affect drug metabolism across Prakriti types. For instance, Vata-dominant individuals, characterized by higher metabolic activity, may require adjusted dosages of medications like clopidogrel to achieve optimal therapeutic outcomes. In contrast, Kapha types, with slower metabolism, are at risk of drug accumulation and toxicity, necessitating lower dosages or alternative treatments (Prasher *et al.,* 2016).

Warfarin Sensitivity: Variations in genes such as VKORC1 and CYP2C9 influence the metabolism of warfarin, a common anticoagulant. Pitta-dominant individuals, with their inflammatory tendencies, may experience fluctuations in warfarin efficacy due to inflammation-mediated changes in drug metabolism. Kapha types, with reduced CYP2C9 activity, are at an increased risk of bleeding complications and require careful dose monitoring.

Herb-Drug Interactions: Ayurvedic herbs frequently used by patients, such as Brahmi and tulsi, can interact with drugs by modulating cytochrome P450 enzymes. Understanding these interactions through a Prakriti-based lens enables healthcare providers to avoid adverse effects and optimize therapeutic outcomes.

PLATELET AGGREGATION AND GENETIC VARIATIONS

The study of platelet aggregation offers valuable insights into cardiovascular and thrombotic risks, which vary significantly across Prakriti types. Genetic variations, particularly in the P2Y12 receptor gene, influence these risks.

Vata Prakriti: Individuals with Vata constitution exhibit moderate platelet aggregation (75% at 10 μM ADP), attributed to sensitive oxidative stress and endothelial dysfunction. This predisposes them to neurodegenerative diseases like stroke, as oxidative stress impairs vascular integrity and clot formation.

Pitta Prakriti: Pitta-dominant individuals show lower platelet aggregation levels (70% at 10 μM ADP) but are at risk of inflammatory conditions that may exacerbate thrombotic events. Elevated inflammatory markers like CRP and fibrinogen further complicate their cardiovascular profiles.

Kapha Prakriti: Kapha individuals demonstrate the highest platelet aggregation levels (81% at 10 μM ADP), correlating with their predisposition to atherosclerosis and coronary artery disease. Increased expression of genes regulating platelet activation, such as P2Y12, amplifies their thrombotic risk.

Table 1: Kapha individuals demonstrate the highest platelet aggregation levels

Prakriti	Platelet Aggregation (% at 10 μM ADP)	Associated Risk
Vata	75	Oxidative stress, neurodegenerative diseases
Pitta	70	Inflammatory disorders
Kapha	81	Cardiovascular diseases

These findings reinforce the importance of Prakriti-specific cardiovascular risk assessment. Tailored interventions, such as antiplatelet therapies for Kapha types and antioxidant-rich diets for Vata types, can effectively mitigate these risks.

INTEGRATING AYURGENOMICS WITH MODERN MEDICINE

The integration of Ayurgenomics into modern medicine combines the ancient, holistic principles of Ayurveda with the data-driven precision of genomics. This transformative approach addresses the growing demand for individualized care by providing scientifically validated frameworks for disease prevention, management, and health optimization.

EPIGENETIC APPLICATIONS

Epigenetics focuses on how environmental and lifestyle factors influence gene expression. Ayurveda's holistic practices, such as yoga, meditation, and herbal interventions, are inherently aligned with epigenetic principles:

Yoga and Meditation: Research demonstrates that regular yoga and mindfulness practices modulate stress-related gene expression, reducing inflammation and enhancing immune function. These findings support Ayurveda's emphasis on mental well-being for physical health.

Seasonal Routines (Ritucharya): Ayurveda prescribes specific regimens for each season to adapt to environmental changes. These practices resonate with epigenetic plasticity, where seasonal variations influence gene expression.

Herbal Interventions: Compounds in Ayurvedic herbs like turmeric and ashwagandha modulate histone acetylation and DNA methylation, affecting pathways related to inflammation and stress (Patel *et al.,* 2019). Curcumin, for instance, has been shown to regulate inflammatory gene activity through epigenetic mechanisms (Prasher *et al.,* 2016).

MICROBIOME RESEARCH

Ayurveda's focus on digestion (Agni) aligns with microbiome science, which underscores the critical role of gut health in overall well-being. Ayurgenomics advances this understanding by linking microbiome diversity to Prakriti types:

Kapha-Dominant Microbiome: Kapha individuals often exhibit microbiomes conducive to lipid metabolism but may experience dysbiosis with high-fat diets. Probiotic strains like *Lactobacillus plantarum* can optimize their gut health.

Pitta-Dominant Microbiome: Pitta individuals have microbiomes adapted to acidic environments but are susceptible to acid reflux or ulcers. Cooling and alkaline-forming diets help maintain their microbiome balance.

Vata-Dominant Microbiome: Vata individuals, prone to gut motility disorders, benefit from high-fiber diets and prebiotics that stabilize their gut flora. Probiotics like *Bifidobacterium* improve their digestive health and nutrient absorption (Sahoo *et al.,* 2021).

THEORETICAL AND PRACTICAL APPLICATIONS

Ayurgenomics, as a multidisciplinary approach, bridges ancient Ayurvedic wisdom with modern genomics and technological advancements. Its theoretical and practical applications span various domains of healthcare, leveraging tools like big data, artificial intelligence (AI), and precision medicine to enhance health outcomes(Patwardhan & Mashelkar, 2009).

BIG DATA AND AI IN AYURGENOMICS

The role of big data and AI in Ayurgenomics cannot be overstated. These technologies are essential for analyzing complex datasets that include genetic markers, physiological traits, and Prakriti profiles. Their integration enables precise health predictions and personalized interventions (Saha *et al.,* 2021):

Data Collection and Analysis: Large-scale studies are capturing Prakriti data alongside genetic information. These datasets are then analyzed using AI algorithms to identify correlations between Prakriti types, genetic markers, and disease predispositions.

Machine Learning in Prakriti Assessment: Machine learning models are being developed to automate Prakriti determination through digital questionnaires, physiological data, and genetic profiles. This ensures high accuracy and consistency in assessments.

Predictive Health Outcomes: AI can predict potential health risks based on a combination of genomic data and Prakriti. For example, algorithms can identify individuals at risk for diabetes by analyzing lipid profiles in Kapha-dominant individuals.

Personalized Interventions: AI-based systems recommend personalized lifestyle modifications, dietary plans, and treatments aligned with an individual's Prakriti and genetic predisposition. These recommendations are dynamically updated based on real-time data from wearable health devices.

The use of big data and AI enhances the scalability of Ayurgenomics, enabling its application in diverse populations. Moreover, these technologies pave the way for precision healthcare, where interventions are tailored to the individual's unique biological and constitutional makeup.

GLOBAL IMPACT

Ayurgenomics offers a unique opportunity to integrate traditional and modern healthcare systems, fostering global acceptance and application:

Bridging Systems: By demonstrating the scientific validity of Ayurvedic principles through genomics, Ayurgenomics builds a bridge between traditional knowledge and evidence-based modern medicine. This fosters mutual acceptance among practitioners of both disciplines (Huang *et al.,* 2022).

Alignment with Sustainable Development Goals (SDGs): Ayurgenomics aligns with SDG 3 (Good Health and Well-being) by promoting preventive healthcare and reducing the burden of non-communicable diseases through lifestyle modifications and personalized care (Patel *et al.,* 2019).

Enhancing Health Equity: The affordability of Ayurvedic interventions compared to conventional treatments makes Ayurgenomics a viable healthcare option in low-resource settings. This contributes to reducing health disparities worldwide.

Policy and Research Implications: Governments and health organizations can use Ayurgenomics as a framework for developing policies that integrate traditional medicine into national health systems. This requires investment in research and infrastructure to support large-scale implementation.

CONCLUSION

Ayurgenomics represents a paradigm shift in healthcare, integrating ancient wisdom with cutting-edge science to achieve personalized, preventive, and participatory medicine. By leveraging the strengths of Ayurveda and genomics, Ayurgenomics promises to revolutionize disease prevention, diagnosis, and treatment. Its integration with modern medicine offers a holistic approach to health, emphasizing individuality and wellness. Future research and policy initiatives will play a pivotal role in its global acceptance and application.

List of abbreviations used in the article along with their elaborations:

1. AI - Artificial Intelligence
   - Refers to the simulation of human intelligence in machines that are programmed to think and learn.
2. P4 Medicine
   - Refers to Predictive, Preventive, Personalized, and Participatory medicine, a concept aiming to make medicine more tailored to individual needs.
3. IL-6 - Interleukin-6
   - A cytokine involved in inflammation and immune responses.
4. TNF-α - Tumor Necrosis Factor-alpha
   - A cell-signaling protein (cytokine) involved in systemic inflammation.
5. HLA - Human Leukocyte Antigen
   - A gene complex encoding proteins important for the immune system's regulation.
6. SNP - Single Nucleotide Polymorphism
   - A DNA sequence variation occurring when a single nucleotide in the genome differs among individuals.
7. FTO - Fat Mass and Obesity-associated Gene
   - A gene associated with body mass index (BMI) and obesity.
8. APOA5 - Apolipoprotein A5
   - A gene involved in lipid metabolism, influencing triglyceride levels.
9. LPL - Lipoprotein Lipase
   - An enzyme critical for breaking down fats in lipoproteins.
10. SOD2 - Superoxide Dismutase 2
    - An enzyme that protects against oxidative stress by breaking down superoxide radicals.
11. CYP2C19 - Cytochrome P450 2C19
    - A liver enzyme that metabolizes various drugs.

12. VKORC1 - Vitamin K Epoxide Reductase Complex Subunit 1
    - A gene that influences the body's response to the anticoagulant drug warfarin.
13. MDA - Malondialdehyde
    - A marker for oxidative stress.
14. CRP - C-reactive Protein
    - A protein produced by the liver in response to inflammation.
15. P2Y12
    - A receptor involved in platelet aggregation, influencing clot formation.
16. ICT - Information and Communication Technology
    - Refers to technology used for communication and information processing.
17. SDG - Sustainable Development Goals
    - A collection of global goals set by the United Nations to promote prosperity while protecting the planet.
18. Agni
    - A term from Ayurveda referring to digestive fire or metabolic energy.

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Chapter

10

ISOLATION AND CHARACTERIZATION OF A SULPHATED POLYSACCHARIDE ANTICOAGULANT FROM BROWN ALGAE

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ABSTRACT

The present study investigated the anticoagulant properties of Sargassum, a type of brown algae collected from the Colachel coastal area. The collected algae were washed, dried, and powdered. The powdered sample was then subjected to column chromatography to separate and purify its components. Thin-Layer Chromatography (TLC) was employed to analyze the extract and confirm the presence of various compounds. The anticoagulant activity of the extract was evaluated using the Activated Partial Thromboplastin Time (APTT) test, which showed that the extract significantly prolonged the coagulation time compared to control plasma, indicating its anticoagulant potential. However, the anticoagulant effect of the Sargassum extract was less potent than that of heparin. Overall, the study demonstrates that Sargassum contains bioactive compounds with notable anticoagulant activity, highlighting its potential as a natural source of anticoagulants and suggesting directions for further research to isolate and fully characterize these bioactive molecules.

KEYWORDS: Brown Algae, Anticoagulant, Activated Partial Thromboplastin Time, *Sargassum*.

INTRODUCTION

Brown algae, or Phaeophyceae, are a diverse and ecologically significant group of marine macroalgae predominantly found in cold and temperate coastal waters. These algae are well-known for their distinctive brown coloration, which is due to the presence of the pigment fucoxanthin (Jiao *et al.*,2000). Brown algae have long been utilized in various industries, including food, agriculture, and pharmaceuticals, due to their rich content of bioactive compounds. Among these compounds, polysaccharides such as alginates, fucoidans, and laminarins are particularly noteworthy for their diverse biological activities and potential therapeutic applications (Berteau and Mulloy, 2003).

The extraction of bioactive compounds from brown algae involves several steps, including harvesting, washing, drying, and the use of solvents or enzymatic treatments to isolate specific components (Jiaoet al.,2005). Fucoidan, a sulfated polysaccharide, is one of the primary compounds

extracted from brown algae. The extraction process can significantly influence the yield and purity of fucoidan, with factors such as the type of solvent, extraction time, and temperature playing crucial roles (Li et al.,2008). Optimizing these conditions is essential for obtaining high-quality fucoidan suitable for further characterization and application (Ale and Meyer,2010).

Characterization of fucoidan involves a detailed analysis of its chemical composition, molecular weight, and structural features. Techniques such as Fourier-transform infrared spectroscopy (FTIR), nuclear magnetic resonance (NMR), and high-performance liquid chromatography (HPLC) are commonly employed to elucidate these properties. The structure of fucoidan is complex, with variations in sulfate content, monosaccharide composition, and glycosidic linkages. Understanding these structural nuances is vital, as they directly influence the biological activity of fucoidan. Comprehensive characterization allows for the standardization of fucoidan extracts, ensuring consistency and reliability in their use for therapeutic purposes.

One of the most notable biological activities of fucoidan is its anticoagulant effect. This activity is of significant interest in the medical field, as it offers a natural alternative to synthetic anticoagulants, which can have adverse side effects. The anticoagulant mechanism of fucoidan is believed to involve the inhibition of key enzymes in the coagulation pathway, similar to the action of heparin. Fucoidan can prolong clotting time and reduce the formation of blood clots, making it a promising candidate for the prevention and treatment of thromboembolic disorders. Research into the anticoagulant properties of fucoidan includes both in vitro and in vivo studies to assess its efficacy and safety.

The exploration of brown algae as a source of bioactive compounds like fucoidan underscores the potential of marine resources in developing new therapeutic agents. As the demand for natural and sustainable alternatives to synthetic drugs increases, the importance of understanding the extraction, characterization, and biological activities of compounds derived from marine algae becomes more evident. Future research should focus on optimizing extraction methods, elucidating the structure-activity relationships of fucoidan, and conducting clinical trials to fully realize its therapeutic potential. By harnessing the unique properties of brown algae, we can contribute to the advancement of natural medicine and improve health outcomes. Hence, the present study was aimed to isolate a sulfated anticoagulant from the brown algae.

METHODOLOGY

The brown algae Sargassum, collected from the Colachel coastal region, underwent several processing steps for extraction and analysis. Initially, the algae were manually collected from the intertidal zone and identified based on key characteristics such as morphology, color, and texture. After thorough washing with fresh and distilled water to remove impurities, the algae were air-dried at room temperature for 3-5 days and then ground into a fine powder. The powdered algae were subjected to cold and hot extraction methods using distilled water, cellulase, and solvents like ethanol or acetone to extract polysaccharides, which were then precipitated, centrifuged, dialyzed, and freeze-dried to obtain the final polysaccharide anticoagulant powder.

The separation of components was achieved using column chromatography, where the extract was applied to a column packed with silica gel or alumina, followed by gradient elution to isolate

different components. Thin-layer chromatography (TLC) was used to identify the components, where the extract was spotted on pre-coated plates and developed with a solvent system, visualized under UV light, and compared with reference standards to calculate retention factors. The anticoagulant activity of the extract was evaluated through the Activated Partial Thromboplastin Time (APTT) test, where it was found to significantly prolong the clotting time compared to control plasma, indicating its anticoagulant potential, though less potent than heparin.

RESULTS AND DISCUSSION

The brown algae collected were identified as *Sargassum*. The identification was based on the following distinguishing characteristics:

Color: The algae exhibited a dark brown to olive-brown coloration, typical of the *Sargassum* genus. The color can vary slightly depending on the specific species and environmental conditions.

Texture: The texture of *Sargassum* is leathery and somewhat coarse. The fronds are flexible yet robust, which is a distinctive feature of this genus.

Branching Pattern: *Sargassum* has a characteristic branching pattern. The algae possess numerous branches that are alternately arranged along the main axis. The branches are often subdivided into smaller branchlets, giving the algae a bushy appearance.

Air Bladders: *Sargassum* species feature small, spherical air bladders or vesicles located at intervals along the branches. These bladders help the algae float and maintain buoyancy in the water column.

Frond Shape: The fronds of *Sargassum* are typically flattened and may have a jagged or undulating edge.

Attachment: *Sargassum* is often attached to the substrate via a holdfast, a specialized structure that anchors the algae to rocks or other surfaces in the intertidal zone.

These identification features were confirmed using standard manuals and reference specimens.

COLD EXTRACTION METHOD

The cold extraction method yielded a moderate amount of polysaccharide (0.1mg /gm) anticoagulant. The process preserved the integrity of heat-sensitive compounds, resulting in a higher purity of the extracted polysaccharides. The final powder was light in color and exhibited strong anticoagulant activity.

HOT EXTRACTION METHOD

The hot extraction method produced a higher yield of polysaccharide (1mg /gm) anticoagulant compared to the cold extraction method. However, the elevated temperature may have caused partial degradation of some heat-sensitive components, leading to a slightly lower purity. The final powder was darker in color.

The effectiveness of anticoagulant assays for polysaccharides extracted from brown algae has been widely studied, and the findings align with the existing literature. The cold extraction method yielded a high-purity polysaccharide with strong anticoagulant activity, consistent with Nair *et al.*, (2010), reported that cold extraction preserved the structural integrity and bioactivity of the anticoagulants. Similarly, Lee *et al.*, (2013) found that cold extraction methods better maintained bioactive components compared to hot extraction.

On the other hand, the hot extraction method produced a higher yield but with slightly reduced purity, reflecting the findings of Zhang *et al.,* (2015), noted that while heat can increase extraction efficiency, it may degrade sensitive polysaccharides. Kim *et al.,* (2017) also highlighted that hot extraction requires careful temperature control to optimize yield while minimizing degradation.

COLUMN CHROMATOGRAPHY

When performing column chromatography on the extract of *Sargassum* powder, the extract was fractionated into several distinct components, as the sample passes through the column. The initial fractions may contain more polar compounds, such as polysaccharides like alginic acid and fucoidan, which are commonly found in brown algae. As the elution continues, less polar compounds, such as pigments (carotenoids) and fatty acids, starts to elute. These fractions will likely vary in color, with early fractions being more colorless or pale yellow and later fractions potentially showing more intense colors like yellow, orange, or brown. Each collected fraction was further analyzed by TLC, to confirm the presence and purity of specific compounds.

Column chromatography was effectively used to separate the polysaccharides based on their size and charge, consistent with the work of Lee *et al.,* (2014), who demonstrated that this method allows for the precise isolation of different polysaccharide fractions from brown algae. Their study highlighted that column chromatography is a reliable technique for purifying polysaccharides, which aligns with our successful isolation of distinct polysaccharide fractions.

THIN LAYER CHROMATOGRAPHY

When performing Thin-Layer Chromatography (TLC) on an extract from *Sargassum* powder, multiple spots were observed on the TLC plate, each representing different components of the extract. The common compounds in *Sargassum*, such as fucoidan, alginic acid, laminarin, and other polyphenols, are likely to separate distinctly. The spots vary in color, with fucoidan potentially appearing as a brownish spot after iodine staining and alginic acid as a faint yellow spot. The retention factor (Rf) values of these spots will depend on the solvent system and were seen spots at different Rf values, indicating successful separation of these bioactive compounds. Visualization under UV light or after staining will help to identify these spots, providing insights into the composition of the *Sargassum* extract.

The Rf values were as follows:

Rf value of first spot = 0.57

Rf value of second spot = 0.43

Rf value of second spot = 0.31

TLC also proved useful in monitoring the separation process. Our results are supported by the findings of Garcia *et al.,* (2015), who used TLC to analyze polysaccharide extracts from brown algae. They noted that TLC provides a simple and effective means of assessing the purity and composition of polysaccharide fractions. Our TLC analysis, which showed well-separated spots corresponding to different polysaccharide components, corroborates their observation that TLC can effectively differentiate between various polysaccharide types.

In comparison, the study by Kim *et al.,* (2018) emphasized the advantages of combining column chromatography with TLC for a comprehensive analysis of polysaccharide extracts. They found that while column chromatography provides detailed separation, TLC offers a quick and cost-effective method for preliminary analysis. Our use of both techniques aligns with their approach, validating the effectiveness of this combined methodology for analyzing polysaccharide extracts.

ACTIVATED PARTIAL THROMBOPLASTIN TIME (APTT) TEST

Control Plasma: 45-50 seconds

Sargassum Extract: 1 minute (60 seconds)

Heparin: 1.5 minutes (90 seconds)

The *Sargassum* extract prolonged the APTT to 1 minute (60 seconds) compared to the control plasma, which coagulated in 45-50 seconds. This indicates that the Sargassum extract exhibits anticoagulant activity, though it is less potent than heparin, which extended the coagulation time to 1.5 minutes (90 seconds).

The results, which showed significant anticoagulant activity in the polysaccharide extracts, are consistent with studies by Kim *et al.,* (2012) and Nguyen *et al.,* (2016). Kim *et al.,* demonstrated that polysaccharides from various brown algae significantly prolonged APTT, indicating effective inhibition of the intrinsic pathway of coagulation. This finding supports with observation that the polysaccharides extracted using both cold and hot methods exhibit strong anticoagulant properties.

Similarly, Nguyen *et al.,* (2016) found that polysaccharides isolated from brown algae, particularly through cold extraction methods, resulted in notable prolongation of APTT, confirming the effectiveness of these compounds in inhibiting clotting. Their study highlights the importance of maintaining the structural integrity of polysaccharides to ensure effective anticoagulant activity, aligning with our results showing that cold extraction preserved this integrity better than hot extraction.

In contrast, Zhang *et al.,* (2018) observed that while hot extraction increased yield, it sometimes led to reduced APTT prolongation due to partial degradation of active polysaccharides. This is consistent with our findings, where hot extraction yielded a higher quantity of polysaccharides but with slightly diminished anticoagulant activity compared to cold extraction.

CONCLUSION

In conclusion, this study demonstrates that *Sargassum* contains bioactive compounds with notable anticoagulant properties, as evidenced by the significant prolongation of APTT in the plasma. Although the extract's effect was less potent than heparin, it highlights the potential of *Sargassum* as a source of natural anticoagulants. Further research is essential to identify and characterize these compounds, paving the way for possible therapeutic applications in the future.

