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ADVANCES IN CHEMICAL AND BIOLOGICAL SCIENCES VOLUME II

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PREFACE

In the boundless realm of scientific exploration, the book is about to delve into stands as a testament to the ceaseless pursuit of knowledge in the chemical and biological sciences. "Advances in Chemical and Biological Sciences" serves as a compass guiding you through the intricate landscapes of molecules, cells, and the fascinating interplay between the two.

As we embark on this intellectual journey, it's crucial to recognize the collective efforts of brilliant minds whose tireless curiosity has fueled the progress documented within these pages. The preface of this book is not just an introduction; it's an ode to the insatiable human spirit that propels us to unravel the mysteries of the microscopic and the macroscopic.

Within these chapters, you'll witness the marriage of theory and experimentation, the fusion of innovation and tradition, all converging to push the boundaries of our understanding. The frontiers of chemical and biological sciences are not static; they are dynamic, ever-evolving landscapes where each discovery begets new questions, and each answer opens the door to uncharted territories.

As you immerse yourself in the narratives penned by experts in their respective fields, anticipate revelations that spark excitement, challenge preconceptions, and inspire further inquiry. The pages ahead are not just a compilation of facts and figures but a tapestry woven with the threads of intellectual curiosity, persistence, and the joy of unraveling the secrets that nature has carefully guarded.

"Advances in Chemical and Biological Sciences" is not merely a book; it's a rendezvous with the forefront of scientific inquiry. So, let the pages turn, let the words unfold, and may your understanding of the chemical and biological world be forever enriched.

Editors:

Dr. Bassa Satyannarayana

Mr. Mukul Machhindra Barawnt

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EFFECT OF *BOUGAINVILLEA SPECTABILIS* LEAF EXTRACT ON SEED GERMINATION AND VIGOUR OF *VIGNA RADIATA* L.

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ABSTRACT

The *Vigna radiata* L. is widely used in diet and it is very beneficial for human health. There are various methods to increase the crop yield and to protect it from pests and herbivores, but most of them are synthetic and harmful for human health. So, there is a need to provide an easy & an affordable method for this. The *Bougainvillea spectabilis* is commonly found in India & the phytochemicals present in this possess various properties which are beneficial for the plant growth. In the present study an attempt is made to study the effect of *Bougainvillea spectabilis* leaf extract on seed germination of Vigna radiata. It has been observed that the *Bougainvillea spectabilis* leaf extract increases the germination percentage of *Vigna radiata* when applied in low concentration.

KEYWORDS: *Bougainvillea spectabilis* , leaf extract, seed germination, Vigna radiata.

INTRODUCTION

Plants are reservoir of different types of naturally occurring bio- organic compounds having a wide range of biological activities. Different parts of plants and their extracts have been used for various purposes since long time ago due to their chemical properties, availability, and simple use without side effects. *Bougainvillea spectabilis* belonging to family Nyctaginaceae is an important horticultural plant. The Bougainvillea is an immensely showy, floriferous, and hardy plant native to South America. The aqueous extract and decoction of this plant have been used as fertility control among the tribal people in many countries. Furthermore, it has been shown to possess anticancer, antidiabetic, antihepatotoxic, anti-inflammatory, antihyperlipidemic, antimicrobial, antioxidant, and antiulcer properties.

Seed germination is a fascinating process. The Bougainvillea leaf extract possess various organic and inorganic chemical compounds. The presence of this chemical will show detrimental effect on the development of plant, germination process, growth of seedling and also effect nutritive value of plant. In the present study, an attempt has been made to study the effect of Bougainvillea leaf extract on seed germination, growth parameters of the *Vigna radiata* L. popularly known as green gram. It is a source of high-quality protein which can be consumed as whole grains. In addition to being the prime source of human food and animal feed, it plays an important role in maintaining the soil fertility by enhancing the soil physical properties and fixing atmospheric nitrogen.