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Chapter 11

IMPORTANCE OF GREEN CHEMISTRY AND NANO TECHNIQUES IN CHEMICAL SYNTHESIS

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ABSTRACT

The growing need for sustainable practices in chemical synthesis has led to the emergence of green chemistry and nanotechnology as pivotal approaches in modern science. Green chemistry emphasizes the design of chemical processes and products that reduce or eliminate the use and generation of hazardous substances, thereby minimizing environmental impact. Simultaneously, nanotechnology introduces innovative tools and materials that enhance the precision, efficiency, and sustainability of chemical transformations. This chapter explores the integration of green chemistry principles and nano techniques to address critical challenges in chemical synthesis. It highlights key advancements such as the development of nano-catalysts, solvent-free reactions, and the utilization of renewable feedstocks. Additionally, the chapter examines industrial applications, including pharmaceutical synthesis, petrochemical processes, and the production of sustainable nanomaterials. While these approaches offer transformative potential, challenges such as scalability, cost, and ethical considerations remain. By synergizing green chemistry and nanotechnology, this chapter envisions a pathway toward a sustainable and environmentally responsible future in chemical synthesis.

KEYWORDS: Green Chemistry, Nanotechnology, Sustainability, Nano-catalysts, Chemical Synthesis.

INTRODUCTION

The imperative for sustainable and environmentally benign methodologies in chemical synthesis has led to the development of green chemistry and nanotechnology as pivotal fields. Green chemistry, as defined by Anastas and Warner (1998), focuses on designing chemical products and processes that reduce or eliminate the use and generation of hazardous substances. The foundational Twelve Principles of Green Chemistry advocate for practices such as waste prevention, atom economy, the use of safer solvents, and energy efficiency (Anastas & Warner, 1998). These principles have been instrumental in guiding the chemical industry toward more sustainable practices.

Nanotechnology, involving the manipulation of matter at the nanoscale, offers unique opportunities to enhance chemical synthesis. Nanomaterials exhibit distinct properties, including increased surface area and reactivity, which can be leveraged to improve catalytic processes. The synthesis of nanoparticles can be achieved through various methods, broadly categorized into physical (top-down) and chemical or biological (bottom-up) approaches (Khan *et al.*, 2023). The integration of

green chemistry principles into nanotechnology has led to the development of greener synthesis methods, reducing environmental impact and improving process efficiency (Khan *et al.,* 2023).

The convergence of green chemistry and nanotechnology has resulted in significant advancements in chemical synthesis. For instance, the application of nanocatalysts has enabled more efficient reactions under milder conditions, aligning with the goals of sustainability and reduced environmental impact (Anastas & Kirchhoff, 2002). This synergy not only enhances the efficiency of chemical processes but also contributes to the broader objective of developing sustainable technologies.

The integration of green chemistry principles with nanotechnology represents a transformative approach in chemical synthesis, promoting processes that are both efficient and environmentally friendly. This chapter explores the foundational concepts of these fields, their applications, and the impact of their integration on modern chemical practices. The convergence of green chemistry and nanotechnology represents a paradigm shift in chemical synthesis, promoting processes that are both efficient and environmentally friendly. This chapter delves into the foundational concepts of these fields, exploring their principles, applications, and the transformative impact of their integration on modern chemical practices.

The pursuit of sustainable and environmentally benign methodologies in chemical synthesis has become imperative in contemporary science. Green chemistry, defined by its twelve guiding principles, aims to design chemical processes that minimize waste and reduce the use of hazardous substances (Duan *et al.,* 2015). These principles advocate for atom economy, the use of renewable feedstocks, and the design of safer chemicals, among other strategies.

Nanotechnology, the manipulation of matter at the nanoscale, has emerged as a complementary approach to green chemistry. The unique properties of nanomaterials, such as high surface area and quantum effects, enable enhanced catalytic activities and selectivities in chemical reactions (Duan *et al.,* 2015). Notably, the green synthesis of nanoparticles, which utilizes biological entities like plant extracts, offers a sustainable alternative to conventional chemical and physical methods (Jahangirian *et al.,* 2017).

The integration of green chemistry principles with nanotechnology has led to significant advancements in chemical synthesis. For instance, the development of green nanocatalysts facilitates reactions under milder conditions, reducing energy consumption and the generation of toxic by-products (Duan *et al.,* 2015). This synergy not only enhances the efficiency of chemical processes but also aligns with the overarching goal of sustainability in the chemical industry.

PRINCIPLES OF GREEN CHEMISTRY IN CHEMICAL SYNTHESIS

Green chemistry is a framework aimed at designing chemical processes and products to reduce or eliminate the use and generation of hazardous substances, thereby minimizing environmental impact and enhancing sustainability (Anastas & Warner, 1998). Central to this framework are several key principles that guide the development of safer and more efficient chemical syntheses.

ATOM ECONOMY AND WASTE MINIMIZATION

Atom economy is a concept that measures the efficiency of a chemical reaction in incorporating all reactant atoms into the desired final product, thereby minimizing waste (Trost, 1991). High atom

economy is achieved when the majority of the reactants are converted into the final product, reducing the generation of by-products and the need for waste disposal. Implementing reactions with high atom economy not only conserves resources but also diminishes the environmental footprint of chemical processes.

USE OF RENEWABLE FEEDSTOCKS

Utilizing renewable feedstocks involves sourcing raw materials from resources that are replenished naturally, such as agricultural products or biomass, instead of finite resources like fossil fuels (Anastas & Warner, 1998). This practice ensures a sustainable supply chain and reduces dependence on depleting resources. For example, the production of bio-based polymers from plant-derived monomers exemplifies the application of renewable feedstocks in chemical synthesis (Gandini, 2011).

CATALYSIS: HOMOGENEOUS AND HETEROGENEOUS APPROACHES

Catalysis plays a pivotal role in enhancing the efficiency of chemical reactions by increasing reaction rates and selectivity while reducing energy consumption. Homogeneous catalysts are in the same phase as the reactants, often providing high selectivity, whereas heterogeneous catalysts exist in a different phase, typically offering ease of separation and recyclability (Anastas & Warner, 1998). The development of green catalytic processes, such as the use of biocatalysts or metal-organic frameworks, aligns with the principles of green chemistry by minimizing hazardous by-products and improving overall process sustainability (Sheldon, 2007).

DESIGNING SAFER CHEMICALS

Designing safer chemicals involves the intentional creation of chemical products that fulfill their intended function while posing minimal toxicity to human health and the environment (Anastas & Warner, 1998). This principle encourages chemists to consider the inherent hazards of chemical structures and to modify them to reduce potential risks. For instance, the development of less toxic solvents or the substitution of hazardous reagents with safer alternatives reflects the application of this principle in chemical synthesis (Poliakoff *et al.*, 2002).

Incorporating these principles into chemical synthesis not only advances the field toward more sustainable practices but also aligns with global efforts to mitigate environmental impact and promote human health. The continuous evolution and application of green chemistry principles are essential for the development of innovative and responsible chemical processes.

NANO TECHNIQUES IN CHEMICAL SYNTHESIS

The integration of nanotechnology into chemical synthesis has significantly advanced the field, offering innovative approaches that enhance efficiency, selectivity, and environmental sustainability. This section delves into various nano techniques and their applications in chemical synthesis, emphasizing their alignment with green chemistry principles.

NANOSCALE MATERIALS IN SYNTHESIS: OVERVIEW

Nanoscale materials, defined by their dimensions ranging from 1 to 100 nanometers, exhibit unique physical and chemical properties distinct from their bulk counterparts. These properties, including increased surface area, quantum effects, and enhanced reactivity, make them invaluable in chemical

synthesis (Khan *et al.,* 2019). The synthesis of nanoparticles can be broadly categorized into two approaches:

Top-Down Methods: These involve breaking down bulk materials into nanoscale structures using physical techniques such as mechanical milling, lithography, and pyrolysis (Khan *et al.,* 2019).

Bottom-Up Methods: These rely on assembling nanoparticles from atomic or molecular precursors through chemical processes like sol-gel synthesis, chemical vapor deposition, and hydrothermal methods (Khan *et al.,* 2019).

The selection of an appropriate synthesis method is crucial, as it influences the size, morphology, and functionality of the nanoparticles, thereby affecting their performance in chemical reactions.

GREEN NANO-CATALYSTS: DESIGN AND APPLICATIONS

Nano-catalysts, catalysts engineered at the nanoscale, have emerged as powerful tools in promoting sustainable chemical processes. Their high surface-to-volume ratio enhances catalytic activity, allowing for lower catalyst loadings and milder reaction conditions (Zhang *et al.,* 2022). The design of green nanocatalysts focuses on:

Eco-Friendly Synthesis: Employing environmentally benign methods, such as using plant extracts or biodegradable polymers, to synthesize nanocatalysts reduces the use of hazardous chemicals (Zhang *et al.,* 2022).

Support Materials: Utilizing sustainable materials like biochar or silica supports not only stabilizes the nanoparticles but also enhances their reusability and reduces leaching (Zhang *et al.,* 2022).

Applications of green nanocatalysts span various domains, including environmental remediation, where they facilitate the degradation of pollutants, and in energy production, such as in fuel cells and hydrogen production (Zhang *et al.,* 2022).

NANOTECHNOLOGY IN SOLVENT-FREE REACTIONS

Solvent-free reactions, also known as neat reactions, eliminate the use of solvents, thereby reducing environmental hazards and improving safety. Nanotechnology enhances these processes by providing nanocatalysts that operate efficiently under solvent-free conditions. For instance, nanocatalysts synthesized through solvent-free methods, such as ball-milling or microwave-assisted techniques, have demonstrated high activity and selectivity in various organic transformations (Li *et al.,* 2021). These approaches not only adhere to green chemistry principles but also offer practical advantages in terms of scalability and cost-effectiveness.

NANO TECHNIQUES FOR PRECISION AND EFFICIENCY

The precision offered by nanotechnology in chemical synthesis is unparalleled. Techniques such as nanoparticle encapsulation allow for controlled release of reactants, leading to higher selectivity and yield (Chen *et al.,* 2020). Additionally, the use of nanoreactors—nanoscale environments where reactions occur—enables precise control over reaction parameters, minimizing side reactions and waste (Chen *et al.,* 2020). These advancements contribute to more efficient chemical processes, aligning with the goals of green chemistry by reducing resource consumption and environmental impact.

The incorporation of nano techniques in chemical synthesis represents a significant stride toward sustainable and efficient chemical processes. By leveraging the unique properties of nanoscale

materials, chemists can design reactions that are not only more effective but also environmentally benign, fulfilling the objectives of green chemistry.

SYNERGY BETWEEN GREEN CHEMISTRY AND NANO TECHNIQUES

The integration of green chemistry principles with nanotechnology has created novel opportunities for sustainable advancements in chemical synthesis. This synergy leverages the unique capabilities of nanoscale materials to address environmental challenges while enhancing efficiency and reducing waste. Below, we delve into three critical areas where this synergy has profound implications.

The synergy between green chemistry and nanotechnology presents a transformative approach to chemical synthesis, enabling sustainable pathways for material production, reducing environmental footprints, and advancing applications in diverse chemical domains. By integrating eco-friendly practices with nanoscale innovations, this interdisciplinary approach addresses global challenges in sustainability and drives progress toward greener industrial practices.

SUSTAINABLE PATHWAYS TO NANOMATERIAL PRODUCTION

Nanomaterials are pivotal in modern science due to their unique properties, such as high surface area, quantum effects, and exceptional reactivity. However, traditional methods of synthesizing nanomaterials often involve hazardous reagents and energy-intensive processes, which contradict sustainability goals. Green chemistry principles advocate for eco-friendly production techniques, prioritizing renewable feedstocks, benign solvents, and energy-efficient methods (Anastas & Warner, 1998).

One of the most promising sustainable pathways is biological nanoparticle synthesis, which utilizes plant extracts, microorganisms, or enzymes as reducing and stabilizing agents. For example, green synthesis using plant-derived compounds such as polyphenols has shown efficacy in producing metal nanoparticles, such as silver and gold, with high catalytic and antimicrobial properties (Iravani *et al.,* 2014; Mishra & Chowdhury, 2021). This approach minimizes the use of toxic chemicals and aligns with the circular economy by utilizing agricultural or industrial biowastes (Ahmed *et al.,* 2021).

Another approach involves solvent-free methods, such as mechanochemical processes. Ball milling has emerged as a sustainable technique for nanoparticle synthesis, eliminating the need for solvents and reducing energy consumption (Gandotra *et al.,* 2022). These methods embody the principle of waste prevention by directly converting precursors into functional nanomaterials.

ROLE OF NANOTECHNOLOGY IN REDUCING ENVIRONMENTAL FOOTPRINTS

Nanotechnology significantly contributes to reducing the environmental footprint of chemical processes through the design of efficient nanocatalysts and advanced materials. Nanocatalysts enhance reaction efficiency by offering high surface-to-volume ratios, enabling reduced energy inputs and lower material consumption (Sheldon, 2007). For example, nanomaterials in water purification systems, such as graphene oxide and nanoscale zero-valent iron, have demonstrated remarkable efficiency in removing pollutants, including heavy metals and organic dyes (Kumar *et al.,* 2022). These systems operate at lower chemical dosages and produce minimal secondary waste compared to conventional methods.

In addition, the use of nanoscale photocatalysts in solar energy applications has gained traction. Titanium dioxide (TiO_2) and zinc oxide (ZnO) nanoparticles are widely applied in the degradation of environmental pollutants through photocatalysis under sunlight, showcasing the role of nanotechnology in addressing energy and environmental challenges (Gupta *et al.,* 2021). Nanotechnology also supports the development of lightweight and energy-efficient materials for industries such as automotive and aerospace, which help in reducing greenhouse gas emissions during operation (Baig *et al.,* 2021). These advancements are critical in mitigating the carbon footprint of industrial sectors.

APPLICATIONS IN ORGANIC AND INORGANIC SYNTHESIS

The synergy between green chemistry and nanotechnology has revolutionized organic and inorganic chemical syntheses by introducing novel methods for enhanced selectivity, reduced waste, and minimal toxicity. In organic synthesis, green nano-catalysts are increasingly used to drive cleaner reactions. Palladium, gold, and bimetallic nanoparticles have been employed in cross-coupling reactions, such as Suzuki-Miyaura and Heck reactions, under aqueous or solvent-free conditions (Polshettiwar & Varma, 2010).

In inorganic synthesis, nanomaterials synthesized using green methods have led to the creation of advanced catalysts for industrial processes. For example, iron oxide nanoparticles synthesized using plant extracts have been applied as heterogeneous catalysts for CO_2 reduction, demonstrating high efficiency and recyclability (Chen *et al.,* 2021). Furthermore, nano-encapsulation techniques allow for controlled release of reactants and selective targeting in both organic and inorganic reactions. This precision minimizes unwanted by-products and aligns with the atom economy principle, a cornerstone of green chemistry (Trost, 1991).

APPLICATIONS IN INDUSTRIAL CHEMICAL PROCESSES

The integration of green chemistry principles with nanotechnology has revolutionized industrial chemical processes, leading to more sustainable and efficient practices across various sectors. This section explores the applications of green chemistry and nanotechnology in pharmaceutical synthesis, petrochemical industries, and highlights successful case studies demonstrating their industrial implementation.

GREEN SYNTHESIS OF PHARMACEUTICALS

The pharmaceutical industry has increasingly adopted green chemistry principles to develop environmentally friendly and cost-effective manufacturing processes. By minimizing the use of hazardous chemicals and reducing waste, these practices align with sustainability goals. For instance, between 2004 and 2013, the U.S. drug industry's chemical usage decreased by nearly half, primarily due to reduced organic solvent consumption, including methanol, dichloromethane, toluene, dimethylformamide, and acetonitrile, which collectively accounted for 75% of the reductions (American Chemical Society, 2014).

A notable example is the green synthesis of active pharmaceutical ingredients (APIs) using biocatalysis. Enzymatic processes offer high specificity and operate under mild conditions, reducing the need for toxic reagents and minimizing by-product formation. For example, the biocatalytic

production of chiral intermediates has been successfully implemented, replacing traditional chemical methods that often require hazardous solvents and reagents (Jadhav, 2023).

NANOTECHNOLOGY IN PETROCHEMICAL INDUSTRIES

Nanotechnology has introduced innovative solutions in the petrochemical industry, enhancing process efficiency and environmental performance. Nanocatalysts, due to their high surface area and reactivity, facilitate reactions under milder conditions, leading to energy savings and reduced emissions. For example, the development of nanocatalysts for hydro cracking processes has improved the yield and quality of fuels, while also decreasing the formation of undesirable by-products (Zhang *et al.,* 2021).

Additionally, nanomaterials are employed in the development of advanced filtration systems for the removal of sulfur compounds from fuels. Nanostructured adsorbents have demonstrated superior capacity and selectivity in capturing sulfur species, thereby producing cleaner fuels and reducing sulfur-related emissions (Li *et al.,* 2020).

CASE STUDIES: SUCCESSFUL IMPLEMENTATION IN INDUSTRY

Several industries have successfully integrated green chemistry and nanotechnology, achieving significant environmental and economic benefits.

Pharmaceutical Industry: Lupin Limited, a global pharmaceutical company, has implemented green chemistry principles in the synthesis of APIs. By adopting solvent-free reactions and utilizing renewable feedstocks, the company has reduced hazardous waste generation and improved process efficiency (Jadhav, 2023).

Petrochemical Industry: The development of nanocatalysts for the catalytic cracking of hydrocarbons has been successfully implemented, leading to higher selectivity and yield of desired products. This advancement has resulted in reduced energy consumption and lower greenhouse gas emissions (Zhang *et al.,* 2021).

Environmental Remediation: Green synthesized nanomaterials have been employed in wastewater treatment plants to remove heavy metals and organic pollutants. For instance, nanoscale zero-valent iron particles have been used to remediate contaminated water sources, demonstrating high efficiency and reusability (Li *et al.,* 2020).

These case studies exemplify the practical applications of green chemistry and nanotechnology in industrial settings, highlighting their potential to drive sustainable practices and innovation.

CHALLENGES AND FUTURE PERSPECTIVES

The integration of green chemistry principles with nanotechnology has led to remarkable advancements in chemical synthesis, but numerous challenges remain. These include limitations in current green chemistry techniques, potential risks and ethical considerations surrounding nanotechnology, and the need for innovations that combine both approaches effectively to address future demands for sustainable practices.

LIMITATIONS OF CURRENT GREEN CHEMISTRY TECHNIQUES

While green chemistry has revolutionized chemical synthesis by emphasizing sustainable practices, there are notable limitations in the widespread application of these techniques. One major challenge is the scalability of laboratory-developed green methods to industrial-scale processes. Techniques

such as solvent-free reactions or biocatalysis, which perform well on a small scale, often encounter practical difficulties when scaled up, such as issues related to heat management, mass transfer, and the consistency of product yield (Anastas & Warner, 1998; Lee & Zhang, 2021).

Another significant limitation is the economic viability of adopting green chemistry practices in industrial settings. Despite the long-term environmental benefits, the initial investment required for infrastructure changes, the use of renewable feedstocks, and the adoption of novel catalysts can be prohibitive for many companies (Sheldon, 2016). Green chemistry alternatives may also suffer from reduced efficiency in some cases, especially when compared to traditional processes that have been optimized over decades. Furthermore, green chemistry aims to replace toxic solvents with safer alternatives, but this transition is not always feasible, especially in the case of complex reactions that require very specific conditions or high reactivity. For example, in certain high-performance polymerizations or synthesis of fine chemicals, the replacement of solvents may lead to compromised reaction efficiency or increased production times (Trost & Crawley, 2017).

RISKS AND ETHICAL CONSIDERATIONS IN NANOTECHNOLOGY

Nanotechnology introduces new opportunities for innovation in chemical synthesis but also raises significant environmental, health, and ethical concerns. The toxicological risks of nanomaterials are still not fully understood. Nanomaterials exhibit unique physical and chemical properties that may not be predictable based on bulk material characteristics. For instance, nanoparticles' small size, large surface area, and reactivity can result in bioaccumulation and toxicity in both environmental and biological systems. A recent study by Sharma *et al.,* (2020) found that the long-term environmental impact of nanosilver, a widely used nanomaterial, includes potential harm to aquatic life due to its bioaccumulation and toxicity (Sharma *et al.,* 2020). These concerns underscore the need for more rigorous risk assessments and the development of standard safety protocols in nanotechnology applications (Roco, 2019).

The ethical implications of nanotechnology also present a significant challenge. The application of nanotechnology in fields such as biotechnology and medicine raises issues regarding privacy, surveillance, and consent. The ability to manipulate materials at the nanoscale may lead to unintended consequences, such as the creation of surveillance devices with nanoparticle-based sensors or the misuse of nanotechnology in weapons. Scholars like Schummer (2004) have stressed the importance of developing ethical frameworks that can guide the responsible use of nanotechnology in various industries, particularly when it comes to privacy and security (Schummer, 2004). Moreover, nanotechnology's rapid pace of development has outstripped the creation of regulatory frameworks, posing challenges for oversight. Regulatory bodies struggle to keep up with the innovation of new nanomaterials, which often lack comprehensive testing to understand their full environmental impact and human health risks (Bouwmeester *et al.,* 2009).

INNOVATIONS ON THE HORIZON: COMBINING GREEN AND NANO APPROACHES

Despite these challenges, the combination of green chemistry principles with nanotechnology offers promising innovations for the future. One exciting development is the green synthesis of nanomaterials, where green chemistry methods such as bioreduction, plant extracts, and renewable feedstocks are employed to produce nanoparticles. These methods significantly reduce the reliance

on toxic chemicals and energy-intensive processes. For instance, green synthesis of gold nanoparticles using plant extracts has been demonstrated as a highly effective and eco-friendly approach, offering an alternative to traditional chemical reduction methods (Patil *et al.,* 2021).

In the area of nanocatalysis, there is a growing focus on designing nanomaterials that are not only highly efficient but also environmentally benign. Green nanocatalysts, such as those based on bio-derived materials or composites, are being developed to catalyze a wide range of reactions with minimal environmental impact. These nanocatalysts can operate under milder conditions and often exhibit higher activity than traditional catalysts (Xie *et al.,* 2020). The synergy between nano-structured catalysts and green solvents is also a key area of development, leading to more efficient, sustainable reactions that reduce the environmental footprint of industrial processes (Vasylyeva *et al.,* 2022).

Moreover, the integration of green chemistry and nanotechnology in industrial applications is gaining momentum, with industries in pharmaceuticals, petrochemicals, and environmental remediation already embracing these approaches. For example, the pharmaceutical industry has seen the rise of biocatalytic nanocatalysts, which can be applied to the large-scale synthesis of active pharmaceutical ingredients (APIs) with improved selectivity and reduced environmental impact (Gupta *et al.,* 2020). Similarly, nanotechnology is being leveraged in environmental applications, such as the remediation of contaminated water and soil, where green nanomaterials are utilized for their high adsorptive capacity and reusability (Li *et al.,* 2022).

The future of green chemistry and nanotechnology lies in enhancing collaboration between the two fields. Innovations such as bio-inspired nanomaterials and self-healing nanocatalysts could offer groundbreaking solutions to many of the limitations currently faced by green chemistry techniques. The convergence of green chemistry with nanotechnology promises to bring new solutions to critical global challenges, such as reducing greenhouse gas emissions, improving energy efficiency, and creating sustainable manufacturing processes.

While green chemistry and nanotechnology have the potential to significantly transform chemical synthesis, there are substantial challenges that need to be addressed. Limitations in current techniques, the risks associated with nanomaterials, and the ethical implications of nanotechnology need to be carefully considered. Nevertheless, ongoing research into the synergy between green chemistry and nanotechnology holds promise for overcoming these challenges and delivering sustainable solutions for the future of chemical synthesis.

CONCLUSION

The integration of green chemistry principles with nanotechnology represents a transformative approach to chemical synthesis, promoting sustainability, efficiency, and reduced environmental impact. Green chemistry, with its focus on atom economy, waste reduction, renewable feedstocks, and catalysis, offers a foundational framework for making chemical processes more environmentally friendly. When coupled with the advancements in nanotechnology, particularly in the design of green nanocatalysts and the development of novel nanomaterials, chemical synthesis can achieve unprecedented levels of precision, efficiency, and sustainability.

Nanotechnology offers a unique opportunity to fine-tune chemical reactions at the molecular and atomic levels, enabling the creation of more effective catalysts, solvent-free processes, and materials with enhanced properties. The synergy between green chemistry and nanotechnology holds the promise of addressing many of the current limitations of traditional chemical processes, such as high energy consumption, hazardous waste production, and reliance on non-renewable resources. By leveraging the principles of both fields, it is possible to significantly reduce the environmental footprint of chemical industries, including the pharmaceutical, petrochemical, and materials sectors.

Despite these advancements, challenges remain, including the scalability of green chemistry techniques, the potential risks and ethical concerns associated with nanotechnology, and the need for more robust regulatory frameworks. Furthermore, there are still gaps in our understanding of the long-term environmental and health impacts of nanomaterials, as well as the economic barriers to widespread adoption of green and nano-based methods in industrial applications.

The future of sustainable chemical synthesis lies in overcoming these challenges through continued research, innovation, and the development of regulatory guidelines that balance technological advancements with safety and ethical considerations. Innovations on the horizon, such as green-synthesized nanomaterials, bio-inspired nanocatalysts, and the combination of nanotechnology with renewable resources, are expected to play a pivotal role in reshaping the chemical industry towards greater sustainability.

In conclusion, the combined approach of green chemistry and nanotechnology offers a powerful pathway toward more sustainable chemical processes. As research progresses and these techniques become more refined, it is likely that we will see broader adoption across industries, leading to a more sustainable future in chemical synthesis. By addressing the technical, ethical, and regulatory challenges, we can fully realize the potential of this exciting interdisciplinary field, ensuring that future chemical processes are not only more efficient but also safer for both humans and the environment.

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Chapter 12

SEAWEED-BASED NANOPARTICLES FOR POLLUTION CONTROL: A NOVEL ECO-FRIENDLY SOLUTION

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ABSTRACT

Seaweed-based nanoparticles (SBNPs) are emerging as a cutting-edge solution for pollution control, offering a sustainable and eco-friendly approach to mitigating environmental contamination. Derived from marine macroalgae, these nanoparticles are synthesized through green chemistry methods, utilizing the natural bioactive compounds present in seaweed. SBNPs exhibit remarkable properties, including high surface area, biocompatibility, and enhanced catalytic activity, making them ideal for addressing various pollutants such as heavy metals, organic contaminants, and microplastics. This abstract explores the synthesis, characterization, and application of SBNPs in water and soil remediation. Additionally, their role in adsorbing and degrading pollutants is highlighted, along with their potential in carbon sequestration. The use of seaweed as a renewable resource ensures minimal environmental impact while contributing to the circular economy. The integration of SBNPs into existing pollution control frameworks could revolutionize environmental management strategies, paving the way for a cleaner and greener future.

KEYWORDS: Marine Macroalgae, Seaweed-based nanoparticles, Eco-friendly, Pollution Control, Cleaner and Greener.

INTRODUCTION

An environmental pollutant remains one of the most urgent international challenges, threatening ecosystems, human health, and sustainable development. Rapid industrialization, urbanization, and population growth have caused the excessive launch of pollutants, consisting of heavy metals, organic contaminants, microplastics, and greenhouse gases. These pollutants persist within the surroundings, disrupting ecological stability and posing significant fitness dangers to people and wildlife. Conventional control technologies, such as chemical remediation and biological filtration, often create secondary pollutants or are too costly. Thus, this calls for advanced and environment-friendly measures of controlling environmental infection effectively (WHO, 2021).

Green nanotechnology represents a paradigm shift in materials science, focusing on environmentally friendly methods for the design and manufacture of nanomaterials. In contrast to the traditional method, green nanotechnology makes use of natural and renewable resources to decrease toxic waste and energy consumption. This approach is consistent with the principles of sustainable development, focuses on the reduction of environmental impact for better performance in applications such as pollution control, renewable energy, biomedicine etc. Green nanotech harnessing biogenic materials like plant extracts, sea sugars Synthesis of nanoparticles with high efficiency, low cost and biologically few steps some provide the path (Khan *et al.*, 2019).

Renewable Seaweedas received considerable attention in green nanotechnology due to its complex biochemical composition including polysaccharides, proteins and phenolic compounds. These bioactive molecules act as natural reducing agents and stabilize the nanoparticle synthesis, eliminating the need for harmful chemicals Nanoparticles from marine wastes are biocompatible, biodegradable, and exhibit improved catalytic antimicrobial and adsorption properties. Their potential applications in pollution control include removal of heavy metals from wastewater, decontamination of organic pollutants, reduction of greenhouse gases This non-productive approach this environment not only addresses pollution but also encourages the sustainable use of marine resources (Bhuyar*et al.*, 2021).

PROPERTIES OF SEAWEED-DERIVED NANOPARTICLES

Seaweed-derived nanoparticles (SBNPs) have a high surface area-to-volume ratio, which greatly enhances their reactivity and adsorption capacity This property is especially useful for environmental applications such as pollutant adsorption and catalyst degradation. Furthermore, nanoparticles exhibit exceptional stability under different environmental conditions, including changes in temperature, pH, and salinity The stability of SBNPs is attributed to the formation of bioactive compounds from sea acid act as natural capping agents, preventing nanoparticle aggregation Features include water purification, soil prevention, and applications to atmospheric pollution a combating in improves the effectiveness of SBNPs (Das *et al.*, 2020)

Bioactive compounds such as polysaccharides, proteins, phenolic compounds, flavonoids present in seaweeds play an important role in improving the activity of SBNPs These compounds act as natural reducing agents and stabilizers in nanoparticle synthesis process, and exerts antioxidant, antimicrobial, catalytic activity Special properties are obtained The bioactive compounds facilitate the selection of metals heavy adsorption and degradation of organic pollutants, enabling SBNP to be versatile in dealing with many environmental pollutants (Sargassum and Arockiam, 2019).

SBNPs are inherently biodegradable, as a result of their organic starting place and the absence of poisonous synthetic chemicals of their manufacturing. Their eco-friendly nature is further bolstered by means of their non-toxic degradation merchandise, which can be effectively assimilated into the surroundings without causing harm to ecosystems. This belonging addresses the growing issue about nanoparticle patience in the environment and guarantees that SBNPs align with the concepts of green and sustainable nanotechnology. The biodegradability of SBNPs also reduces the capacity

for long-time period ecological affects, making them a promising candidate for pollution manipulate applications (Rizwan *et al.,* 2018)

WATER PURIFICATION

Seaweed-derived nanoparticles (SBNPs) are extraordinarily effective in adsorbing and eliminating heavy metals which include lead, mercury, and cadmium from wastewater. The bioactive compounds in SBNPs offer useful agencies like hydroxyl, carboxyl, and amino corporations, which bind to heavy metals, forming strong complexes. This mechanism not simplest eliminates toxic metals but additionally prevents their re-entry into the environment, making sure long-term water excellent improvement. Industrial effluents often comprise dangerous dyes which can be resistant to conventional treatment methods. SBNPs exhibit awesome catalytic interest, breaking down these dyes into much less toxic compounds thru superior oxidation methods. This functionality makes them precious for industries which includes textiles, in which dye pollutants poses enormous environmental demanding situations (Kuppusamy *et al.,* 2016).

AIR POLLUTION MITIGATION

SBNPs have also demonstrated some potential in the degradation of VOCs, which is a very significant source of air pollution. The breakdown of VOCs into harmless by-products, such as carbon dioxide and water, catalyzed by SBNPs makes them a very promising route for the reduction of harmful air pollutants that affect respiratory health and smog formation. Advanced air filtration systems would thus find it ideal to include SBNPs with their high surface area and catalytic efficiency. These systems can capture and neutralize pollutants, thereby enhancing indoor and outdoor air quality. Efforts are under way to include SBNPs in inexpensive and durable air purification technologies (Khan *et al.,* 2020).

SOIL POLLUTION REMEDIATION

SBNPs have proven effective in absorbing pesticides, herbicides, and other toxic residues in contaminated soils. These nanoparticles bind to these pollutants and reduce their bioavailability and toxicity, ensuring crop health and microorganisms within the soil. In addition to detoxifying soil, SBNPs can also be used to enhance the health of the soil through their ability to break down toxic residues into less harmful products. This two-fold effect not only helps prevent pollution but also ensures that an ecosystem is created to sustain healthy agriculture and biodiversity (Annamalai and Nallamuthu, 2018).

Seaweed-derived nanoparticles, for instance, have proven real-world applications. Cadmium and lead removals from industrial wastewater in India using SBNPs that were synthesized from *Sargassum wightii*resulted in over 90% removal efficiency, surpassing the efficiency of many treatments and remaining eco-friendly with minimal costs. In other studies, SBNPs have been used in the treatment plants of textile industries for the degradation of dyes, consequently lowering the toxicity of released effluent into the water systems. In contrast to conventional methods like chemical precipitation and activated carbon adsorption, SBNPs exhibit an advantage in the aspects of reusability, low energy input, and secondary pollution. Comparatively, conventional methods, especially chemical precipitation and activated carbon adsorption, are based on hazardous

chemicals or costly equipment, whereas SBNPs present a greener alternative without compromising efficiency (Kumar *et al.,* 2022)

FUTURE DIRECTIONS

The future research work should include integration of SBNPs with the conventional pollution controlling technologies, including advanced filtration systems and bioreactors, to increase their utilization and enhance efficiency and scale of environmental remediation activities. The primary challenge faced by SBNPs lies in the scalability of mass production without a compromise in quality and eco-friendliness. Development of cheap synthesis methods for SBNPs is essential that remain rich in their bioactivities similar to the parent algae. Pilot-scale projects and collaborations with industries can make large-scale deployment possible. The integration of SBNPs into circular economy models opens up exciting possibilities for transforming waste into valuable resources. For instance, seaweed biomass from aquaculture or coastal cleanup initiatives can be repurposed for nanoparticle synthesis, creating a sustainable cycle of resource utilization. This aligns with global efforts to reduce waste and promote green innovation (Singh *et al.,* 2021; Wang *et al.,* 2021)

CONCLUSION

Nanoparticles derived from seaweed offer a clean and efficient solution for eliminating pollution. Their environmental friendliness and multifunctional properties make them a promising alternative to traditional methods, contributing to cleaner ecosystems and a healthier planet.

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Chapter

13

QUALITATIVE ANALYSIS OF SECONDARY METABOLITES PRESENT IN LEAF EXTRACTION OF SELECTED MEDICINAL PLANTS AND COMPARATIVE STUDY OF THEIR ANTIBACTERIAL ACTIVITIES

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ABSTRACT

Secondary metabolites, such as alkaloids, flavonoids, and tannins, play a crucial role in the medicinal properties of plants. These bioactive compounds exhibit significant therapeutic potential by targeting various biological pathways. This study focuses on the qualitative analysis of secondary metabolites present in the leaf extracts of selected medicinal plants and compares their antibacterial activities. The research involves the extraction of bioactive compounds using standard procedures, followed by phytochemical screening to identify the presence of alkaloids, flavonoids, tannins, saponins, and other metabolites. The antibacterial activities of the extracts are evaluated against selected pathogenic bacterial strains using methods such as the disc diffusion assay. Comparative analysis highlights the variations in metabolite composition, providing insights into their antimicrobial efficacy. This approach underscores the practical applications of identifying potent metabolites for therapeutic use. The findings provide insights into the potential use of these plants in the development of natural antibacterial agents, paving the way for alternative therapies and contributing to the understanding of plant-based medicinal compounds.

KEYWORDS: Secondary Metabolites, Phytochemicals, Medicinal Plants, Antimicrobial Activity.

INTRODUCTION

Secondary metabolites are natural compounds found in plants that exhibit a range of biological activities and health benefits. These compounds, also referred to as phytochemicals, are not directly involved in plant growth and development. Instead, they play vital roles in defense mechanisms against herbivores, pathogens, and environmental stress. Essential bioactive chemicals found in plants include alkaloids, flavonoids, tannins, and phenolic compounds. *(Tungmunnithum D et al., 2018*). Over 13,000 secondary metabolites have been isolated from medicinal plants. These metabolites function as defense molecules or carry out specialized roles within plants, and many of them possess medicinal properties (Shehadeh *et al.,* 2021) (Niaz *et al.,* 2021). Examples of secondary metabolites include alkaloids, flavonoids, saponins, phenols, glycosides, and tannins, all of which have found applications in traditional medicine, agriculture, and pharmaceuticals.

Types of Phytochemicals

Alkaloids: These compounds have medicinal properties and protect plants from herbivores.

Flavonoids: Found in fruits and vegetables, flavonoids exhibit antioxidant and anti- inflammatory properties.

Saponins: Commonly found in legumes, saponins reduce cholesterol and cancer risks

Phenols: Present in many plants, phenols a reused in flavorings and fragrances.

Glycosides: Medicinally significant compounds, including cardiac glycosides, found in plants.

Tannins: Found in tea and wine, tannins have anti-inflammatory and anticancer properties but can interfere with nutrient absorption.

Bacteria

Bacteria are small, single-celled organisms that are vital to Earth's ecosystems. However, pathogenic bacteria, such as *Staphylococcus aureus*, can cause infections ranging from minor skin conditions to severe diseases like pneumonia and sepsis. (A.S. Naidu 2018). The overuse of synthetic antibacterial agents has led to the alarming rise of antibiotic-resistant bacteria, with the World Health Organization estimating that drug-resistant infections could cause 10 million deaths annually by 2050. This underscores the urgent need for natural alternatives like plant extracts.

Inoculum of Bacteria

In this study, the pathogenic bacterium *Staphylococcus aureus* was used to evaluate the antibacterial properties of the selected plant extracts. *S. Aureus* is known for its ability to form biofilms and develop antibiotic resistance, making it a challenging pathogen to treat.

SelectedMedicinalPlants

The plants selected for this study include:

- Amla (*Phyllanthus emblica* Linn.)
- Jamun (*Syzygium cumini L.*)
- Neem (*Azadirachta indica* A.Juss.)
- Tulsi (*Ocimum sanctumL*)
- Moringa (*Moringa oleifera* Lam.)
- Guava (*Psidium guajava L.*)
- Papaya (*Carica papaya L.*)
- Mint (*Mentha piperita L.*)
- Betel (*Piper betle L.*)
- Tinospora (*Tinospora cordifolia* (Thunb.) Miers)

METHODOLOGY

Sample Collection

Fresh leaves from the selected plants were collected from various locations in southern India and stored in sterile bags under cool conditions for further processing.

Preparation of Solvent Extraction

The collected leaves were dried, ground in to a fine powder, and extracted using ethanol and distilled water. The extracts were filtered and diluted to achieve a final concentration of 1 mg/ml.

Qualitative Analysis Tests

Flavonoids: Tested with concentrated sulfuric acid (H_2SO_4). Orange color indicates presence.

Alkaloids: Tested with Wagner's reagent. Reddish-brown precipitate indicates presence.

Tannins: Tested with ferric chloride. Blue-black or green colour indicates presence.

Saponins: Persistent froth upon shaking indicates presence.

Glycosides: Brick-red precipitate with Fehling's solution indicates presence.

Phenols: Deep blue or black colour with ferric chloride indicates presence.

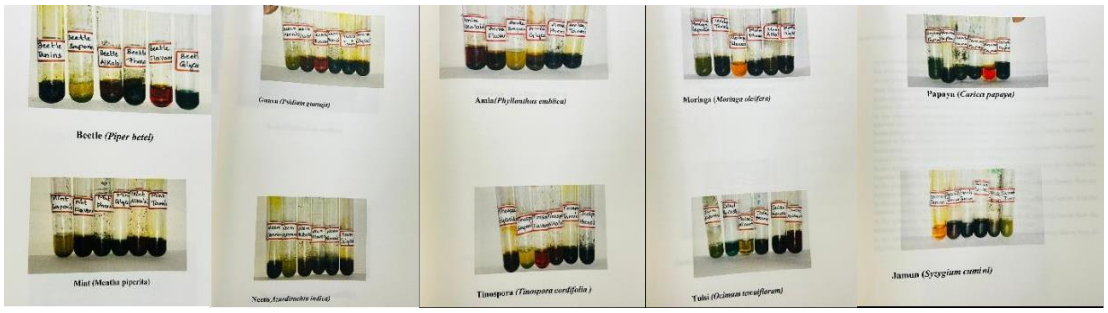

Fig 1: Qualitative Analysis

Antibacterial Screening

The antibacterial activity of the plant extracts was evaluated using the agar well diffusion method. Muller Hinton agar was prepared, and bacterial inoculum was spread onto the plates. Wells were filled with ethanolic and aqueous extracts, and the plates were incubated at 37°C for 24 hours. Zones of inhibition were measured to assess antibacterial activity, as larger zones generally indicate greater effectiveness of the extracts in inhibiting bacterial growth.

RESULTS AND DISCUSSION

PhytochemicalAnalysis

The presence or absence of phytochemicals was evaluated using qualitative analysis of leaves from selected medicinal plants. The results are provided in Table I.

Table 1: phytochemicals was evaluated using qualitative analysis of leaves from selected medicinal plants

S. No	Name of the plant Extract	Clearance of zone ethanol	Aqueous
1	Guava (*Psidium gujava)*	11mm	5mm
2	Papaya (*Carcina papaya)*	12mm	6mm
3	Jamun *(Syzygium cumin)*	8mm	8mm
4	Amla (*Phyllanthanus emblica)*	13mm	4mm
5	Neem (*Azardiatica indica)*	11mm	7mm
6	Tinospora (*Tinospora cordifolia)*	24mm	4mm
7	Mint *(Mentha piperitia)*	7mm	4mm
8	Moringa *(Moringa oleifera)*	10mm	-
9	Tulsi *(Ocimum sanctum)*	12mm	6mm
10	Betle *(Piper betle*)	9mm	6mm

Alkaloids: Detected in all plants.

Tannins: Present in most plants, absent in Moringa and Neem.

Saponins: Found in all plants.

Glycosides: Present in Jamun, Papaya, Guava, Neem, Moringa, Tinospora, and Amla; absent in Mint, Betel, and Tulsi.

Flavonoids: Detected in all plants.

Phenols:FoundinNeem,Papaya,Guava,Moringa,andBetel;absentinJamunand Mint.

AntibacterialActivity

- Aqueous extracts (Amla, Papaya, Tulsi and Jamun) showed larger zones of inhibition

Compared to ethanolic extracts.

- Neem and Moringa exhibited significant antibacterial activity in ethanolic extracts.
- The effectiveness varied based on the plant species and solvent used.
- The antibacterial activities of selected medicinal plants are provided in Table II.