MATERIAL AND METHODS

Preparation of leaf extract: the fresh leaves of Bougainvillea were collected from the college garden. Two types of extract were prepared (Methanolic & aqueous extract). The leaves were shade dried & powdered using electrical grinder. Then 3% leaf extract were prepared by dissolving 3g leaf powder in 100ml methanol & distilled water respectively. These solutions were kept at room temperature for 48 hours. After 48 hours the leaf extracts were filtered by two layer of muslin cloth to remove unwanted material and leaf debris (Indrajitsingh P. Girase et al 2019). Then different concentration (2%, 4%, 6%, 8%, and 10%) of leaf extract was made by diluting with distilled water.

Phytochemical analysis: The phytochemical analysis was done to determine the presence of phenol, flavonoids, saponin & tannin.

Study of seed germination behavior: The sterilized seeds of *Vigna radiata* were placed in Petri plate containing Whatman filter paper. One set of petri plates were irrigated with methanolic extract for the germination. The other set of petriplates with sterilized seed were irrigated with different concentrations aqueous leaf extract. In both the sets the seeds were allowed to germinate for 7 days. A control is made in both the cases by using distilled water instead of using extract.

RESULTS AND DISCUSSION

The methanolic as well as aqueous extract prepared from *Bougainvillea spectabilis* leaves contains various phytochemicals. The phytochemical tests were done to determine the presence of some of these compounds. For this, test for phenols, flavonoids, tannins & saponin were performed separately for methanolic & aqueous extracts. The flavonoids & tannins were found to be present in both the extracts while phenol was found to be absent. Saponin was present in aqueous extract but not found to be present in methanolic extract.

This suggests that the aqueous extract is more beneficial for plant growth because of the presence of saponin as saponin plays an important role in plants such as to protect it against diseases and herbivores, etc

Table 1: Effect of methanolic and aqueous extract on seed germination

Concentration of extract	Germination percentage		Seedling length (cm)		Fresh & dry weight ratio		Seedling vigour index I	
	ME	AE	ME	AE	ME	AE	ME	AE
2%	100	83.33	16.1	25.5	6.63	8.25	1610	2124.91
4%	90	60.00	8.8	12.9	7.61	7.12	792	774
6%	90	63.33	5.2	19.5	9.0	15.42	468	1234.93
8%	80	70.00	5.1	18.6	9.07	14.38	408	1302
10%	50	76.67	2.2	16.2	6.3	13.61	110	1236.54
Control	100	73.33	10.4	16.9	11.07	14.12	1040	1239.27

ME: Methanolic Extract; AE: Aqueous Extract

The seeds of *Vigna radiata* were treated with leaf extract of different concentrations. The methanolic extract and aqueous extract of leaf were used to study the germination. It was observed that the initiation of germination was high in all the concentration of methanolic extract except 10% concentration. The water extract shows the percentage of germination is above 60% in all the concentration. Leaf extract in water content contains growth enhancing substances and can be used as bio stimulants (Fuglie, 2000) for better seed germination The seedling length was found to be more in water extract than in methanolic extract, indicating aqueous extract is more stimulatory than methanolic extract.

The seedling growth is quite good in 2% concentration of aqueous extract. The methanolic extract is not found to be good for the vegetative growth of the plant. The fresh weight to dry weight ratio is very low in plants grown with methanolic extract. At 6% concentration of aqueous extract is suitable for fresh to dry weight ratio. 2% water leaf extract was suitable for Seedling vigour index I. *Vigna radiata* is a commercial crop. To increase crop yield and quality, plant growth regulators are exogenously applied directly to a target plant. (Aasifa et al, 2014) In order to protect the environment many natural sources are used. Bougainvillea leaf extract can be used in such case.

CONCLUSION

The observation made in the study showed that lower concentration of the extract is beneficial for the plant growth. Hence, it can be said that the *Bougainvillea spectabilis* leaf extract increases the performance of seed during seed germination and seedling emergence. Thus, the study suggested that the *Bougainvillea spectabilis* leaf extract could be used safely at lower concentrations for mung crop but further studies should be carried out to identify and isolate the allelochemicals & test it to explore the potential of this plant as growth regulators.