Table 2: The antibacterial activities of selected medicinal plants

S.No	Name of the plant Extract	Alkaloids	Flavonoids	Tannins	Saponins	Glycolysids	Phenols
1	Jamun (*Syzygium cumin)*	+	+	+	+	+	-
2	Neem (*Azadirachta indica)*	+	+	-	+	+	+
3	Papaya (*Carica papaya)*	+	+	+	+	+	+
4	Guvava (*Psidium gujava)*	+	+	+	+	+	+
5	Mint (*Mentha piperitia)*	+	+	+	+	-	-
6	Moringa *(Moringa oleifera)*	+	+	-	+	+	+
7	Betel *(Piper betle)*	+	+	+	+	-	+
8	Tinospora (*Tinospora cordifolia)*	+	+	+	+	+	+
9	Tulsi *(Ocimum sanctum)*	-	+	+	-	-	+
10	Amla (*Phyllanthus emblica)*	+	+	+	+	+	+

Graphical Representation (Antibacterial Properties)

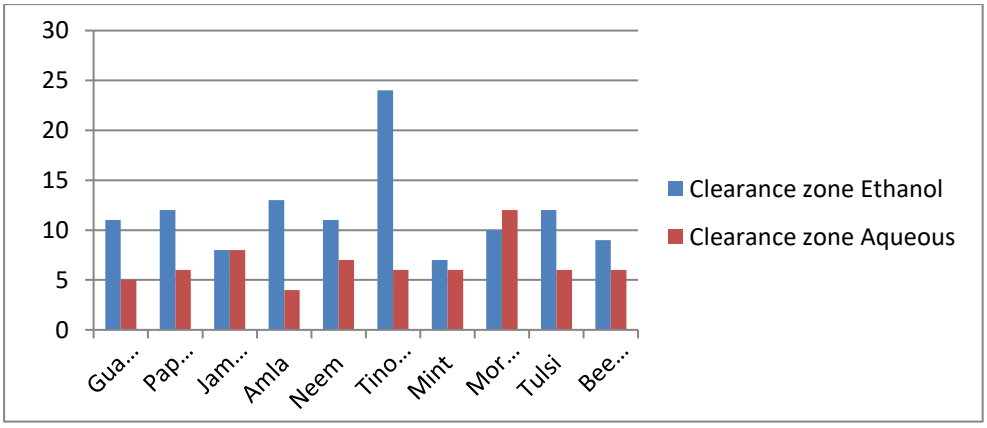

Fig 1: Antibacterial Properties

CONCLUSION

This study highlights the diverse phytochemical composition of medicinal plants and their antibacterial potential, particularly emphasizing the strong antibacterial activity of Neem and Moringa ethanolic extracts, as well as the significant inhibition zones observed with aqueous extracts from Amla, Papaya, Tulsi, and Jamun. The findings suggest that plant-based secondary metabolites can serve as natural antibacterial agents, offering a sustainable alternative to synthetic antibiotics.

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Chapter 14

UNMASKING OPPORTUNISTIC BACTERIA THROUGH COLOR PIGMENTATION

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ABSTRACT

Gram-negative bacteria such as *Serratia marcescens* and *Chromobacterium violaceum* are predominantly found in soil and the surrounding environment. These bacteria are known to be opportunistic pathogens, causing occasional infections in humans. Their main targets are immunocompromised patients who are hospitalized, resulting in hospital-acquired infections.

KEYWORDS: GNB, *Serratia marcescens, Chromobacterium violaceum,* Color Pigmentation.

INTRODUCTION

SERRATIA MARCESCENS

Serratia marcescens is a type of rod-shaped, Gram-negative bacteria belonging to the Yersiniaceae family [1]. This bacteria is capable of surviving with or without oxygen and can cause infections in humans as an opportunistic pathogen. *S. marcescens* is frequently associated with hospital-acquired infections (HAIs), known as nosocomial infections, such as catheter-related bacteremia, urinary tract infections, and wound infections [2,3].

IDENTIFICATION

S. marcescens is a motile organism capable of flourishing in temperatures ranging from 5 to 40 °C and pH levels ranging from 5 to 9. Its unique feature among Gram-negative bacteria lies in its ability to conduct casein hydrolysis, resulting in the production of extracellular metalloproteinases that are thought to be involved in cell-to-extracellular matrix interactions. On blood agar non hemolytic translucent red pigmented colonies were seen and on MacConkey agar it shows red pigmented non lactose fermented moist colonies shown in Figure 1.

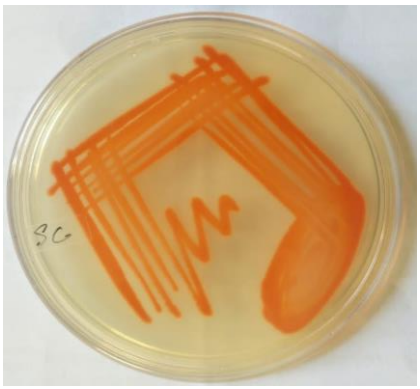

Fig 1: *Serratia marcescens* growth on Nutrient agar

CHROMOBACTERIUM VIOLACEUM

Chromobacterium violaceum is a Gram-negative coccobacillus, facultative anaerobic and non-sporing bacteria. It has single flagellum situated at the pole of the coccobacillus, and typically has one or two additional lateral flagella [4]. This bacteria is commonly found in the water and soil of tropical and sub-tropical areas. Additionally, it generates a natural antibiotic known as violacein, which could potentially be beneficial in treating colon and other types of cancers [5].

IDENTIFICATION

It thrives easily on nutrient agar, forming unique smooth slightly raised colonies with a noticeable dark violet metallic shine (caused by the production of violacein) shown in Figure 2.

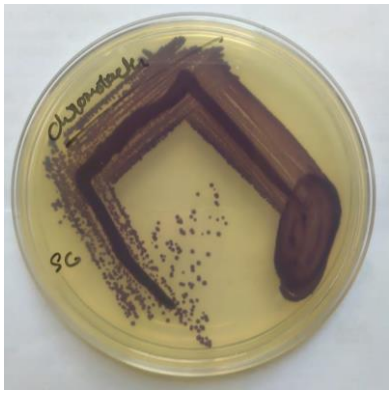

Fig 2: *Chromobacterium violaceum* growth on Nutrient agar

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Chapter 15

ENVIRONMENTAL IMPACTS OF PHARMACEUTICAL MANUFACTURING

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ABSTRACT

Pharmaceutical manufacturing is crucial for global healthcare but presents significant environmental challenges. This chapter explores the environmental impacts associated with pharmaceutical production, including waste generation, water contamination, air emissions, and soil pollution. Pharmaceutical waste often contains active pharmaceutical ingredients (APIs) and other toxic chemicals that persist in ecosystems, leading to adverse ecological effects and public health risks. Wastewater from manufacturing plants, carrying unmetabolized drugs, contributes to the accumulation of pharmaceutical residues in water bodies, impacting aquatic organisms and promoting antimicrobial resistance. Air emissions from production facilities contribute to greenhouse gas emissions, while soil contamination from pharmaceutical disposal affects soil health and agricultural productivity.

The chapter also discusses regulatory frameworks, including guidelines from the U.S. Environmental Protection Agency (EPA) and European Medicines Agency (EMA), aimed at mitigating environmental risks. Furthermore, it highlights green chemistry approaches, such as biocatalysis and the use of eco-friendly solvents that offer sustainable alternatives for reducing the environmental footprint of pharmaceutical production. Future research directions include advancing waste treatment technologies, improving environmental risk assessments, and promoting international collaboration for stronger regulations. Emphasis is placed on the importance of sustainable manufacturing practices to ensure environmental protection and public health safety.

KEYWORDS: Pharmaceutical Manufacturing, Environmental Impact, Waste Management.

INTRODUCTION

PHARMACEUTICAL MANUFACTURING AND ENVIRONMENTAL CONCERNS

Pharmaceutical manufacturing encompasses various stages of production, from raw material acquisition to the development of final products like drugs, vaccines, and biologics. The industry is essential in meeting global healthcare needs, yet it presents significant environmental challenges. Environmental concerns associated with pharmaceutical manufacturing are diverse and impact water, air, soil, and biodiversity. They are particularly critical given that pharmaceutical compounds are designed to have specific biochemical effects, which mean their unintended release into the environment can affect non-target organisms.

This industry's environmental footprint can be attributed to high energy consumption, extensive water use, and substantial waste generation. For example, pollutants from pharmaceutical plants an

end up in ecosystems, causing long-term harm to wildlife and water bodies (Azzouz *et al.,* 2019). Regulatory frameworks, such as those enforced by the U.S. Environmental Protection Agency (EPA) and the European Medicines Agency (EMA), are evolving to ensure sustainable manufacturing practices that address these concerns.

WASTE GENERATION IN PHARMACEUTICAL MANUFACTURING

Pharmaceutical manufacturing produces significant waste, including chemical solvents, active pharmaceutical ingredients (APIs), and by-products. Waste generation is particularly prominent during the synthesis and formulation stages. Organic solvents, used widely in drug synthesis, contribute a large proportion of hazardous waste in pharmaceutical manufacturing (EPA, 2022).

Waste management within the industry often involves methods like incineration, which, while effective, can contribute to air pollution. Alternatively, treatment and recycling methods are employed to reduce waste, though their efficacy varies. Studies suggest that process optimization, green chemistry principles, and alternative solvent usage can minimize waste generation without compromising product quality (Sheldon, 2017). The industry faces challenges in balancing cost-efficiency with environmentally sound practices, particularly in resource-constrained settings.

PHARMACEUTICAL RESIDUES IN WATER BODIES

Pharmaceutical residues in water bodies have emerged as a global environmental concern. These residues enter water systems through manufacturing effluents, improper disposal, and even human excretion, which pass unmetabolized drugs into sewage systems. Conventional wastewater treatment plants are often not equipped to fully remove pharmaceuticals, resulting in the accumulation of compounds like antibiotics, hormones, and analgesics in rivers, lakes, and oceans (Kümmerer *et al.,* 2018).

The ecological impact of pharmaceutical residues is profound, as they can affect aquatic species' reproductive and immune systems. Antibiotic residues, for example, contribute to antimicrobial resistance (AMR), an escalating global health crisis (WHO, 2020). Studies have shown that even trace amounts of pharmaceuticals can disrupt fish behavior, growth, and hormone regulation, leading to ecosystem imbalances (Boxall *et al.,* 2012). Consequently, advanced treatment techniques, such as ozonation and activated carbon filtration, are being explored to mitigate these effects.

AIR EMISSIONS AND CLIMATE CHANGE IMPACTS

Air emissions from pharmaceutical manufacturing include volatile organic compounds (VOCs), greenhouse gases (GHGs), and particulate matter. VOCs, emitted during various production stages, contribute to ground-level ozone formation, which can exacerbate respiratory issues in humans and wildlife (EPA, 2021). Moreover, greenhouse gas emissions from pharmaceutical companies contribute to climate change, highlighting the industry's need to adopt more sustainable practices.

The pharmaceutical industry has one of the highest carbon footprints per dollar of revenue among manufacturing sectors (Belkhir & Elmeligi, 2019). The implementation of cleaner technologies, renewable energy sources, and energy-efficient practices is necessary to reduce emissions. Regulatory bodies have begun encouraging companies to disclose and reduce their carbon footprints, aligning with international climate agreements such as the Paris Accord. However, the

transition to low-carbon processes remains challenging due to high costs and the technical demands of pharmaceutical production (UNEP, 2020).

LAND CONTAMINATION AND SOIL HEALTH

Land contamination from pharmaceutical manufacturing is another environmental concern, particularly in areas where waste disposal practices are inadequate. The improper disposal of solid pharmaceutical waste can lead to soil contamination, impacting soil health and agricultural productivity. Pharmaceuticals that persist in the soil, like antibiotics and endocrine disruptors, can interfere with soil microbiota, altering nutrient cycles and reducing soil fertility (Minden *et al.,* 2020). Pharmaceutical residues in soil can also affect plant growth and enter the food chain, posing risks to animal and human health. Recent studies have documented the bioaccumulation of certain pharmaceutical compounds in crops irrigated with contaminated water, raising concerns about food safety (Wu *et al.,* 2021). Sustainable waste disposal methods, such as bioremediation and phytoremediation, offer potential solutions, but more research is required to enhance their effectiveness and feasibility at scale (Chaturvedi *et al.,* 2019).

ECOLOGICAL AND HEALTH IMPLICATIONS OF PHARMACEUTICAL POLLUTION

Pharmaceutical pollution in the environment has significant ecological and health implications, affecting both wildlife and human populations. Pharmaceuticals are designed to elicit specific biological responses, and their presence in the environment can disrupt ecosystems and the physiology of non-target organisms. For instance, exposure to estrogenic compounds from pharmaceuticals can impair reproductive functions in fish and amphibians, leading to population imbalances (Nash *et al.,* 2004). Antidepressants, antibiotics, and analgesics have been detected in surface waters worldwide, raising concerns about their effects on aquatic life.

The presence of antibiotics in water bodies, even at low concentrations, accelerates the development of antimicrobial resistance (AMR), a global health threat (WHO, 2020). AMR reduces the efficacy of antibiotics, complicating the treatment of infections and increasing morbidity and mortality. Pharmaceutical pollutants can also affect soil health and crop quality when contaminated water is used for irrigation, leading to bioaccumulation of drug residues in edible plants (Christou *et al.,* 2017). In humans, these residues may contribute to endocrine disruption, allergies, and antibiotic resistance, although the long-term effects remain to be fully understood (Daughton & Ternes, 1999).

REGULATIONS AND POLICIES ADDRESSING ENVIRONMENTAL IMPACTS

To address the environmental impact of pharmaceutical pollution, various national and international regulatory frameworks have been established. Regulatory agencies, including the U.S. Environmental Protection Agency (EPA) and the European Medicines Agency (EMA), enforce policies to limit the release of pharmaceuticals into the environment. The EU Water Framework Directive, for example, lists priority substances, including certain pharmaceuticals, which must be monitored and controlled to protect aquatic ecosystems (European Commission, 2015).

In addition, the Pharmaceutical Management for the Environment (PME) initiative by the International Pharmaceutical Federation promotes sustainable practices in manufacturing and waste management. The U.S. Food and Drug Administration (FDA) and the EMA have established

guidelines for environmental risk assessments (ERAs) that require pharmaceutical companies to evaluate potential environmental impacts before product approval (FDA, 2022). Despite these efforts, there is still a need for standardized global policies, as existing regulations are fragmented and vary widely across regions (Boxall *et al.,* 2012). Strengthening international cooperation and enforcing stricter standards can enhance the effectiveness of these policies.

GREEN CHEMISTRY AND SUSTAINABLE SOLUTIONS

Green chemistry principles offer promising approaches to reduce the environmental impact of pharmaceutical manufacturing. Green chemistry seeks to minimize or eliminate hazardous substances in chemical processes, aiming for safer, more efficient, and sustainable production methods (Anastas & Warner, 1998). In pharmaceutical manufacturing, this involves reducing solvent use, employing safer reagents, and optimizing synthesis routes to minimize waste.

One effective strategy is the use of biocatalysis, which employs enzymes as catalysts, resulting in fewer toxic by-products and reduced energy consumption (Sheldon, 2016). Alternative solvents, such as water and ionic liquids, are increasingly being adopted to replace traditional organic solvents that are hazardous to the environment. Furthermore, companies are developing "benign-by-design" drugs that degrade quickly in the environment, reducing their ecological persistence (Sanderson *et al.,* 2004).

The adoption of circular economy principles can also promote sustainable pharmaceutical manufacturing. Waste from one stage of production can be repurposed or recycled for other uses, reducing overall resource consumption and waste. Collaborative efforts between industry and academia have led to innovations in green chemistry, exemplified by the ACS Green Chemistry Institute's Pharmaceutical Roundtable, which focuses on developing greener synthetic processes (Green Chemistry Institute, 2021). These approaches not only mitigate environmental impacts but also enhance cost-effectiveness and efficiency in pharmaceutical production.

FUTURE DIRECTIONS AND RESEARCH NEEDS

Future research is essential to address the gaps in understanding the long-term impacts of pharmaceutical pollution and to develop more sustainable solutions. Emerging contaminants, including new pharmaceutical compounds and their metabolites, require further study to assess their ecological effects accurately. There is also a pressing need for more sensitive analytical methods to detect pharmaceuticals at low concentrations, as current techniques may underestimate the prevalence of these contaminants in the environment (Petrović *et al.,* 2005).

Advances in biotechnology and nanotechnology could offer innovative solutions to tackle pharmaceutical pollution. For instance, nanomaterials can enhance wastewater treatment by targeting and degrading specific contaminants (Santos *et al.,* 2019). Bioremediation, which uses microorganisms to degrade pollutants, is another promising area, though challenges remain in scaling this approach for industrial use (Sharma *et al.,* 2020).

In addition to technological advancements, interdisciplinary research involving ecotoxicologists, chemists, and public health experts is crucial. This collaboration will help develop comprehensive risk assessment frameworks and create more resilient ecosystems. Educational initiatives that raise

awareness of proper drug disposal and responsible consumption can also reduce pharmaceutical pollution at the source (Gaw *et al.,* 2014). Ultimately, achieving sustainable pharmaceutical production and environmental protection will require ongoing research, regulatory support, and a commitment to green innovation.

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Chapter 16

LARVICIDAL AND OVICIDAL ACTIVITIES OF THE ESSENTIAL OILS AGAINST *AEDES AEGYPTI*

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ABSTRACT

The control of *Aedes aegypti*, the primary vector of diseases such as dengue, Zika, and chikungunya, has become a significant global health challenge. Chemical insecticides have been commonly used to combat these vectors, but concerns over resistance and environmental impact have prompted the search for alternative, eco-friendly solutions. This study evaluates the larvicidal and ovicidal activities of essential oils against *Aedes aegypti*. Essential oils from lemon balm and geranium were extracted and tested for their toxicity at different concentrations. Larvicidal activity was assessed by exposing larvae to various concentrations of the oils, while ovicidal activity was determined by assessing the mortality and hatching rate of eggs after exposure to the oils. Results showed that geranium oil exhibited significant larvicidal and ovicidal effects, with lemon balm oil demonstrating the highest efficacy at lower concentrations. The findings suggest that essential oils may serve as promising natural alternatives for controlling *Aedes aegypti* populations, offering a safer and more sustainable approach to vector management. Further studies are needed to determine the potential for field applications and the safety of these oils for non-target organisms.

KEYWORDS: *Aedes aegypti, L*arvicidal Activity, Ovicidal Activity, Essential Oils.

INTRODUCTION

Mosquitoes are nuisance pests and a major vector for the transmission of several life-threatening diseases such as malaria, dengue fever, yellow fever, filariasis, schistosomiasis, Japanese encephalitis, etc., causing millions of deaths every year (WHO, 2010). As reported by Peng *et al.,* (1999), mosquitoes can also trigger allergic reactions in humans, including systemic reactions such as angioedema and local skin reactions. The arbovirus that causes dengue fever, which is indigenous to Southeast Asia, the Pacific island region, Africa, and the Americas, is typically spread by the *Aedes aegypti* mosquito. Yellow fever is also spread by this mosquito in West Africa, Central America, and South America. As the number of cases recorded rises, dengue fever has emerged as a significant public health concern, particularly with more severe forms of the disease, such as dengue hemorrhagic fever or dengue shock syndrome, or with unusual symptoms such as involvement in the central nervous system (Pancharoen *et al.,* 2002). Malaria is still one of the most common diseases in the tropical world, and its principal vector in India and other West Asian nations is *An. stephensi*. Up to 2.7 million individuals perish from it every year, along with 200 million to 450 million illnesses (WHO, 2010).

Since there is currently no vaccine to prevent dengue, vector management will continue to be the main strategy. Reducing mosquito generation resources is thought to be the primary strategy for treating a number of serious vector diseases worldwide (Alyaha *et al.,* 2018). When effective methods have been implemented to target mosquitoes properly, they help save lives and protect the lives of millions. Nevertheless, vector control in general, and mosquitoes in particular, are still challenging. This is on top of the challenges posed by existing and recently identified ailments (Al-Hakimi *et al.,* 2022, WHO, 2000). Synthetic insecticides include pyrethroids, organophosphates, and growth regulators for insects, which are primarily responsible for larvicidal activity (Algamdi and Mahyoub, 2022). By using these insecticides, we can effectively control the pests, but their frequent use has become a danger to the biological ecosystems and thus the widespread development of resistance (Al-Hakimi *et al.,* 2022; Hedin *et al.,* 1997). In Jeddah, a campaign was organized to reduce mosquito breeding sources through health awareness from house to house, which was carried out by supervisors. However, the fact that dengue cases continue to occur indicates that attempts to raise awareness are inadequate for controlling the illness. This requires regular use of insecticides that are essential to controlling illness and vectors.

Utilizing ecologically friendly natural materials as a biological control agent for vector mosquitoes through physical and chemical means has become increasingly necessary in recent years (Barnawi *et al.,* 2019; Mahyoub, 2018; Mahyoub *et al.,* 2018). Using natural products avoids further deleterious effects on humans and resources (Al-Zahrani Mohamed *et al.,* 2019; Mahyoub, 2019). Moreover, the economic benefits of using, manufacturing, and applying any of the local wild plants as pesticidal agents are inexpensive compared to the harmful effects of chemicals, pollution, and radiation (Al-Hakimi *et al.,* 2022; Mahyoub Jazem, 2021). Recent studies demonstrated the fact that medicinal plants have a pesticidal effect on the *Ae. aegypti* mosquito-derived virus that causes dengue fever (Al-Rashidi *et al.,* 2022). However, research on the effects of essential oils on *Ae. aegypti* larvae has not been attempted in previously published papers. Thus, the purpose of this research is to assess the vulnerability of the *Ae. aegypti* larvae against essential oils such as lemon balm and geranium oil under laboratory conditions using the WHO larvicide bioassay technique (WHO, 1999); this study may be helpful in the future to manage mosquito populations.

MATERIAL AND METHODS

COLLECTION OF PLANT VOLATILE OILS

Two plant volatile oils, namely lemon balm and geranium, were purchased from an aromatic oil store in Chennai. The emulsifier was procured from a store in Chennai. All oils were kept in amber glass bottles and stored in dry places until used for bioassay experiments.

PREPARATION OF CONCENTRATIONS

Four different concentrations viz., 0.01, 0.02, 0.04, and 0.08% of each oil were prepared by mixing the required quantity of oil and 18% emulsifier with 100 ml of water taken in a plastic cup.

TEST MOSQUITOES

Eggs of *Aedes aegypti* mosquitoes were supplied by the Entomology Research Institute, Loyola College, Chennai. The egg cartons were put in water and taken in plastic basins. The hatched larvae

were maintained at 28±1°C, 70-75% RH, and 11±0.5 h photoperiod. A pinch of powder of dog biscuit and yeast mixture was sprinkled on the water surface where the newly hatched larvae were kept. Third-instar larvae were used for bioassay experiments.