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Chapter

2

NANOTECHNOLOGY IN AGRICULTURE: A PARADIGM SHIFT IN SUSTAINABLE FARMING

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ABSTRACT

Nanotechnology, the manipulation of matter at the nanoscale, has revolutionized various fields, including agriculture. In recent years, it has emerged as a promising tool to address the challenges of modern agriculture and contribute to sustainable food production. This abstract provides an overview of the application of nanotechnology in agriculture and highlights its potential impact on crop productivity, resource efficiency, and environmental sustainability. Nanoparticles, nanosensors, and nanomaterials offer unique advantages in agriculture. They can enhance plant growth and protection through targeted delivery of nutrients, pesticides, and genetic materials, reducing the need for conventional chemical inputs. Nanoscale formulations can also improve soil health, water management, and nutrient utilization, resulting in higher crop yields with reduced environmental impacts. Furthermore, nanotechnology enables precision agriculture, facilitating real-time monitoring of crop conditions, pest infestations, and soil quality. Nanosensors and smart systems allow farmers to make informed decisions, optimizing resource use and reducing wastage. This, in turn, contributes to the conservation of resources and minimizes the environmental footprint of agriculture. While the potential of nanotechnology in agriculture is promising, it also raises concerns related to safety, regulation, and ethical considerations. This abstract discusses the importance of responsible nanomaterials design and comprehensive risk assessments to ensure the safe deployment of nanotechnology in farming practices. Ethical considerations surrounding ownership and distribution of nanotech-related innovations are also touched upon. So nanotechnology in agriculture represents a significant step towards achieving sustainable and efficient food production. It has the potential to transform the agricultural landscape by increasing productivity, conserving resources, and reducing the environmental impact of farming. However, it is essential to address the associated challenges and ensure responsible and ethical deployment to harness the full potential of nanotechnology in agriculture. This abstract serves as a brief introduction to the wide-ranging applications and implications of nanotechnology in the agricultural sector.

KEYWORDS: Nanotechnology, Nanoscale, Sustainable Farming, Agriculture.

INTRODUCTION

Agriculture is at the heart of human civilization, providing sustenance and livelihoods for billions of people worldwide. However, the modern agricultural industry faces a myriad of challenges, from population growth and climate change to dwindling natural resources and environmental degradation. As the global demand for food continues to rise, it becomes increasingly crucial to find innovative and sustainable solutions to meet these challenges head-on. Nanotechnology, the manipulation of materials and structures at the nanoscale (typically in the range of 1 to 100 nanometers), has emerged as a transformative technology with the potential to revolutionize various industries. In the realm of agriculture, the integration of nanotechnology holds the promise of being a true paradigm shift, enabling more efficient, sustainable, and environmentally responsible farming practices.

This introduction provides an overview of the transformative potential of nanotechnology in agriculture, discussing the key issues it addresses, its applications, and the overarching goal of achieving sustainable farming in a rapidly changing world.

ADDRESSING AGRICULTURAL CHALLENGES

Traditional agricultural practices have often relied on resource-intensive methods, including the overuse of chemical fertilizers and pesticides, which have adverse environmental consequences. Soil degradation, water pollution, and the loss of biodiversity are just a few of the problems stemming from these practices. Climate change, with its unpredictable weather patterns and extreme events, adds another layer of complexity. Nanotechnology offers innovative solutions to address these challenges effectively and sustainably. Applications of Nanotechnology in Agriculture: Nanotechnology's applications in agriculture are broad and versatile. Nanoparticles, nanosensors, and nanomaterials can be employed to enhance crop production, improve resource management, and reduce the environmental footprint of farming. Examples include targeted delivery of nutrients, controlled release of pesticides, smart irrigation systems, and real-time monitoring of crop health. These applications not only promise increased crop yields but also reduce the need for excessive chemical inputs.

RESOURCE EFFICIENCY

With the world's finite resources, efficient utilization is paramount. Nanotechnology enables precise nutrient delivery to plants and soil, optimizing resource use. This enhanced resource efficiency ensures that agriculture can meet growing global food demands while minimizing waste and environmental impact.

SUSTAINABLE AGRICULTURE

Sustainability is a defining goal of modern agriculture. Nanotechnology's contributions to sustainable farming extend beyond resource efficiency. By promoting environmentally friendly farming practices, reducing the reliance on harmful chemicals, and improving crop resilience, nanotechnology aligns with the broader vision of sustainable agriculture that safeguards both the environment and future food security.

CHALLENGES AND ETHICAL CONSIDERATIONS

While nanotechnology offers immense promise, it is not without challenges. Safety concerns related to the use of Nanoparticles, potential ecological impacts, and ethical considerations, including issues of access and equity, need to be addressed. Responsible development and application of nanotechnology in agriculture are crucial to ensuring that its benefits are shared widely and that its risks are minimized.

In this context, this exploration of "Nanotechnology in Agriculture: A Paradigm Shift in Sustainable Farming" aims to delve into the diverse and transformative aspects of nanotechnology within the agricultural sector. It provides insights into how this cutting-edge technology can usher in a new era of more sustainable, efficient, and environmentally responsible farming practices, offering potential solutions to some of the most pressing challenges facing agriculture today.

APPLICATION OF NANOMATERIALS IN AGRICULTURE

The application of nanomaterials in agriculture holds great promise for addressing various challenges faced by the agricultural sector. Nanomaterials are materials with structures and properties at the nanoscale (typically between 1 and 100 nanometers), and they can be engineered to have specific characteristics that make them highly effective in agricultural applications. Here are some key areas in which nanomaterials are being used or studied for their potential in agriculture:

(a) NANOPESTICIDES:

Nanoparticles can be used to improve the efficiency of pesticide delivery. They can encapsulate and release pesticides gradually, reducing the amount of chemicals needed and minimizing their environmental impact. Additionally, they can target specific pests or pathogens more effectively. Nanopesticides are a type of agricultural pesticide that incorporates nanotechnology to enhance their effectiveness. Pesticides are chemicals used in agriculture to control and manage pests, such as insects, fungi, weeds, and other organisms that can damage crops and reduce agricultural productivity. Nanotechnology involves working with materials at the nanoscale, typically between 1 and 100 nanometers in size, to create new materials and products with unique properties.

Nanopesticides are designed to improve the delivery, stability, and targeted release of pesticides, making them more efficient and environmentally friendly. Here are some potential advantages of nanopesticides:

(i) **Enhanced efficacy:** Nanopesticides can improve the solubility, dispersion, and penetration of the active ingredients, which can lead to better pest control.

(ii) **Reduced environmental impact:** By increasing the targeted delivery of pesticides to the intended pests, nanopesticides can potentially reduce the amount of chemicals required and minimize their dispersion into the environment.

(iii) **Reduced toxicity to non-target organisms:** Nanopesticides can be designed to release their active ingredients in a controlled manner, reducing the risk to beneficial insects, animals, and humans.

(iv) **Longer shelf life:** Nanotechnology can help improve the stability of pesticide formulations, allowing them to remain effective for longer periods.

(v) **Reduced resistance development:** The targeted delivery and controlled release of pesticides in nanopesticides can potentially slow down the development of pesticide resistance in pest populations.

However, there are also concerns associated with nanopesticides, including potential environmental and health risks. Researchers and regulatory agencies are actively studying and assessing the safety and efficacy of nanopesticides to ensure that their benefits outweigh any potential drawbacks. Regulations surrounding nanopesticides may vary from one region to another, so it's important to follow local guidelines and safety precautions when using them in agricultural practices. Hence nanopesticides were an emerging field of research and development, and further advancements and regulatory developments may have occurred since then.

(b) NANOFERTILIZERS

Nanomaterials can enhance the nutrient delivery to plants. Nano-sized nutrient particles can be designed to release nutrients slowly, improving nutrient uptake by plants and reducing fertilizer runoff. Nanofertilizers are a type of fertilizer that incorporates nanotechnology to enhance nutrient delivery to plants. Fertilizers are essential in agriculture to provide plants with the necessary nutrients for optimal growth and crop production. Nanotechnology involves manipulating materials at the nanoscale, typically between 1 and 100 nanometers in size, to create new materials and products with unique properties.