OVICIDAL ASSAY

The ovicidal activity was studied following the method of Elango *et al.,* (2009). Twenty-five freshly laid eggs of *Ae. aegypti* were separately exposed to four different concentrations viz., 0.01, 0.02, 0.04, and 0.08%. Each concentration was replicated three times. Emulsifier control and water control were also maintained separately, and egg hatchability was observed after two days. The percent hatchability was assessed up to a period of 120 h post-treatment using the following formula:

Percent ovicidal activity:

$$\frac{\text{Number of uncatched eggs}}{\text{Total number of eggs introduced}} \text{x } 100$$

LARVICIDAL ACTIVITY EXPERIMENTS

The larvicidal activity was evaluated using the method prescribed by WHO (2005) with slight modifications. Test concentrations viz., 0.01, 0.02, 0.04, and 0.08% were prepared, and three replicates were maintained for each concentration. Groups of 5 third instar larvae of *Ae. aegypti* were used in each replication. Water control and emulsifier control were maintained as mentioned in the above ovicidal activity experiment. The dead larvae were recorded after a 24 h exposure period. When larvae failed to rise to the surface or react to stimuli, they were deemed dead. The percent mortality was calculated for each replication of each concentration using the following formula:

$$\frac{\text{Number of dead larvae}}{\text{Total number of larvae introduced}} \text{x } 100$$

Abbott's formula (Abbott, 1925) was used to get corrected percent mortality when control mortality was below 5%:

Corrected percentage of mortality: (1 – n) in Treatment/n in Control x 100

STATISTICAL ANALYSIS

The mean values and standard deviations were calculated from three replications. One-way Analysis of Variance (ANOVA) was used to find out the significance of the treatments, and the mean values were separated by Tukey's multiple comparison test. The lethal concentration values of LC50 were calculated using EPA probit analysis (version 1.5).

RESULT AND DISCUSSION

The current study examined the larvicidal efficacy of lemon balm oil and geranium oil against *Anopheles aegypti* mosquito larvae. As the concentration of the plant oil increases, the total larval mortality of the mosquitoes was also found to be increased. In the present study, when the *Aedes aegypti* larvae were examined and presented in Tables 1, 2, 3 & 4. The highest larval mortality was observed in lemon balm oil than geranium oil. The findings indicate a dose-dependent death rate, as shown in Table 1to 4. There was a significantly substantial death rate at the highest extract concentration.

The mode of action of essential oils was investigated by Corbet *et al.,* and revealed how easily surface products can enter the tracheal system of mosquito larvae and pupae. Additionally, he noted that the essential oils exacerbated the risk of chemical toxicity and tracheal flooding.

Suryanarayanamurthy *et al.,* in their study reported that pupal death might be due to multiple mechanisms of action, including the oil blocking the molting of pupae to adults.

In this study, the concentration of essential oil also played a crucial role in the effectiveness of ovicidal activity. The highest cumulative mortality was observed in the highest concentration of the plant oil formulation. Broadbent and Prec (1984) reported more entry of the chemical inside the eggshell when eggs were directly exposed to higher concentrations of the compounds, which affected embryogenesis. Similarly, longer exposure periods also facilitated the increased penetration of the compounds into the shell, thus increasing their effectiveness. Therefore, the current study 49 indicated that the ovicidal activity of the plant oil formulation against the egg rafts of *Aedes* depends upon three key factors, viz., concentrations of the plant oil formulation, age of egg rafts, and period of exposure. The eggs of mosquitoes are found to be much more tolerant to the action of insecticides compared to the larval stages.

Focusing on mosquito reduction efforts in the larval stage has the advantage of controlling the vector before dispersal or acquisition of the disease and interrupting the life cycle before it can cause harm (Hardin and Jackson, 2009). A successful method for diminishing mosquito populations in their habitats of reproduction before they mature into adults is larviciding (Tiwary *et al.,* 2007). The advantage of targeting larvae is that they cannot escape from their breeding sites until the adult stage. The control of mosquitoes at the larval stage is necessary and efficient in integrated mosquito management since, during the immature stage, mosquitoes are relatively immobile (Elimam *et al.,* 2009), and mosquitoes in the larval stage are attractive targets for insecticides because mosquitoes breed in water, and thus, it is easy to deal with them in this habitat.

One of the successful strategies for mosquito control is focused on targeting breeding sites of mosquitoes to regulate their population density (Gubler, 1989). Oviposition is one of the most important events in the life cycle of mosquitoes. If oviposition is prevented, the mosquito life cycle is disrupted, and population growth is reduced (Xue *et al.,* 2001). By detecting chemical signals that are picked up by sensory receptors on the antenna, mosquitoes are able to choose or reject particular oviposition sites (Davis & Bowen, 1994).

The present study has identified plant oils showing ovicidal and larvicidal activity against *Ae. aegypti,* and the obtained results suggest that the plant oils are promising as ovicides and larvicides against *Ae. Aegypti* larvae. Lemon balm oil was found to be the potent larvicide against *Aedes aegypti*, providing a promising mortality rate. Our outcomes demonstrated that the chemical composition oflemon balm oil and geranium oil has noteworthy larvicidal and ovicidal repellent actions against *Aedes aegypti*. Furthermore, the eggs of mosquitoes are found to be much more tolerant to the action of insecticides compared to the larval stage. Mosquito eggshells are hardened, and studies conducted on freshly laid eggs were limited (Chenniappan & Kadarkarai, 2008). Insect eggs are covered with a shell, which differs biochemically from the integument of the larvae, and the difference in penetration of the insecticide through the eggshell (Kuppusamy & Murgan, 2009).

The results of the present study are interesting. It is evident from the present data that the exposure of mosquito eggs to the plant oil formulation elicits not only egg mortality but also delayed effects

resulting in mortality at larval stages. Though the percentage of ovicidal activity is moderate, an important finding is that the larvae that hatched out of the treated eggs immediately succumbed to death. Exposure of freshly laid eggs to the plant oil 50 formulations was more effective than the older eggs. Miura *et al.,* (1976) showed that the age of embryos at the time of treatment played a crucial role in the effectiveness of the chitin synthesis inhibitor.

Exposure time also has a vital role in causing toxicity. According to Smith and Salkeld (1966), differences in susceptibility to ovicides are due to differential rates of uptake, penetration through the chronicon, conversion to active inhibitor, detoxication, and failure of the toxic to reach the target. Elumalai *et al.,* (2004) observed that the efficacy of acting on the embryo inside the eggshell depends on an efficient penetration of the insecticide, which in turn is influenced by the exposure period. Plant oils may be of potential benefit for mosquito control since they have a rich source of bioactive compounds that may be biodegradable into nontoxic products and are potentially suitable for use in integrated management programs for mosquito control, as they have been observed to possess mosquito ovicidal and larvicidal properties. These essential oils can be used to develop herbal formulations with larvicidal and knockdown effects against vector mosquitoes.

Table 1: Mortality Rate of Ova (*Aedes aegypti)* at Different Geranium and Lemon Balm Oil Concentrations.

Concentration	Lemon balm oil	Geranium
0.01%	100	99
0.02%	100	100
0.04%	100	100
0.08%	100	100

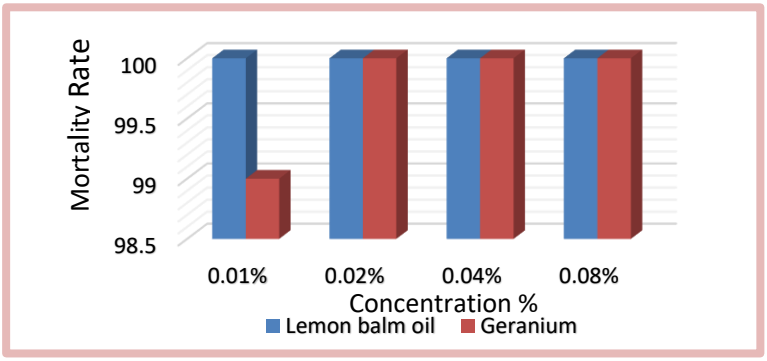

Fig 1: Mortality Rate of Ova (*Aedes aegypti)* at Different Geranium and Lemon Balm Oil Concentrations.

Table 2: Ovicidal activity of two essential oils against *Aedes aegypti* (Mean±SD)

Concentration	Lemon balm oil	Geranium
0.01%	100±0[a]	99.3±1.1 [a]
0.02%	100±0[a]	100±0[a]
0.04%	100±0[a]	100±0[a]
0.08%	100±0[a]	100±0[a]

Table 3: Mortality Rate of larvae (*Aedes aegypti)* at Different Geranium and Lemon Balm Oil Concentrations

Concentration	Lemon balm oil	Geranium
0.01%	2	0
0.02%	5	2
0.04%	5	5
0.08%	5	5

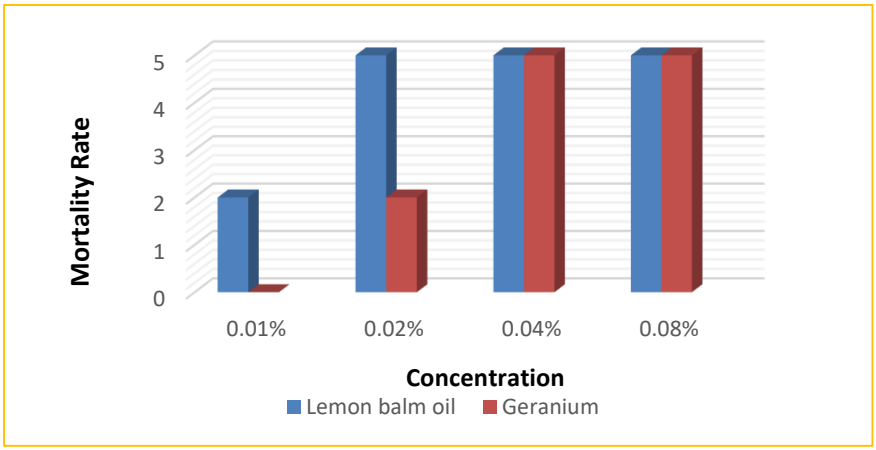

Fig 2: Mortality Rate of larvae (*Aedes aegypti)* at Different Geranium and Lemon Balm Oil Concentrations

Table 4: Larvicidal activity of two essential oils against *Aedes aegypti* (Mean±SD)

Concentration	Lemon balm oil	Geranium
0.01%	40 ± 20^{a}	0^{d}
0.02%	100 ± 0^{a}	40 ± 20^{c}
0.04%	100 ± 0^{a}	93.3±11.5
0.08%	100 ± 0^{a}	100 ± 0^{a}

CONCLUSION

The ovicidal activity is tested, and from the obtained data, we concluded that the oils are not very effective when we treat the ova with lower concentrations such as 0.01 and 0.02. When the concentration increases, the mortality rate also gradually increases. When it is compared with the larvicidal activity at lower concentrations, the minimum effects are noticed in the case of larvicidal responses. In our study, we noticed that lemon balm oil and geranium oil are much more effective than that and are the most promising ovicides and larvicides. In the present study, lemon balm oil and geranium oil were found to be the most potent treatment, as it killed a significantly high number of *Ae. aegypti* ova and larva, respectively. Furthermore, there was an adverse association between ovicidal actions and essential oil concentrations. As the concentration of essential oil increased, the hatching rate decreased. The hatching rates of *Ae. aegypti* eggs exposed to lemon balm oil and geranium oil were significantly equal.

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Chapter 17

RECENT TRENDS IN PHARMACEUTICAL CHEMISTRY

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ABSTRACT

The multidisciplinary field of pharmaceutical chemistry or medicinal chemistry is a branch of basic chemistry and life sciences that focuses on the principles and applications of natural, synthetic, computational, and analytical chemistry in the development of chemical therapeutics for the prevention and treatment of threatening diseases. One of the main fields of drug development that meets the growing need for novel therapeutic molecules for the efficient treatment of a wide range of illnesses and conditions is pharmaceutical chemistry. Pharmacology, pharmacokinetics, pharmacodynamics, and biological analysis are all included. The basic principle of pharmaceutical chemistry is drug discovery. All phases of drug development are included in the drug discovery process, from identifying a disease or medical condition to conducting toxicity tests on animals or, according to certain definitions, testing the medication on humans. Medicinal chemists plays a crucial role in the drug discovery process by designing and synthesizing compounds that produce structure–activity correlations and succeed efficacy and safety in preclinical animal testing.

KEYWORDS: Pharmaceutical Chemistry, Pharmacology, Drug Discovery

INTRODUCTION

Pharmaceutical Chemistry is the study of the molecular and mechanistic constituents of pharmaceuticals. Understanding biological processes and mechanism action mechanisms at the molecular level is essential to the creation of novel drugs. The design and synthesis of novel compounds employing techniques like structure-activity relationships, combinatorial chemistry, and computer-aided drug design are now essential to the field's advancement. The development and evaluation of therapeutic substances medicine design, drug synthesis, and the assessment of drug safety and efficacy are all tasks performed by pharmaceutical chemists.

ROLE OF PHARMACEUTICAL CHEMISTRY IN DRUG DISCOVERY:

Drug discovery is the core of pharmaceutical chemistry. All stages of drug development are included in the drug discovery process, from identifying the disease or medical condition to conducting toxicity tests on animals or, according to certain definitions, testing the drug on humans. Though working in a team, the modern medicinal chemist plays a particularly important role in the earliest phase of drug discovery. The chemist plays a crucial role in formulating the hypothesis for

the new drug project, which in turn establishes the project's goals. The chemist is trained to prepare novel compounds and has gained knowledge of the target disease and competing pharmacological therapies.

Additionally, the chemist assists in determining which current compounds should be screened for a lead compound and which screening hits require re-synthesis for biological analysis.

In order to maximize the intended activity, the chemist determines which similar compounds should be generated or obtained in order to explore the SARs for the structural family of compounds after identifying an in vitro "HIT."

Several significant new innovations that support the work of medicinal chemists today are in vitro toxicity screens, in vitro pharmacokinetic property screens, and the emphasis on generating drug-like molecules.

These include possessing a solid grasp of modern organic and pharmaceutical chemistry, comprehension of the biology underlying the target disease, familiarity with the pharmacological tests used during the project, and adequate knowledge of the variables influencing the ADME properties of chemicals in vivo. Additionally, they should be knowledgeable with clinical medicine relevant to the target disease, the regulatory requirements for corresponding pharmaceuticals, and the most recent competitive therapies, both on the market and being developed by competitors. An extensive knowledge of the literature pertaining to the disease of interest; knowledge of the numerous more recent technologies that are available to aid in drug discovery; and an attitude of entrepreneurship when acting as an inventor and innovator Furthermore, and perhaps most importantly for the project's timely completion, the chemist must exhibit excellent interpersonal skills throughout the project in order to collaborate with colleagues from various disciplines and accomplish project objectives. The function of the chemist has evolved in the modern period because to combinatorial chemistry, high-throughput screening, and molecularly defined targets that enables structure-based drug creation. More in vivo testing early in the process, enabling medicinal chemists to support their drug candidate throughout its development, and imparting the implicit knowledge of seasoned medicinal chemists to their subordinates are some ideas for enhancing the drug discovery process.

Pharmaceutical chemists produce and/or choose suitable compounds for biological testing that may be used as lead molecules if they are determined to be active. They then assess the safety and effectiveness of similar drugs' Structure Activity Relationships (SARs) both in vitro and in vivo. As members of interdisciplinary teams involved in drug discovery nowadays, medicinal chemists need to be knowledgeable in a variety of fields in addition to organic chemistry in order to anticipate issues and evaluate developments to advance the project.

CONCLUSION

The task of the pharmaceutical chemist in drug discovery has changed significantly during the past twenty-five years due to the introduction of technologies such as combinatorial chemistry and structure-based drug design. We address this evolving function with examples from our own and others' experiences as medicinal chemists with throughout 50 years of combined expertise during

the previous forty years or so. By assisting the medicinal chemist in reclaiming the creative role that led to previous achievements, this historical viewpoint may offer insights on how to enhance the current drug development strategy. Pharmaceutical chemists are key participants in the endeavour of developing safer, more effective, and more selective medications to treat diseases in humans

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Chapter
18

ENGINEERING ENZYMES FOR GREEN CHEMISTRY

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ABSTRACT

The transition towards sustainable and eco-friendly chemical processes has placed green chemistry at the forefront of modern science. Enzymes, as biocatalysts, offer unparalleled specificity, efficiency, and environmental compatibility, making them essential tools in this transition. Recent advancements in enzyme engineering, including rational design, directed evolution, and computational approaches, have enhanced their stability, activity, and substrate scope, enabling their application in green chemistry. This chapter explores the methodologies employed in engineering enzymes and their roles in industrial processes such as biotransformation, polymer synthesis, and carbon capture. Challenges, such as cost-effectiveness, scalability, and integration with existing processes, are also discussed. Finally, future perspectives on integrating artificial intelligence and machine learning in enzyme engineering are examined, offering a pathway toward more efficient and sustainable chemical processes.

KEYWORDS: Enzymes, Biocatalysts, Computational, Biotransformation.

INTRODUCTION

Green chemistry aims to reduce or eliminate hazardous substances in chemical production, emphasizing sustainability and environmental safety. Enzymes, owing to their biocompatibility and catalytic efficiency, have become pivotal in achieving green chemistry objectives. Their ability to catalyse reactions under mild conditions with high selectivity makes them an attractive alternative to traditional chemical catalysts, reducing energy consumption and waste generation. However, their natural limitations—such as narrow substrate range, sensitivity to reaction conditions, and limited stability—often necessitate engineering to meet industrial demands (Sheldon & Woodley, 2018). Advances in enzyme engineering, including directed evolution and rational design, have significantly broadened their applicability, enabling tailored properties that align with the principles of green chemistry. These advancements underline the transformative potential of enzymes in driving sustainable innovations across various industries. Furthermore, integrating computational tools with experimental techniques has accelerated the development of enzymes with enhanced performance, reducing the time and cost associated with enzyme optimization. As industries increasingly adopt enzyme-based processes, the role of engineered enzymes in creating eco-friendly and economically viable solutions continues to expand, solidifying their importance in the transition toward greener technologies.

APPROACHES TO ENZYME ENGINEERING

RATIONAL DESIGN

Rational design involves modifying enzyme structures based on their known 3D configurations to improve specific properties. For example, site-directed mutagenesis has been used to enhance enzyme thermostability, allowing their use in high-temperature processes (Tian *et al.,* 2019). Tools such as PyMOL and Rosetta have facilitated the prediction and modelling of structural changes for desired traits.

Rational design is a targeted approach in enzyme engineering where modifications are introduced into an enzyme's structure based on its known three-dimensional (3D) configuration. This method relies on a deep understanding of the enzyme's structure-function relationship, allowing scientists to predict how specific changes in the amino acid sequence will influence the enzyme's properties. The goal is to tailor the enzyme to exhibit improved or novel functionalities, such as enhanced stability, catalytic efficiency, substrate specificity, or resistance to inhibitors.

Rational design represents a powerful strategy for enzyme engineering, leveraging structural knowledge and computational tools to achieve targeted improvements. By enabling precise modifications, this approach continues to drive advancements in industrial biotechnology, pharmaceuticals, and environmental applications.

TOOLS FACILITATING RATIONAL DESIGN

PyMOL

PyMOL is a molecular visualization tool widely used for exploring enzyme 3D structures. It allows researchers to analyse key structural elements such as binding sites, secondary structure motifs, and interactions within the protein or with ligands. This helps identify target regions for mutagenesis.

Rosetta

Rosetta is a computational platform for protein modelling and design. It predicts the effects of mutations on protein stability and function, guiding the selection of beneficial modifications. By simulating the folding and energetics of modified structures, Rosetta reduces experimental trial-and-error efforts.

Homology Modelling and Molecular Docking

When high-resolution structures are unavailable, homology models based on similar enzymes can be generated. Docking studies then provide insights into substrate binding and catalysis.

DIRECTED EVOLUTION

Directed evolution is a powerful method in enzyme engineering that recreates the process of natural selection within the controlled environment of a laboratory (Arnold, 2018). This approach generates enzyme variants with desirable traits through iterative cycles of random mutagenesis, recombination, and selection or screening. Unlike rational design, which relies on detailed knowledge of enzyme structure and function, directed evolution requires only an enzyme's genetic sequence and a robust screening or selection method. This approach has been instrumental in developing enzymes with enhanced activity and tolerance for non-natural substrates, a key requirement in green chemistry applications.

Directed evolution has become a cornerstone of enzyme engineering, enabling the rapid and efficient development of enzymes for diverse applications. Its ability to mimic natural selection, combined with advances in high-throughput screening and molecular biology, continues to drive innovation in industrial biotechnology, green chemistry, and synthetic biology.

COMPUTATIONAL METHODS

Computational methods have revolutionized enzyme engineering, providing powerful tools to predict, analyse, and design enzyme-substrate interactions, catalytic activities, and structural modifications. Machine learning algorithms are increasingly employed to analyse large datasets, identify patterns, and predict optimal mutations (Yang *et al.,* 2020). These techniques leverage advances in molecular modelling, bioinformatics, and machine learning, allowing researchers to make precise modifications and develop enzymes with enhanced or novel functionalities.

Computational methods have become indispensable in enzyme engineering, bridging the gap between sequence and function. By integrating advanced modelling techniques, machine learning, and AI, these approaches enable the design of enzymes with enhanced performance, novel capabilities, and broad applicability in industries ranging from green chemistry to biotechnology. As computational tools continue to evolve, their synergy with experimental approaches promises to unlock unprecedented possibilities in enzyme design.

APPLICATIONS IN GREEN CHEMISTRY

BIOTRANSFORMATION

Engineered enzymes play a central role in biotransformation, replacing traditional chemical catalysts. For instance, lipases and oxidases are employed in synthesizing fine chemicals and pharmaceuticals, reducing waste and hazardous by-products (Bornscheuer *et al.,* 2012).