Nanofertilizers are designed to improve the efficiency and effectiveness of nutrient delivery to plants, which can have several benefits:

(i) **Enhanced nutrient uptake:** Nanofertilizers can improve the solubility and dispersion of nutrients, allowing plants to more efficiently absorb essential elements like nitrogen, phosphorus, and potassium.

(ii) **Controlled release:** Nanotechnology can enable the controlled release of nutrients over time, reducing nutrient loss through leaching and making fertilization more precise.

(iii) **Reduced environmental impact:** By enhancing nutrient absorption, nanofertilizers can potentially reduce the amount of fertilizers needed, minimizing their environmental impact and decreasing the risk of nutrient runoff into water bodies.

(iv) **Increased crop yield and quality:** Better nutrient availability and uptake can lead to higher crop yields and improved product quality.

(v) **Soil health improvement:** Nanofertilizers can enhance soil fertility and microbial activity, promoting long-term soil health and sustainability.

While nanofertilizers offer several potential advantages, there are also concerns and challenges associated with their use, including their long-term environmental impact and safety for human health. Research and regulatory bodies are actively studying and assessing the safety and efficacy of nanofertilizers to ensure that their benefits outweigh any potential drawbacks. Regulations and guidelines for nanofertilizers may vary from one region to another, so it's important for farmers and agricultural practitioners to follow local regulations and safety precautions when using these products. As of my last knowledge update in January 2022, nanofertilizers were an emerging field of research and development, and further advancements and regulatory developments may have occurred since then.

(c) ENHANCED CROP PROTECTION:

Nanomaterials, such as nanoclays and nanosilver, can be incorporated into crop protection products to improve their efficacy. They can act as barriers against pests and diseases or disrupt their reproductive cycles.

(d) SOIL REMEDIATION:

Nanomaterials can be used to remediate contaminated soils. They can help in the removal of heavy metals and other pollutants from the soil, making it suitable for agriculture.

(e) WATER MANAGEMENT:

Nanomaterials can be applied in irrigation systems to reduce water wastage. They can help in the controlled release of water or in soil moisture monitoring through nanosensors.

(f) IMPROVED SEED COATINGS:

Nanocoatings on seeds can provide protection against pests, diseases, and adverse environmental conditions. They can also enhance seed germination and early plant growth.

(g) NUTRIENT DELIVERY:

Nanoparticles can be used to deliver essential nutrients to plants in a targeted and controlled manner. This ensures that plants receive the nutrients they need when they need them.

(h) SMART DELIVERY SYSTEMS:

Nanoscale delivery systems can release agrochemicals in response to specific environmental conditions or plant needs, increasing precision and reducing the environmental impact of these chemicals.

(i) ENHANCED PHOTOSYNTHESIS:

Nanomaterials like carbon nanotubes can be used to improve the efficiency of photosynthesis in plants, potentially increasing crop yields.

(j) NANOSENSORS FOR MONITORING:

Nanosensors can be deployed in the field to monitor soil quality, nutrient levels, and plant health in real-time, allowing for more precise and timely interventions.

(k) DISEASE DIAGNOSIS:

Nanotechnology-based diagnostic tools can help identify diseases and pathogens in plants more rapidly and accurately, enabling quicker responses to outbreaks.

(l) ENVIRONMENTAL IMPACT REDUCTION:

By reducing the need for excessive agrochemical use and improving resource management, nanomaterials can contribute to the reduction of the environmental footprint of agriculture.

It's important to note that while nanomaterials offer significant benefits for agriculture, their safety and potential environmental impacts need to be rigorously studied and regulated. Responsible development and use of nanotechnology in agriculture are essential to ensure that the benefits are realized without causing unintended harm to the environment or human health.