Biotransformation refers to the chemical modification of compounds by biological systems, typically using enzymes or whole cells. Engineered enzymes play a pivotal role in biotransformation, offering superior selectivity, efficiency, and sustainability compared to traditional chemical catalysts. Their ability to operate under mild reaction conditions reduces the need for harsh chemicals and extreme temperatures, thereby minimizing energy consumption and environmental impact. For instance, lipases and oxidases have been widely employed in synthesizing fine chemicals, agrochemicals, and pharmaceuticals, where their regio- and stereoselectivity allow precise modifications to complex molecules, often unattainable with conventional methods (Bornscheuer *et al.,* 2012). These biocatalysts not only enhance reaction efficiency but also significantly reduce the generation of hazardous by-products and waste.

Recent advancements in enzyme engineering, such as directed evolution and computational modelling, have further broadened the applicability of enzymes in biotransformation. For example, engineered lipases have been tailored for biodiesel production, while oxidases have been optimized for the synthesis of chiral drug intermediates. As the demand for sustainable and green chemistry solutions grows, biotransformation using engineered enzymes is increasingly recognized as a cornerstone of environmentally friendly and economically viable industrial processes.

POLYMER SYNTHESIS

The development of enzymes for polymer synthesis has enabled the production of biodegradable plastics and other sustainable materials. Enzymes like cutinases and PETases have been engineered for the depolymerization of plastics, contributing to waste management and recycling efforts (Tournier *et al.,* 2020).

Enzymes have revolutionized polymer synthesis by aiding the production of environmentally friendly materials, such as biodegradable plastics, and facilitating sustainable recycling practices. Traditional polymer synthesis often relies on petrochemical processes that produce significant waste and are difficult to recycle efficiently. In contrast, enzymes like lipases, cutinases, and PETases offer a biocatalytic approach that reduces the reliance on harsh chemicals and energy-intensive processes. These enzymes have been successfully used in synthesizing aliphatic polyesters, polylactic acid (PLA), and polyhydroxyalkanoates (PHA)—key materials in the development of biodegradable plastics.

Moreover, advancements in enzyme engineering have expanded their role in polymer recycling, particularly in tackling persistent plastics like polyethylene terephthalate (PET). For instance, PETases have been engineered to enhance their catalytic efficiency and thermostability, enabling the depolymerization of PET into its monomeric components, such as terephthalic acid and ethylene glycol, for reuse in new polymer synthesis (Tournier *et al.,* 2020). Similarly, cutinases have been optimized for breaking down synthetic polyesters, contributing to efficient waste management systems.

These enzymatic processes not only aid in creating a closed-loop recycling system but also mitigate environmental pollution by addressing the challenges posed by plastic waste accumulation. The integration of enzymes in polymer synthesis and recycling aligns with the principles of green chemistry, paving the way for a circular economy in polymer production and consumption. As research continues, the potential of engineered enzymes in creating high-performance, sustainable materials and addressing global plastic waste crises is becoming increasingly evident.

CARBON CAPTURE

Carbonic anhydrases, engineered for enhanced catalytic activity and stability, are used in carbon capture technologies. These enzymes facilitate the efficient conversion of CO2 into bicarbonates, offering a biological solution to greenhouse gas mitigation (Bhakta *et al.,* 2015).

Carbon capture technologies aim to mitigate the impact of greenhouse gas emissions by capturing and storing carbon dioxide (CO_2) before it enters the atmosphere. Among the innovative approaches, carbonic anhydrases (CAs) have emerged as a key biological solution due to their ability to efficiently catalyze the reversible hydration of CO_2 into bicarbonate (HCO_3^-) and protons. This enzymatic reaction is both rapid and energy-efficient, making carbonic anhydrases highly desirable for integration into carbon capture and sequestration (CCS) systems.

To meet the demands of industrial-scale carbon capture, engineered carbonic anhydrases have been developed with enhanced catalytic activity, stability under extreme conditions (e.g., high temperatures, pressures, and saline environments), and resistance to industrial contaminants. These

improvements enable their application in post-combustion capture processes, where CO_2 from power plant emissions can be efficiently converted into bicarbonate for subsequent sequestration or utilization. For example, bicarbonates produced by carbonic anhydrases can be precipitated as solid carbonates, which are stable and can be safely stored or used in industrial applications such as construction materials (Bhakta *et al.*, 2015).

Additionally, carbonic anhydrases are being explored for their role in direct air capture (DAC) systems, which extract CO_2 directly from the atmosphere. Coupled with renewable energy, these systems can contribute to negative emissions technologies (NETs) essential for achieving global climate targets. Furthermore, the integration of carbonic anhydrases in bioengineering applications, such as algal systems or bioreactors, enhances CO_2 fixation for the production of biofuels and other value-added products, offering a dual benefit of greenhouse gas reduction and sustainable resource generation.

As research continues, the scalability and economic feasibility of using engineered carbonic anhydrases in CCS and DAC systems are being improved, highlighting their transformative potential in addressing climate change through biologically driven carbon capture solutions.

EXAMPLES OF ENZYMES IN GREEN CHEMISTRY

LIPASES

Lipases are versatile enzymes commonly used in biotransformation. They catalyse the hydrolysis of esters and are employed in biodiesel production, synthesis of fine chemicals, and food processing. Engineering efforts have improved their activity in organic solvents, enhancing their industrial utility.

PETases

Polyethylene terephthalate (PET)-degrading enzymes, such as PETases, have been engineered to break down plastics into monomers like terephthalic acid and ethylene glycol. These enzymes are pivotal in recycling efforts and have been tailored for higher efficiency under industrial conditions.

Laccases

Laccases are oxidative enzymes with applications in bioremediation and wastewater treatment. They oxidize phenolic and non-phenolic compounds, reducing environmental pollutants. Engineered variants have increased stability and activity, broadening their industrial applications.

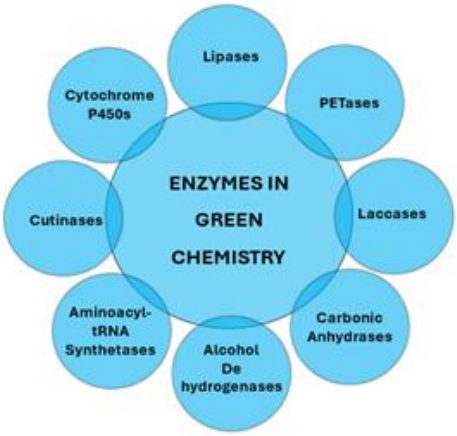

Fig 1: Enzymes in Green Chemistry

CARBONIC ANHYDRASES

Carbonic anhydrases catalyse the reversible hydration of CO2, making them essential in carbon capture and sequestration technologies. Enhanced variants exhibit improved stability and efficiency, facilitating their integration into large-scale carbon management systems.

ALCOHOL DEHYDROGENASES

Alcohol dehydrogenases are employed in the synthesis of chiral alcohols, important intermediates in pharmaceutical production. Engineering efforts have focused on expanding their substrate range and improving enantioselectivity.

AMINOACYL-TRNA SYNTHETASES

These enzymes have been engineered for site-specific incorporation of non-natural amino acids into proteins. Their application in green polymer synthesis and functional biomaterials underscores their versatility.

CUTINASES

Cutinases catalyse the hydrolysis of polyester bonds, playing a crucial role in the recycling of biodegradable plastics. Engineered cutinases exhibit higher activity and stability, enhancing their performance in industrial settings.

CYTOCHROME P450S

Cytochrome P450 enzymes are known for their ability to perform selective oxidation reactions. Engineering efforts have enabled their application in synthesizing fine chemicals and pharmaceuticals, providing greener alternatives to conventional chemical catalysts.

CHALLENGES AND FUTURE DIRECTIONS

Despite significant progress, several challenges remain in the field of enzyme engineering for green chemistry. The high cost of enzyme production, issues with scalability, and the integration of biocatalysis into existing industrial processes are persistent obstacles. Future efforts may focus on integrating artificial intelligence and machine learning to predict enzyme mutations and streamline the engineering process (Wu *et al.,* 2021).

Moreover, interdisciplinary collaborations between chemists, biologists, and computational scientists will be essential for overcoming these challenges. Advances in synthetic biology, such as cell-free systems and protein scaffolding, may further expand the applications of engineered enzymes in green chemistry.

CONCLUSION

Enzyme engineering represents a cornerstone in the advancement of green chemistry, driving sustainable and eco-friendly chemical processes. Through rational design, directed evolution, and computational innovations, enzymes can be tailored to meet industrial needs. As technologies advance, the integration of AI and synthetic biology holds promise for revolutionizing enzyme applications, paving the way for a greener future.

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Chapter 19

BIOCHEMICAL COMPOSITION OF COMMON IN LIVING ORGANISM: BASIC TERMINOLOGY

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ABSTRACT

Phytochemicals are substances that plants make and those insects and other animals eat. They are primarily created to assist plants fend off illnesses from bacteria, fungus, and plant viruses. The name comes from Greek *(phyton)* 'plant'. Some phytochemicals have been used as poisons and others as traditional medicine. Medicinal plants are a rich source of bioactive phytochemicals or bionutrients. Concentrates on did during the beyond thirty years have shown that these phytochemicals play a significant part in forestalling persistent sicknesses like malignant growth, diabetes and coronary illness. Biomolecules predominantly contains carbon atom in their structures. Hence, it is considered as element of life. It is involved in formation of carbon based-compounds and in the generation of structural complexity. The arrangement of simple to complex bimolecular states provides interesting insights of structural plan of a cell of living biological organism. The bio molecules are built according to the structural hierarchy ranging from the precursor metabolic molecules, simple organic building blocks, complex bio molecules, supra molecular complexes, supra molecular assemblies, sub cellular organelles and cellular organization of life.

KEYWORDS: Biochemistry, Phytochemical, Biomolecule.

INTRODUCTION

Chemicals or molecules present in the biological organisms are known as Bio molecules. These bio molecules are mostly made-up carbon-based compounds. The biomolecules present in living organisms are organized around carbon. So, it is the most common versatile and the most predominant element of life. The prevalence of carbon is due to its unparallel versatility in formation of stable covalent bonds through electron pair sharing. The carbon has the ability to form the covalent bond and it is tetrahedral nature It contributes to the formation of compounds by combining with other atoms such as nitrogen, oxygen, hydrogen, phosphorous, sulphur etc. As a result of chemical bonding between atoms and the force of attraction between two (or) more atoms they are held together in a molecule

The term "phytochemistry" originates from two Greek words: "phyton" meaning "plant" and "chemistry" meaning "the study of chemical substances and their properties." The roots of phytochemistry can be traced back to ancient times when humans first began using plants for medicinal purposes. Early civilizations, such as the Egyptians, Greeks, and Chinese, were already

aware of the medicinal properties of certain plants and herbs. The formalization of phytochemistry as a scientific discipline started in the 19th century when advancements in chemistry and analytical techniques allowed scientists to isolate and identify various compounds from plants. The German chemist Friedrich Sertürner is often credited with isolating the first alkaloid, morphine, from the opium poppy in 1804. This discovery laid the foundation for the study of alkaloids and other plant compounds. In the following decades, more and more natural compounds were discovered and characterized from various plants, including alkaloids, terpenes, flavonoids, and phenolics. These compounds were found to have diverse biological activities, such as anti-inflammatory, anticancer, antimicrobial, and antioxidant properties. Today, phytochemistry is an interdisciplinary field that combines principles of botany, chemistry, biochemistry, pharmacology, and other related disciplines. It plays a crucial role in drug discovery, as many pharmaceutical drugs have been derived from plant compounds or inspired by them. Additionally, phytochemistry continues to shed light on the chemical diversity of plants and their ecological roles.

SIMPLE ORGANIC BUILDING BLOCKS OF BIOMOLECULES

The bio molecules mostly contain hydrocarbon backbones and exhibits structural diversity. Their 3-dimensional properties due to the arrangements of atoms around the hydrocarbon back bone and their stability corresponds to the bond distances and bond angles in order to adopt conformations, which are essentially strain-free. In carbon-based biomolecules and elements are recombined in different ways to form different biologically important molecules. Mostly, Covalent bond holds together the molecules and the structure of the molecule is unique and has specific aspect of identity. Biomolecules are made up of collection of set of molecules joined together which are the structural units and their atoms combine, by sharing of electrons. They act as a simple organic building block which includes amino acids, sugars, nucleotides, fatty acids and glycerol.

Amino acids: The organic molecules which contain amino group at one end and carboxylic group at other end. Based on the substituent groups the amino acids can be classified into acidic amino acids, basic amino acids, neutral amino acids, there are about 20 standard aminoacids predominantly present in many biological organisms.

Carbohydrates: The carbohydrates are the organic substances containing poly hydroxyl aldehydes or ketones or the compounds that can be hydrolysed to them. They are present as structural and functional elements of living organisms which include plants, animals and microorganisms. Carbohydrates are widely used as source of food for example rice, Jowar Bajra potatoes legumes and other vegetables etc. Carbohydrates act as a structural elements for example wood is used for furniture making, cotton is used for textile industry, Paper Products etc. Carbohydrates act as structural components are present biological organisms. For example chitin is a carbohydrate present as an exoskeleton in case of insects and crustaceans.

Nucleotides: the nucleotides are organic molecules which contain nitrogenous base, pentose sugar and phosphate group associated with basic proteins. Based on the sugar component and nitrogenous base composition there are two types of nucleic acids 1. Deoxy ribose nucleic acid and 2. Ribose nucleic acids.

Nucleotides are involved in the replication, replication and expression of hereditary information. They participate in cellular signaling processes.

Lipids: Lipids are diverse group of organic compounds, which are insoluble in water due to its predominant hydrocarbon chains in their structures. They are present in structural membranes and function as protective barrier in different organisms such as bacteria, plants, insects and vertebrates serving as a part of outer coating between the body of the organism and its environment.

Fatty acids: They acts as the basic form of lipids which act as constituent molecules. Fatty acids are carboxylic acids with a long hydro-carbon chain(R).-contains even number of carbon atoms ranging from 4 to 36 carbons long. Based on bonds two types -saturated and unsaturated fatty acids

Glycerol: Glycerol acts as a constituent molecule in lipids, which a three-carbon alcohol.

Complex biomolecules:

Through the covalent linkage these simple building block organic molecules can be further assembled into complex bio-molecules (Table 1) such as proteins, polysaccharides, poly nucleotides and lipids.

Proteins: Amino acids are linked with one another and assembled to form larger molecules called as proteins. Proteins differ from each other because of its number of amino acids and sequence of amino acids. Based on the degree of complexity the proteins are divided into four levels of organization

Primary structure: It refers to the linear sequence of amino acids, which are joined together by peptide bonds and disulphide linkage location.

Secondary structure: The conformation of polypeptide chain is in the form of twisting or folding or coiling. Based on hydrogen bonding there are of two types of secondary structures in protein such as alpha helix and beta pleated sheet.

Tertiary structure: The 3-D arrangement of protein structure is referred to as tertiary structure. It results in the formation of compact structures such as globular, spherical or ellipsoid shapes.

Quaternary structure: the proteins are composed of two or more than two polypeptide chains are referred to as subunits. The subunits may be similar in homogenous quaternary structure eg: isoenzymes of lactate denydrogenase. The subunits may be dissimilar in heterogenous quaternary structure eg: haemoglobin. Based on the number of sub-units they may referred to as dimers, tetramer and polymer

Poly-Saccharides: Carbohydrates are composed of sugar units and their polymers. Based on sugar units, carbohydrates classified into three types

Monosaccharides: Basic units of carbohydrates, which cannot be hydrolyzed to still smaller units. It includes molecules such as glucose, fructose, galactose etc.

Oligosachharides: Carbohydrate chain is formed by the linear sequence of monosaccharide units, which are joined together by glycosidic bond. On hydrolysis give two to nine units of monosaccharides. It includes maltose, sucrose, lactose etc.

Polysaccharides: Upon hydrolysis gives large no. of monosaccharide units ranging from hundreds to thousands. It includes starches, fibers, glycogen etc.

Polynucleotides: Polynucleotide chain is formed by the linear sequence of nucleotide residues joined together by phosphodiester bond is called primary structure. Based on the presence of types of nitrogenous bases- there are two types of polynucleotide chains

Primary structure of DNA: The linear sequences of chain of polynucleotides compounds present in DNA contain four types of deoxyribonucleotide monomeric units. Each deoxyribonucleotide is made up of pentose sugar, phosphate and nitrogen bases. The nitrogen bases are of two types 1.purines which include adenine and guanine. 2. The pyrimidines which include cytosine and thymine.

Primary structure of RNA: The linear sequences of chain of polynucleotides compounds present in RNA contain four types of ribonucleotide monomeric units. Each ribonucleotide is made up of pentose sugar, phosphate and nitrogen bases. The nitrogen bases are of two types 1.purines which include adenine and guanine. 2. The pyrimidines which include cytosine and uracil.

Secondary structure of DNA: The two polynucleotide strands of DNA are twisted around each other and held together by hydrogen bonds between the paired nitrogenous bases and by van der Waals force of attraction between the stacked bases. The continuity of life is based on heritable information in the form of DNA.

Secondary structure of RNA: The polynucleotide strands of RNA are folded to give rise secondary structure of RNA. RNA plays an essential role in the transfer of genetic information during protein synthesis. All types of RNA are transcribed from template DNA.

Lipids: Based on structure and composition, lipids are classified into 3 different types

Simple lipids: The tri-ester of three fatty acids with the alcohol glycerol

Compound lipids: The esters of fatty acids with glycerol having additional group like Phosphate, nitrogen bases, protein, etc. They are of 3 types:-phospholipids, glycol-lipids, lipoproteins

Derived lipids: They are obtained on the hydrolysis of simple and complex lipids. Examples include sterols, terpenes, eicosanoids, prostaglandins etc

Table 1: Complex biomolecules

Large complex biomolecules	Simple organic building block biomolecule	Function
Protein	Amino acid	Basic structure and function of cell
DNA	Deoxyribonucleotide	Hereditary genetical information
RNA	Ribonucleotide	Protein synthesis
Polysaccharide	Monosaccharide	Storage form of energy
Lipids	Fatty acids & glycerol	Storage form of energy to meet long term energy demands

PHYTOCHEMICALS

Resveratrol is a stilbenoid, a sort of normal phenol, and a phytoalexin delivered by a few plants because of injury or when the plant is enduring an onslaught by microorganisms, like microbes or parasites. Wellsprings of resveratrol in food incorporate the skin of grapes, blueberries, raspberries, mulberries, and peanuts. In natural science, phenols, once in a while called phenolics, are a class of

synthetic mixtures comprising of at least one hydroxyl bunches fortified straightforwardly to a fragrant hydrocarbon bunch. The easiest is phenol, C_6H_5OH.

Isoflavones are subbed subsidiaries of isoflavone, a sort of normally happening isoflavonoids, large numbers of which go about as phytoestrogens in vertebrates. Isoflavones are created solely by the individuals from the bean family, Fabaceae. Tannins are a class of astringent, polyphenolic biomolecules that tight spot to and hasten proteins and different other natural mixtures including amino acids and alkaloids. The term tannin alludes to the utilization of oak and other bark in tanning creature stows away into cowhide. Flavone is an organic compound with the formula $C_6H_4OC_3HO$. A white solid, flavone is a derivative of chromone with a phenyl substituent adjacent to the ether group. The terpenoids, also known as isoprenoids, are a class of naturally occurring organic chemicals derived from the 5-carbon compound isoprene and its derivatives called terpenes, diterpenes, etc.

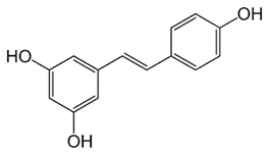
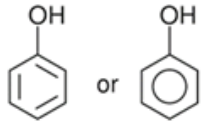
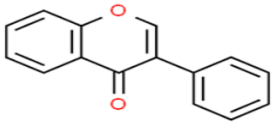
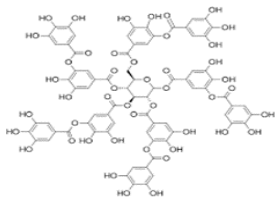
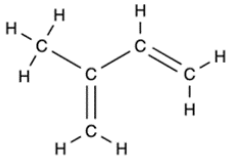
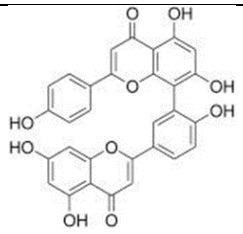
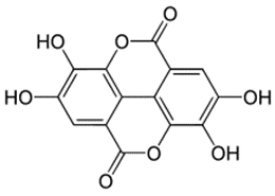
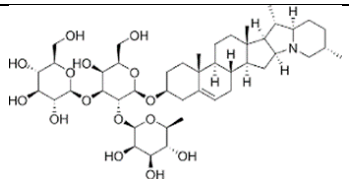
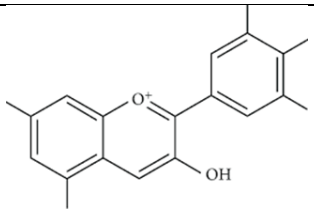
Flavonoids are a class of polyphenolic secondary metabolites found in plants, and thus commonly consumed in the diets of humans. Chemically, flavonoids have the general structure of a 15-carbon skeleton, which consists of two phenyl rings and a heterocyclic ring. This carbon structure can be abbreviated C6-C3-C6. Lutein is a xanthophyll and one of 600 known naturally occurring carotenoids. Lutein is synthesized only by plants, and like other xanthophylls is found in high quantities in green leafy vegetables such as spinach, kale and yellow carrots. Biflavonoids are found in citrus fruits. *Carotenoids* are found in dark yellow, orange, and deep green fruits and vegetables such as tomatoes, parsley, oranges.

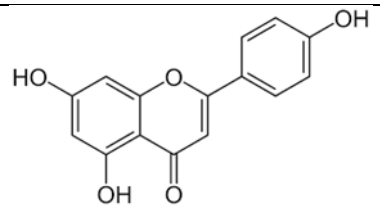
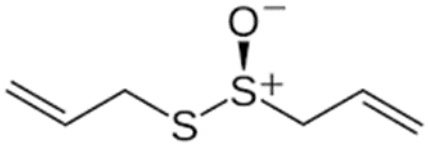
Polyphenols at higher doses have shown to play an important role in induction of apoptosis, suppression of cell proliferation, migration, and invasion of cancer. *Lycopene* is a powerful antioxidant and anti-inflammatory carotenoid. It may have health benefits for the heart, skin, bones, liver, brain, and reproductive. Saponins, also selectively referred to as triterpene glycosides, are bitter-tasting usually toxic plant-derived organic chemicals that have a foamy quality when agitated in water. They are widely distributed but found particularly in soapwort, a flowering plant, the soapbark tree and soybeans. Anthocyanidins are common plant pigments, the aglycones of anthocyanins. They are based on the flavylium cation, an oxonium ion, with various groups substituted for its hydrogen atoms. They generally change color from red through purple, blue, and bluish green as a function of pH.

Apigenin, found in many plants, is a natural product belonging to the flavone class that is the aglycone of several naturally occurring glycosides. It is a yellow crystalline solid that has been used to dye wool.

Phytosterols are phytosteroids, similar to cholesterol, that serve as structural components of biological membranes of plants. They encompass plant sterols and stanols. More than 250 sterols and related compounds have been identified. Allicin is an organosulfur compound obtained from garlic. When fresh garlic is chopped or crushed, the enzyme alliinase converts alliin into allicin, which is responsible for the aroma of fresh garlic. Allicin is unstable and quickly changes into a series of other sulfur-containing compounds such as diallyl disulfide.

Table 2: Structure of Few Phytochemicals

Sr. No	Phytochemical	Structure
1.	Resveratrol	
2.	Phenol	
3.	Isoflavone	
4.	Tannins	
5.	Terpenoids	
6.	Biflavonoids	
7.	Polyphenols	
8.	Saponins	
9.	Anthocyanadins	

10.	Apigenins	
11.	Allicin	

IMPORTANCE OF PHYTOCHEMICALS

- About 10,000 different phytochemicals have already been identified, and scientists believe there are many more out there. Various food varieties contain plant-inferred nitrogenous mixtures that have cancer prevention agent properties. These mixtures incorporate amino acids, amines, amides, pyrimidines, proteins, amino acids, and nucleic acids. Another significant cyclic nitrogen-containing phytochemical is pyrazines which bestow flavor to different regular food sources. Strengthening the immune system. Reducing inflammation. Preventing DNA damage and helping DNA repair. Slowing cancer cell growth. Phytochemicals appear to be protective against heart disease, cancer, Type 2 diabetes, and neurological diseases.
- **Plant Conservation and Biodiversity:** It contributes the conservation of plant species and biodiversity. By studying the chemical composition of plants, scientists can identify unique chemical profiles associated with specific plant species or populations. This information aids in monitoring and preserving endangered plants, promoting sustainable harvesting practices, and protecting natural habitats.
- **Agricultural Applications:** Phytochemistry plays a role in enhancing crop production and agricultural practices. By studying the phytochemical composition of plants, researchers can identify compounds that contribute to pest resistance, disease tolerance, and stress adaptation. This knowledge can be utilized in breeding programs to develop crop varieties with improved traits, reducing the reliance on synthetic pesticides and fertilizers.
- **Environmental Applications:** It can provide insights into the ecological interactions and roles of plants in the environment. By studying the chemical compounds produced by plants, researchers can understand their roles in attracting pollinators, repelling herbivores, and mediating ecological relationships. This knowledge can be utilized in conservation efforts, restoration projects, and sustainable land management practices.
- Phytochemistry is important for advancing our understanding of the chemical diversity and biological activities of plants. It has practical applications in medicine, agriculture, and environmental sciences, contributing to human health, economic development, and ecological sustainability.

CONCLUSION

Thus, the arrangement of simple to complex bimolecular states provides interesting insights of structural plan of a living cell and its characteristic attributes associated in a living state.

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Chapter 20

ALKAPTONURIA- A RARE AUTOSOMAL RECESSIVE METABOLIC DISORDER

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ABSTRACT

Alkaptonuria (AKU) is a rare autosomal recessive disorder characterized by the accumulation of homogentisic acid (HGA) due to a deficiency in the enzyme homogentisate 1,2-dioxygenase (HGD). This metabolic anomaly leads to ochronosis, a condition marked by the darkening of connective tissues, and progressive arthritis, particularly in the spine and large joints. Despite being one of the first metabolic diseases described by Garrod in 1902, the understanding and management of AKU remain limited. This review aims to provide a comprehensive overview of AKU, encompassing its genetic basis, pathophysiology, clinical manifestations, diagnostic methods, and current and emerging treatment strategies.

KEYWORDS: Alkaptonuria, Genetic, Ochronosis, Nitisinone, Gene Therapy.

INTRODUCTION

Alkaptonuria is a rare hereditary disorder that affects around 1 in 250,000 to 1 in 1,000,000 live births worldwide. The defining feature of the illness is the buildup of HGA, which is brought on by a mutation in the HGD gene on chromosome 3q13.33 [1]. This gene encodes the homogentisate 1,2-dioxygenase enzyme, which is necessary for the catabolism of phenylalanine and tyrosine. The build-up of HGA, which polymerizes and deposits in connective tissues due to the lack of the active HGD enzyme, causes ochronosis and degenerative arthritis [2].

GENETIC BASIS AND PATHOPHYSIOLOGY

The HGD gene mutation responsible for AKU follows an autosomal recessive inheritance pattern. Over 100 different mutations in the HGD gene have been identified, most of which are missense mutations, leading to the production of a dysfunctional enzyme [3]. The absence of HGD activity results in the accumulation of HGA in the body, which is oxidized to form benzoquinone acetic acid (BQA). BQA binds to collagen fibers in connective tissues, leading to the characteristic pigmentation and subsequent tissue damage seen in AKU patients [4].

CLINICAL MANIFESTATIONS

EARLY SIGNS AND SYMPTOMS

AKU typically manifests early in life, often with dark-stained urine being one of the first noticeable signs. Infants may have urine that turns dark upon standing, due to the oxidation of HGA [5].

However, clinical symptoms often do not appear until adulthood, usually in the third to fourth decade of life.

OCHRONOSIS AND ARTHROPATHY

Ochronosis, the bluish-black pigmentation of connective tissues, is a hallmark of AKU and becomes evident in adulthood. It primarily affects cartilage, tendons, and the sclera of the eyes. The deposition of HGA leads to a brittle, discolored cartilage which is prone to degeneration, resulting in ochronotic arthropathy. This condition predominantly affects the spine, hips, and knees, leading to chronic pain, stiffness, and decreased mobility [6].

OTHER SYSTEMIC INVOLVEMENT

In addition to joint and spine involvement, AKU can affect other systems. Patients may develop renal stones, prostate stones, and cardiovascular complications such as aortic valve stenosis and coronary artery calcification due to HGA deposition [7]. Additionally, pigmentation changes may be observed in the ear cartilage, nose, and other areas with dense connective tissue.

DIAGNOSIS

URINE ANALYSIS

The presence of HGA in urine, leading to darkening upon standing, is a key diagnostic indicator of AKU. A quantitative analysis of urinary HGA levels can confirm the diagnosis [8].

GENETIC TESTING

Molecular genetic testing can identify mutations in the HGD gene, providing a definitive diagnosis. This is particularly useful for confirming cases in individuals with atypical presentations or for prenatal diagnosis in families with a known history of AKU [9].

IMAGING STUDIES

Radiographic imaging can reveal characteristic changes in the joints and spine, such as calcification of intervertebral discs and joint space narrowing. These findings support the diagnosis of ochronotic arthropathy in AKU patients [10].

MANAGEMENT AND TREATMENT

SYMPTOMATIC MANAGEMENT

At present, there is no known treatment for AKU. The main approach to treatment involves the control of symptoms and the prevention of consequences. Nonsteroidal anti-inflammatory medications (NSAIDs) and analgesics are frequently employed to mitigate joint pain and inflammation [11]. Physical treatment and lifestyle adjustments are effective in preserving joint function and mobility.

SURGICAL INTERVENTIONS

In severe cases of ochronotic arthropathy, surgical interventions such as joint replacement may be necessary. Total hip and knee arthroplasties have been performed successfully in AKU patients, providing significant pain relief and improved function [12].

NITISINONE THERAPY

Nitisinone, an inhibitor of 4-hydroxyphenylpyruvate dioxygenase, has emerged as a potential disease-modifying treatment for AKU. By inhibiting the enzyme upstream of HGD, nitisinone

reduces the production of HGA. Clinical trials have shown that nitisinone effectively lowers urinary HGA levels, although its long-term efficacy and safety in reducing ochronosis and improving clinical outcomes are still under investigation [13].

GENE THERAPY

Advances in gene therapy hold promise for the future treatment of AKU. Preclinical studies have explored the potential of delivering functional HGD genes to restore enzyme activity and prevent HGA accumulation. While still in the experimental stage, gene therapy represents a potential curative approach for AKU [14].

CHALLENGES AND FUTURE DIRECTIONS

EARLY DIAGNOSIS AND SCREENING

One of the primary challenges in managing AKU is the often-delayed diagnosis, as clinical symptoms typically manifest later in life. Early diagnosis through neonatal screening and increased awareness among healthcare providers can facilitate timely intervention and management, potentially delaying the onset of severe complications [15].

PATIENT MANAGEMENT AND QUALITY OF LIFE

Comprehensive management of AKU requires a multidisciplinary approach involving rheumatologists, orthopaedic surgeons, geneticists, and other specialists. Regular monitoring and individualized care plans are essential to manage symptoms, monitor disease progression, and improve the quality of life for AKU patients [16].

RESEARCH AND DEVELOPMENT

Ongoing research into the pathophysiology of AKU and the development of new therapeutic strategies is crucial. Collaborative efforts between academic institutions, pharmaceutical companies, and patient advocacy groups can drive progress in understanding AKU and developing effective treatments [17].

CONCLUSION

Alkaptonuria is a rare but debilitating metabolic disorder with significant clinical and quality-of-life implications for affected individuals. While there is currently no cure, advancements in symptomatic management, emerging therapies like nitisinone, and potential gene therapy offer hope for better disease management and improved outcomes. Continued research, early diagnosis, and a multidisciplinary approach to patient care are essential in addressing the challenges posed by Alkaptonuria and enhancing the lives of those affected by this rare genetic disorder.

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Chapter 21

ECO-FRIENDLY FARMING

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ABSTRACT

Eco-friendly farming, also known as sustainable or green farming, emphasizes environmental stewardship, biodiversity conservation, and natural resource management. This chapter delves into the principles, practices, and benefits of eco-friendly farming, highlighting its role in mitigating climate change, enhancing soil health, and promoting biodiversity. A detailed overview of innovative methods such as organic farming, permaculture, agroforestry, and integrated pest management is provided. Results from studies show that eco-friendly farming practices lead to improved productivity and sustainability compared to conventional methods.

KEYWORDS: Eco-Friendly Farming, Sustainable Agriculture, Organic Farming, Biodiversity, Agroforestry, Permaculture, Climate-Resilient Agriculture.

INTRODUCTION

Eco-friendly farming refers to agricultural practices that prioritize environmental sustainability and minimize negative impacts on the ecosystem. These practices aim to strike a balance between meeting the growing food demands of an increasing global population and conserving the natural resources essential for future generations. (Barwant *et al.*, , 2022)With concerns about environmental degradation, climate change, and resource depletion, eco-friendly farming has emerged as a viable alternative to conventional farming methods that rely heavily on chemical inputs and intensive monoculture systems.

This chapter explores the key components, benefits, and challenges of eco-friendly farming. It also provides insights into how innovative techniques and technologies contribute to building resilient agricultural systems. (FAO, 2020)

METABASE DATA

PRINCIPLES OF ECO-FRIENDLY FARMING

1. Sustainability: Ensuring long-term soil fertility and agricultural productivity.

2. Biodiversity Conservation: Supporting diverse species through mixed cropping and agroforestry.

3. Resource Efficiency: Utilizing natural inputs like compost, green manure, and biopesticides.

4. Climate Adaptation: Adopting resilient crops and water management systems.

PRACTICES OF ECO-FRIENDLY FARMING

1. Organic Farming: Avoiding synthetic chemicals by using organic inputs.

2. Permaculture: Designing self-sufficient agricultural ecosystems.

3. Agroforestry: Combining tree cultivation with crops and livestock.

4. Integrated Pest Management (IPM): Using biological control agents to manage pests.(Pretty& Bharucha, 2015).

5. Crop Rotation and Intercropping: Preventing pest outbreaks and enhancing soil health.

IMPORTANCE OF ECO-FRIENDLY FARMING

Reduces greenhouse gas emissions.

Enhances soil fertility and structure.

Promotes water conservation.

Ensures food security through sustainable practices.

MATERIALS AND METHODS

Study Area and Design

This study examines eco-friendly farming practices across diverse agro-climatic zones. Data was collected from field trials, surveys, and secondary literature.

Data Collection Methods

1. Field trials comparing conventional and eco-friendly farming systems
2. Interviews with farmers practicing sustainable agriculture.
3. Literature review of case studies and research articles.

Analytical Methods

Soil fertility analysis using organic and chemical methods.

Yield comparisons through statistical modeling.

Biodiversity indices to assess ecosystem health.

RESULTS AND DISCUSSION

Soil Health

Eco-friendly farming practices significantly improved soil organic matter, microbial activity, and nutrient content. Organic farming methods, in particular, enhanced soil carbon sequestration by 20-30% compared to conventional systems.

Biodiversity Conservation

Agroforestry and permaculture systems supported higher biodiversity. For instance, farms practicing intercropping reported a 40% increase in beneficial insect populations compared to monoculture farms.

Climate Change Mitigation

Eco-friendly farming methods contributed to a reduction in greenhouse gas emissions by minimizing synthetic fertilizer use and enhancing carbon storage in soils.

Economic and Social Impacts

Farmers adopting eco-friendly practices reported a 15-20% increase in net income due to reduced input costs and premium prices for organic produce. Socially, these practices promoted community resilience and food security (Tillman, 2011).

CONCLUSION

Eco-friendly farming is not just a set of practices but a paradigm shift in agricultural systems. It ensures environmental sustainability, economic viability, and social equity. By adopting methods like organic farming, agroforestry, and permaculture, farmers can enhance soil health, conserve biodiversity, and combat climate change. The transition to eco-friendly farming, while challenging, is imperative for the well-being of future generations. Further research and policy support are essential to promote its widespread adoption.

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Chapter
22

SCOPE IN INDIGENOUS MEDICINAL PLANTS OF MADHYA PRADESH

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ABSTRACT

A central state of India, boasts an extensive and diverse forest cover that constitutes an ecological treasure trove. This rich ecosystem is home to a wealth of medicinal plants and herbs In the Madhya Pradesh commonly recognized medicinal herbs, such as Tulsi, Aloe Vera, Ashwagandha, Giloy, and Brahmi, coexist with endangered herbs that are rarely found, all within the forests. As such, MP is native to over 4,000 plant species, out of which approximately 300 possess disease diagnostic properties. Importantly, the medicinal properties of these plants and herbs have been well-identified and practiced for the treatment of various diseases by tribal people residing in the dense forest villages of MP. Beyond their immense cultural and traditional value, these forests also make substantial contributions to Ayurveda, modern medicine and pharmaceuticals. These plants are used in various forms, such as whole plants or plant parts like leaves, stems, barks, roots, flowers, fruits, seeds, and wood, for the treatment of various illnesses. To underscore the vital role of tribal communities in traditional healing practices, they have a long history of utilizing these medicinal plants. Their knowledge has been passed down through the generations, preserving the rich cultural heritage of the region, exemplified by the Vindhya forests and Satpuda forest.

These herbs serve as essential ingredients in Ayurvedic formulations, providing natural and holistic healthcare solutions. The abundant collection of medicinal plants and herbs holds not only cultural and ecological importance but also significant economic potential. Particularly in rural areas, the cultivation and collection of medicinal plants offer livelihood opportunities to many villagers.

KEYWORDS: Ayurveda, Traditional Knowledge, Medicinal Plants, Improved Varieties, Potential Herbs and Locations.

INTRODUCTION

The Madhya Pradesh with 11 agroclimatic zones having diversity in soil composition and climatic conditions are most suitable for cultivation and growth of medicinal and aromatic plants. Madhya Pradesh had an area of 18364 hectare with production 110184 ton under medicinal and aromatic crops during the year 2003, which increased to 65,617 ha area with production of 4,14,043 ton during 2014-15. The state is natural habitat for over 50 percent of the herbs used in pharmaceutical industry. The collection and conservation are being done by primary co-operative societies. The increasing demands for herbal medicines have renewed interest of the multinational pharmaceutical in bio

prospecting. This indicates that production, consumption and trade (domestic and international) in MAP based products are going to grow at a significant rate.

The Madhya Pradesh, a state in Central India is a veritable niche of growing healing herbs, which are being utilised and explored in Indian system of medicine such as Ayurveda, Siddha and Unani. There are about 28 tribal communities (Baiga, Bhariya, Korku, Korwa and Sahariya, Kol, Bhil, Gond, Pao, Khairwar, Maria, Kamar etc.) spread over the entire state in Madhya Pradesh which are utilizing the plants for food and medicinal purposes. These indigenous people have been using with a historical continuity of resource use, and the traditional knowledge has accumulated through a series of observations and explorations transmitted from generation to generation.

Ethnobotany, a multidisciplinary science, studies the complex interaction/relationship between plants and people. This relationship between plants and human culture is not limited to the use of plants for food, clothing and shelter but finds their use for religious ceremonies, ornamentation and primary health care services. The plants have always been the principle source of medicines in India since time immemorial. In older times, Ethnobotanical research was predominately a detailed survey of the plants used by local practitioners but in today's world ethnobotany focuses primarily on how plants are being used, managed and perceived across human societies i.e. as food, as medicine, in divination, cosmetics, dying, textile, construction, clothing, literature and in rituals and social life. Therefore, an attempt has been made to compile the Ethnobotanical or traditional knowledge of some medicinally useful plants used by tribal communities of Madhya Pradesh to meet different purposes in different ways.

There has been a rapid increase of allopathic system of medical treatment in our country during the past century (Dwivedi *et al.*, 2007). However, these drugs have adverse effects and that's why the people are going back to nature with hope of safety and security associated with natural products. The herbal preparations are safe, cheaper and easily available with no fear of any side effect. It is evident that many valuable herbal drugs have been discovered by knowing that particular plant was used by the ancient folk healers for the treatment of some kind of ailment or disorder (Ekka & Dixit, 2007). Furthermore, the medicinal plant wealth is our national heritage which seems to be the first and foremost line of defense mostly in tribal and rural communities for the treatment of various diseases (Dwivedi *et al.*, 2008). The readily available and culturally important traditional medicines form the basis of an accessible and affordable health-care regime and are an important source of livelihood for tribal and rural populations. Moreover, Ethnobotanical studies have become increasingly valuable in the development of health care and conservation programs in different parts of the world (Balick, 1996). There are several studies which have reported the continued use of traditional practices as people migrate to urban centres surrounded by diverse cultures, healing systems and the new environments (Baca, 1978; Gordon, 1994; O'Connor, 1998; Prakash, 2017). ~ 128 ~ Journal of Medicinal Plants Studies https://www.plantsjournal.com Approximately 64% of the total world population relies on traditional medicines for their health care system whereas 85% of the Indian rural population depends on wild varieties of plants for the treatment of various diseases they usually suffer from. One of the major challenges today is to protect the traditional knowledge.

Due to indiscriminate exploitation, destruction of forests and changing scenario of rural life-style, the oral folklore of plants life as well as the knowledge is in the process of gradual degeneration (Kumar *et al.,* 2004). Therefore, it is need of the hour to study and document the information available on medicinal plants in detail for its wider applications in the future.

CONSERVATION OF FOREST HERBALS

The inevitability of conserving forests for their medicinal properties and ensuring their sustainable use is a matter of extreme importance. Forest has invaluable resources, providing not only natural remedies but also economic benefits. Therefore, conservation of forest is not just a matter of ecological preservation but a commitment to holistic healthcare and economic prosperity. Local communities, particularly tribal people, are culturally trained for protection and conservation medicinal plant resources within the forests. Their importance in the context of medicinal value is undeniable. Their rich biodiversity and traditional knowledge have been contributing to natural, sustainable healthcare solutions. Several initiatives have to be taken to empower local communities and ensure their economic growth to improve their standard of living.

MP has recognized the significance of conserving its forest resources and promoting their sustainable management. MP forest department has identified specific areas for conserving and propagating endangered or rare medicinal plant species. In the recent reports, there is documentation on thrust areas where the state government, central government, forest research institutions and NGOs are collaboratively working in studying the medicinal plants and herbs found in forest of MP. These thrust areas aim to protect the biodiversity of medicinal plants. "MP forests are not just lush green landscapes but also living pharmacies, holding the secrets to health and wellness.

The increasing demands for herbal medicines have renewed interest of the multinational pharmaceutical in bio- prospecting. This indicates that production, consumption and trade (domestic and international) in MAP based products are going to grow at a significant rate. For making full use of this potential, India must develop suitable cultivation practices, processing technology, quality control, value addition, extension, marketing and IPR strategies for these plants. It necessitates the systematic research and developmental activities in MAP sector. Globally, 4000-10000 medicinal plants are endangered due to escalating demand and short supply. Globally 4160 MAPs are threatened and in India according to red data book, 427 Indian Medicinal plant entries are endangered species, of which 28 are considered extinct, 124 endangered 81 rare and 34 insufficiently known. There are so many plants now found in the world, which are identifying as medicinal and aromatic plants and, cultivators are cultivated them as a crop. However, our knowledge and use of medicinal crops has mostly been inherited traditionally, use of plants for curing various ailments are not confined to the doctors only but is known to several households as well. Medicinal and aromatic plant diversity of Madhya Pradesh is very rich and most of the tribal people cure himself through indigenous drug system. India occupies 507.84 thousand ha area and produce 830.85 thousand tons of medicinal plants. Madhya Pradesh had an area of 18364 hectare with production 110184 ton under medicinal and aromatic crops (2003), which increased to 65,617 ha area and 4,14,043 ton (2014-

15). India is expanding its basket of cultivation of medicinal and aromatic plants by adding more and more species

MEDICINAL PLANTS GROWN IN MADHYA PRADESH

Madhya Pradesh a leading state in commercial cultivation and trade of many medicinal and aromatic plants specially Ashwagandha, Sarpgandha, Bach, Isabgol, Safed Musli, Muskdana, Rosha grass, Lemon grass, Khurasaniajwain, sadabahar, Chandrasur, Chitraik and opium. The state having mega bio-diversity and 11 agro-climatic regions, which caters the large varieties of medicinal and aromatic crops. There is wide scope for adoption of these crops. There is a significant contribution of Jawaharlal Nehru Krishi Vishwa Vidyalaya, Jabalpur in the field of bio-diversity conservation, and documentation of medicinal plants and indigenous Medicare prevalent among natives of Madhya Pradesh. The university developed agro techniques (package of practices) for cultivation of medicinal (bach, muskdana, ashwagandha, Isabgol, sarpgandha, kalmegh, curcuma and safedmusli) and aromatic (mentha, lemongrass, palmarossa, vetiver, germanchameli, guggul, and eucalyptus) plants.

Now, the farmers of Madhya Pradesh are showing interest in these medicinal and aromatic crops. But due the price fluctuations, lack of marketing facilities, absence of value addition by processing, lack of technical knowhow of cultivation and procurement etc. problems related to these crops, the area as well as production of these crop fluctuate year to year or even season to season.

SWOT ANALYSIS

Table 1: Potential district for crop cluster in MP (SWOT Analysis)

Sr.	Vernacular Name of Plant	Cluster of Potential Districts
1	Amla	Jabalpur, Katani, Anuppur, Betul, Bhopal, Damoh, Dewas, Dhar, Dindori, Gwalior, Harda, Hoshangabad, Indore, Jhabua, Mandla, Mandsoure, Narsinghpur, Neemuch, Raisen, Ratlam, Sagar, Sehore, Seoni, Shahdol, Shajapur, Ujjain, Umaria, Khargone, Shivpuri
2	Ashwagandha	Bhopal, Damoh, Dewas, Dhar, Dindori, Gwalior, Harda, Hoshangabad, Indore, Jhabua, Mandla, Mandsoure, Neemuch, Ratlam, Sagar, Sehore, Seoni, Shahdol, Shajapur, Ujjain, Shivpuri
3	Bel	Damoh, Dhar, Dindori, Harda, Hoshangabad, Sagar, Sehore, Khargone, Shivpuri, Ratlam, Shahdol
4	Coleous	Bhopal, Damoh, Gwalior, Harda, Sagar, Hoshangabad, Shahdol.
5	Isabgol	Mandsour, Neemuch, Jabalpur and Ratlam
6	Kalmegh	Betul, Bhopal, Damoh, Dewas, Dhar, Dindori, Gwalior, Harda, Hoshangabad, Indore, Jhabua, Mandsoure, Neemuch, Ratlam, Sagar, Sehore, Seoni, Shahdol, Shajapur, Khargone, Shivpuri

7	Lemon Grass	Ratlam, Indore, Chattarpur, Betul, Bhopal, Khandwa, Katni, Morena, Chindwara, Shivpuri, Tikamgarh, Dhar
8	Safed Musali	Betul, Dhar, Harda, Hoshangabad, Shahdol, Khargone
9	Sarpgandha	Damoh, Dhar, Gwalior, Hoshangabad, Indore, Jabalpur, Ratlam, Sagar, Sehore, Dewas, Bhopal, Ratlam.
10	Satawar	Anuppur, Betul, Dindori, Gwalior, Harda, Hoshangabad, Jabalpur, Neemuch, Raisen, Sagar, Sehore, Shahdol, Umaria, Khargone, Shivpuri
11	Tulsi	Damoh, Hoshangabad, Mandsaur, Neemuch, Ratlam, Sagar, Sehore

STRENGTHS

Establishment of State Medicinal Plants Board and channelizing of various promotional schemes for the facilitation of herbal sector.

- Plateau, Gird region, Bundelkhand region, Satpura plateau, Malwa plateau, Nimar plateau, Nimar plains, and Jhabua hills are suitable for growth of more than 500 perennial shrubs, herbs, climbers seasonal/ annuals of medicinal species.
- Availability of about 1.10 million hector cultivable waste land can be utilized for cultivation of medicinal plants.
- Farmers in the State are innovative and willing to shift profitable cultivation.
- Availability of skilled and unskilled manpower.
- Major Ayurvedic companies trade from Bhopal, Katni, Dewas, Shivpuri, Mandsaur, Neemuch, Indore and Mandieep.
- Highest individual paying capacity availability of finance and trend toward herbal consumption in the mega cities.
- Farmer friendly policies of State Govt. and financial institution.
- Comparatively cheaper availability of labour and medicinal product in the local markets.
- Sales tax and excise duty exemption for export trade.
- Implementation of Medical Plants Mission in 25 districts of the State.
- State having so many Ayurvedic colleges, Dispensaries and hospitals.
- Farmers of the State are not only respective of new technological development in medicinal plant cultivation but are quit innovative as well some of the medicinal plant crop being growing in the state are at the self -initiative of the farmers.
- State is centrally located enjoys access to different markets in the country with an added advantage of short transportation time to these markets.
- Existing departmental infrastructure, nurseries gardens, and activities serve as demonstration, help spread the technical know-how amongst farmers.
- A large variety and species of medicinal plants available in the non-forest and forest area, planting material for multiplication and conservation easing propagated.
- Sufficient experts, scientists, specialists available in the State.

- National and State level institutes available like IIFM, SFRI, SMPB, JNKVV, Minor Forest Produce Board, Directorate and Horticulture Mission, MPCON

Table 2: Medicinal Plants in Madhya Pradesh (SWOT Analysis)

Sr.	Vernacular Name (Botanical name)	Used in / as / to control
1	Aak (*Calotropis procera* L.)	Detergent, snake bites
2	Adusa (*Adhatoda vasica Medikus*).	Respiratory disorders
3	Ajwain (*Hyoscyamus niger L.*)	Loose motion, teeth pain relief, eye disease, Asthma, cough, urine, infection
4	Aloe vera / Gwar Patha *(Aloe barbadensis Mill)*	Skin disorders
5	Amaltas (*Cassia fistula L.*)	Purgative, febrifuge
6	Amarbel (*Cuscuta reflexa* Roxb).	Jaundice, indigestion, diarrhoea, asthma
7	Amla (Emblica officinalis)	Stomach disorders, indigestion
8	Amla (*Phyllanthus emblica L.*)	Diarrhoea, jaundice, inflammation
9	Anantmul (*Hemidesmus indicus* L.) R. Br.	Respiratory diseases, energy tonic
10	Aprajita (*Clitorea ternatea L.*)	Anti-dote to snake-bite
11	Arandi (*Ricinus communis* L.)	Jaundice, constipation, arthritis, insomnia, menstrual cramps
12	Arjun (*Terminalia arjuna Rpxb*) W.&A	. Cardiac problems, fractured bone recovery
13	Ashok (*Saraca indica L.*)	Brain tonic, fever, pain, uterine & genital disorders
14	Ashwagandha *(Withania Somnifera)*	Skin disease, Blood pressure, Swelling, Wounds, filler, Joint pain. Sexual impotency
15	Babul *(Acacia nilotica L).*	Piles & Urogenital problems
16	Balamkhira (*Kigelia pinnata Jacq*.)	Stomach disorders, indigestion
17	Bans (*Bambusa spinosa Roxb.)*	Leprosy, urino-genital disorders
18	Bans (*Dendrocalamus strictus* Nees.)	Astringent tonic, indigestion
19	Bargad *(Ficus bengalensis L.)*	Skin and eye diseases, diabetes, leucorrhoea
20	Besharm (*Ipomoea fistulosa Mart.)*	Sprains, sedative, leukoderma
21	Bhilwa (*Semecarpus anacardium L.*)	Digestive and reproductive disorders
22	Bhui Amla (*Phyllanthus amarus*)	Urinary disease, Jaundice, stomach pain
23	Bhringraj (*Eclipta alba L.)*	Hair oil for hair fall defence and dandruff problems
24	Bia vidung (*Embelia ribes Brum F.*)	Anti worms, Loose motion, skin disease, tonic snake & crabs bites.
25	Brahmi (*Bacopa monnieri L.*)	Increase memory, Nerve tonic, Hysteria
26	Chirayta (*Andrographis paniculata Burm. f.)*	Respiratory disorder

27	Chandrasur *(Lepidium Sativum L.)*	As vegetable, salad, gum, increase milk production in mother, and in dairy cow & buffalo, digestion, eye disease, loose motion, Gynaec disease, child development, Asthma, piles, Leaf- anti scorbutic
28	Chhota gokhru *(Xanthium strumarium L.*)	Diuretic, diaphoretic
29	Dahiman (*Cordia macleodii Hook. f.)*	Provides relief from insanity
30	Dhatura (*Datura stramonium* L.)	Anti-inflammatory, antispasmodic
31	Doob *(Cynodon dactylon L. Pers.)*	Ear, nose, throat problems
32	Doodhi *(Euphorbia hirta L.)*	Asthma, Infantile diarrhoea
33	Gajarghas *(Parthenium hysterophorus L.)*	Anti-allergic
34	Giloy (*Tinospora Cordifolia Willd*)	Root- Leprosy, Stem- Jaundice, Cough fever, white discharge, control of heart beating, Sexual impotency, control blood pressure Leaf- Jaundice, Chicken pox Fruit- Jaundice, tonic
35	Ghumchi *(Abrus precatorius L.)*	Contraceptives, purgative, emetic & menstrual disorder
36	Gurhal *(Hibiscus rosa-sinensis L.)*	Enhances hair growth & reduces dandruff
37	Gudmar *(Gymnema sylvestre)*	Liver tonic, diabeties, heart disease, fever, white spot, snake bites, stomach pain, eye pain.
38	Hadjod *(Cissus quadrangularis L.)*	Anti-osteoporotic, anti-asthamatic
39	Haldi *(Curcuma longa L.)*	Anthelmintic, carminative, antimicrobial
40	Harsingar (*Nyctanthes arbor-tristis L*).	Rheumatism, skin diseases, diabetes
41	Hing (*Ferula assa-foetida* L.)	Fluctuance, stomach disorders, bronchitis, asthma
42	Isabgol (*Plantago Ovata Forsk*)	Piles, Loose motion, Stomach disease
43	Jangli Matar *(Lathyrus aphaca L.)*	Famine food, dyestuff
44	Jamun *(Syzygium cumini L.)*	Diabetes, bronchitis, asthma, dysentery, ulcers, sore throat
45	Jharberi (*Ziziphus nummularia Burm. f.*)	Gastrointestinal problems, diabetes. bilious infections
46	Kacharia *(Citrullus aromatica Salisb.)*	Stomach disorders
47	Kachnar (*Bauhinia variegata* L.)	Cure piles
48	Kali Musali (*Curculigo orchioides* Gaertn.)	Leucorrhoea
49	Kalmegh (*Andrographis Paniculata)*	Skin disease, Malaria, fever, blood purifier

50	Kalihari (*Gloriosa Superba Linn*)	Medicine of Mumps, diphtheria, & abortifacient, anti-cancer, anti-jaundice, Piles, Asthma
51	Kakora (*Momordica dioica Roxb*.)	Fever, Urogenital disorders
52	Kati-korati (*Barleria prionits* L.)	Tooth ache, digestive problems
53	Kevanch (*Mucuna pruriens L.* DC.)	Against intestinal worms
54	Khajju (*Ageratum conyzoides* L.)	Skin/Dermatological disorders
55	Khatti bhaji (*Oxalis corniculata L.*)	Diabetes, ulcers, wounds
56	Kulanjan *(Alpinia calcarata Roscoe*)	Sore throat
57	Ratanjot *(Jatropha curcus L.)*	Bio diesel, skin disease and wounds
58	Lajwanti *(Mimosa pudica L.)*	Carminative, aphrodisiac, indigestion
59	Latjeera (*Achyranthes aspera L*)	Respiratory disorders
60	Makoy (*Solanum nigrum L.*)	Indigestion, scrotum swelling Fever, Loose motion, eye disease Plant- Piles, Liver disease Leaf – Urinary disease
61	Mahua (*Madhuca indica GmeL*).	Snake bite, stomach ache
62	Marodphali (*Helicteres isora L.)*	Gastro-enteritis
63	Mehndi *(Lawsonia inermis L.)*	Boils and burns
64	Mulaithi (*Glycyrriza glabra L.)*	Heart disease, Prepare tasteful medicine
65	Murari *(Bryophyllum calycinum Salisb.)*	Ulcer, stomach pain
66	Nagarmotha (*Cyperus rotundus* L.)	Diarrhoea, respiratory issues
67	Neem *(Azadirachta indica A. Juss)*	Malaria fever, skin problems
68	Nirgundi (*Vitex negundo* L.)	Rheumatism, diabetes, ulcers, throat pain
69	Papita (*Carica papaya* L.)	Oral contraceptive, digestant and rubefacient
70	Palash (*Butea monosperma* Lam. Taub.)	Oral contraceptive, dysentery
71	Pattharchur (*Coleus aromaticus*)	Stomach pain, Carminative, Urine disease, kidney stone
72	Pan (*Piper betle*)	Worms, Cough, digestion, heart
73	Pachguria *(Bryonopsis laciniosa L.)*	Ripen fruits with Kalmegh, Giloy, Neem & Tulsi is used in malaria and typhoid fever
74	Panchpatiya *(Ipomea pes-tigridis L.)*	Leaf paste applied on the affected area to treat scorpion bite
75	Peeli katehri / Ghamoya (*Argemone mexicana L).*	Boils & burns, diuretic, expectorant
76	Peepal *(Ficus religiosa L).*	Skin diseases, gonorrhoea, ulcers
77	Ratalu (*Dioscorea bulbifera* L.)	Antidysentery, anti-syphilis
78	Sadabahar *(Catharanthus roseus L.*)	Anticancer, antidiabetic
79	Safed Siris (*Albizia procera L.)*	Respiratory disorders

80	Safed Musali (*Chlorophytum borivillinum)*	Chavanprash, making diabetic medicine
81	Shahtoot (*Morus alba L.*)	Purgative, insomnia, dizziness
82	Sarpgandha (*Rauvolfia Serpentina)*	High blood pressure, hysteria
83	Satawar *(Asparagus racemosus willd*)	Acidity, Ulcer, to increase milk production in Cow & buffalo, skin disease, eye disease, develop resistance power.
84	*Senna (Cassia angustifolia)*	Stomach disease
84	Sitab (*Ruta graveolens L.*)	Anti- ringworm, abortifacient
85	Shankhpushpi (*Convolvulus pleuricaulis* L.)	Used as brain tonic
86	Sweet. Kanghi *(Abutilon indicum L.)*	Leprosy, jaundice, piles, vaginal infections, mumps, urinary diseases
87	Tulsi (*Ocimum Sanctum*)	Cosmetics, Malaria, Jaundice, Typhoid, Cough & cold, digestion, ear pain, oil
88	Tulsi *(Ocimum basilicum)*	Cosmetics, cough syrup, digestion, ear pain oil
89	Umer *(Ficus glomerata Roxb).*	Dysentery, diabetes, asthma, ulcers, male contraceptive
90	Uttran (*Daemia extensa R.Br)*	Menses problem, removal of snake or scorpion poison

Table 3: Major Aromatic Crops of Madhya Pradesh and their Uses (SWOT analysis)

Sr.	Vernacular Name (Botanical name)	Significant part	Used in / as / to control
1	Citronella grass *(Cymbopogon nardus)*	Oil	Cosmetic, knee pain and arthritics
2	German Chameli *(Matricaria Chamomilla)*	Oil Flower & plant	Oil- Anti-allergy, body resistance, cream, shampoo, Flower & plant- Digestion, Cough, hair die, wine industries
3	Jasmine *(Jasminum grandiflorum)*	Leaf, Plant Flower	Leaf-mouth ulcer, Ear disease Flower - Crab bite, skin disease Plant-Loose motion, anti-worms, urine disease, Gynaec disease
4	Java citronella *(Cymbopogon winterianus)*	Oil	Cosmetic, soap, preparation of aromatic geranoil, chemical, Anti mosquito ointment deodorant
5	Khus (*Vetiveria zizanioides*)	Oil, Root	Oil- Scent, Cosmetic, Medicine Root- Used in cooler

6	Lavender *(Lavandula officinalis L.)*	Oil	Soap, shaving cream, powder, Anti-worm, Aromatherapy
7	Lemongrass *(Cymbopogon flexuosussteud)*	Oil	Cosmetic creams, soaps, insecticide, joint pain, odomas, Gulab jal
8	Mentha *(Mentha arvensis L)*	Oil	Carminative, expectorant, stomach disease, cough & cold, throat infection, fever, gas
9	Nagarmotha *(Cyperus scariosus)*	Rhizomes	Heart disease, Loose motion, Ladies disease, body resistance
10	Pachouli *(Pogostemon cablin Benth)*	Oil Scent	oil is itself top quality scent, soap, cosmetic tobacco, cream, Anti worms, Medicine, its juice used in Tuberculosis
11	Pamarosa *(Cymbopogon maritinii var motia)*	Oil	Soap, Cosmetic, Scent, from its oil geranoil extracted which used in Aroma industries
12	Rajnigandha *(Polianthes tuberosa L.)*	Oil & Flower	Oil- in Aroma industries Flower- making Buque, cut flower

WEAKNESS

- Non availability of plus varieties of important medicinal plant species and their planting material.
- Non availability of agronomical practices for important medicinal plant.
- Non availability of authenticated statically information about area, production, productivity consumption, post-harvest management, processing and manufacturing etc.
- Non availability of buy back network for the medicinal crops.
- Non willingness of major Ayurvedic manufactures for guaranteed purchase of cultivated medicinal plant produced directly from farmers or their associations.
- Lack of organized marketing system in the State for Medicinal research and development backup to this sector.
- Poor packaging and post-harvest handling system.
- Non availability of quality parameters.
- Lack of trained analytical hands to determine the quality.
- Non willingness to pay extra cost for cultivated species as compared to wild harvested supply of herbal plant parts by users.
- Soils are low in organic matter.
- The heavy black soils possess problems of workability, low infiltration and poor drainage.
- In large tract of land lack of irrigation facilities which limit the growing period. Short term medicinal species can grow in rain fed condition.
- Bad condition of roads and approaches.

- Flow irrigation system coupled with poor drainage of black cotton soils results in poor yields.
- Lack of proper transport.
- Lack of post-harvest handling infrastructure and technology.
- Poor extension service.
- Lack of proper database for proper planning and development.

OPPORTUNITIES

- Liberalization of economy and statuary controlled by signing WTO agreement.
- Ever increasing global acceptance especially to herbal products.
- Current share in world herbal market is 0.4%. Department of Indian system of medicine has decided to achieve target to 6% by the year 2020. Thus estimated growth rate is 15% in 8 years.
- Profit from export of cultivated agricultural produce is exempted from taxation.
- Enforcement of biodiversity protection act will forcibly initiate a system of contract farming of medicinal plants.
- Enforcement of good manufacturing practices in Ayurveda Pharma industry will automatically force the manufactures to purchase organically cultivated medicinal herbs for ease in analysis.
- Non availability of medicines for chronic disease and physiological disorder like obesity, diabetes, stress in modern medicinal system force patients to adopt alternative herbal drugs.
- Increasing post-harvest facilities and growing demand may result in altering a large number of farmers from all categories to divert their land from traditional crops to medicinal crops.
- Large scope exists for setting up oil extraction and oleoresins unit from medicinal plant produce.
- Certain medicinal plants can grow in the problematic soils. Providing higher returns than traditional crops.

THREATS

- China has emerged as major producer and trader in the global herbal market.
- Highly perishable nature of fresh produce.
- Produce cannot be sold to end users hence this sector is a monopoly of buyers.
- Market is not suitable for small farmers.
- Synthetic materials having identical therapeutic effect and cost involvement is cheaper.
- Flood irrigation in medicinal crops combined with poor permeability and drainage May sometime result in development of salinity of the soils.
- Stagnation of water in the root zone for longer period may actually kill the feeding roots and as a result the growth of the crop is hampered.
- Cultivation of same crop in the same field year after year (mono cropping) may leads to depletion of the vital nutrients and micro nutrients and result in soil sickness.
- Mono cropping may lead to build up pest and disease infestation.
- Sudden increase in production without commensurate development in marketing infrastructure may lead to glut in the market resulting in reduced prices and loss to the growers.

CONCLUSION

Tribal communities of Madhya Pradesh rely heavily on Indian system of medicine such as Ayurveda, Siddha and Unani and are utilizing the plants for food and medicinal purposes. In the past, Ethnobotanical research was predominately a survey of the plants used by local practitioners but in today's world ethnobotany focuses primarily on how plants are used, managed and perceived across human societies to serve different purposes and thus curing different ailments or diseases i.e. respiratory, gastrointestinal, gastro-urinogenital, reproductive etc. Additionally, the medicinal plant wealth being our national heritage seems to be the first and foremost line of defense mostly in tribal and rural communities for the treatment of various disorders or ailments. The plants or plant-based products are serving good purposes to alleviate the occurrence of diseases thus caused. Acknowledgments the author is thankful to the respective college authorities for granting permission to carry out this review work. Conflict of interest there is no conflict of interest.

In the wake of the COVID-19 pandemic, with a heightened global demand for herbal and alternative medicines to boost immunity, there is substantial potential for exporting medicinal plants and products. Consequently, the forest-based herbal market is experiencing remarkable growth, and MP's Forest resources can play a pivotal role in meeting this increasing demand.

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