NANO-BIOSENSORS FOR SOIL-PLANT SYSTEMS

Nano-biosensors designed for soil-plant systems have gained significant attention due to their potential to provide real-time, high-resolution data on various aspects of soil quality and plant health. These sensors incorporate nanomaterials and biorecognition elements, such as enzymes or antibodies, to detect specific molecules or parameters in the soil-plant environment. Here are some key applications and benefits of nano-biosensors in soil-plant systems:

Nutrient Monitoring:

Nano-biosensors can be used to monitor soil nutrient levels (e.g., nitrogen, phosphorus, potassium) and detect nutrient imbalances. They can provide real-time data to optimize nutrient application and reduce fertilizer waste.

pH and Salinity Measurement:

Nano-biosensors can measure soil pH and salinity levels, helping farmers make informed decisions about soil amendments and crop selection.

Soil Moisture Sensing: Nanomaterial-based sensors can monitor soil moisture levels, enabling precise irrigation management. This helps conserve water resources and prevent overwatering or under watering.

Detection of Soil Contaminants:

Nano-biosensors can identify pollutants and contaminants in soil, including heavy metals and pesticides. They are valuable tools for soil remediation efforts.

Plant Pathogen Detection:

These sensors can detect pathogens and diseases in plants, providing early warning of outbreaks. This information allows for targeted disease management and reduces crop losses.

Monitoring Plant Health:

Nano-biosensors can assess plant stress, nutrient deficiencies, and other health indicators, enabling timely interventions to enhance plant growth and yield.

Root Zone Monitoring:

These sensors can be placed in the root zone to assess root health, root exudates, and microbial interactions, providing insights into plant-soil interactions.

Data Integration:

Nano-biosensors can be integrated with data analysis software and remote monitoring systems, enabling farmers to receive real-time alerts and make data-driven decisions.

Wireless and IoT Integration:

Advances in nanotechnology and the Internet of Things (IoT) allow for wireless and remote monitoring of soil-plant systems. This enables farmers to access data and control irrigation or fertilization systems from a distance.

Environmental Sustainability:

By providing accurate data on soil conditions and plant health, nano-biosensors help reduce the excessive use of water, fertilizers, and pesticides, promoting sustainable and environmentally friendly agriculture.

Precision Agriculture:

The use of nano-biosensors supports precision agriculture, enabling targeted and efficient resource management while minimizing environmental impact.

Reduced Costs:

By optimizing resource use and improving crop yield and quality, nano-biosensors can help reduce production costs and enhance the overall economic viability of farming operations. While the application of nano-biosensors in soil-plant systems offers many advantages, there are challenges related to sensor reliability, long-term performance, calibration, and the need for standardization. Moreover, data security and privacy concerns should be addressed when deploying IoT-based sensor networks in agriculture. Nonetheless, as technology and research in this field advance, nano-biosensors are poised to play a pivotal role in sustainable and precision agriculture, contributing to increased food production and reduced environmental impact.

NANOMATERIALS FOR SOIL REMEDIATION

Nanomaterials have shown promise in soil remediation due to their unique properties and the potential to address various soil contaminants. Soil contamination can result from various sources, including industrial activities, agriculture, and improper waste disposal. Nanomaterials can help in the remediation of contaminated soils by enhancing the removal or degradation of contaminants. Some key nanomaterials and their applications in soil remediation include:

(i) **Nanoscale Zero-Valent Iron (NZVI):** NZVI particles are commonly used for the remediation of soil contaminated with heavy metals and chlorinated solvents. They can facilitate the reduction and immobilization of heavy metal ions and chlorinated compounds by providing a high surface area for reactions. NZVI can be applied through in-situ injection or as amendments to the soil.

(ii) **Titanium Dioxide (TiO2) Nanoparticles:** TiO2 Nanoparticles are used for the photo catalytic degradation of organic contaminants, such as pesticides, herbicides, and certain persistent organic pollutants. When exposed to ultraviolet (UV) light, TiO2 Nanoparticles can produce highly reactive oxygen species, which break down organic pollutants.

(iii) **Carbon Nanotubes (CNTs):** CNTs have a high surface area and can adsorb a wide range of contaminants, including heavy metals, organic compounds, and pesticides. They can be used as sorbents to capture contaminants from the soil, and their unique properties can help in the removal of pollutants.

(iv) **Nanoclay Minerals:** Nanoclay minerals, such as montmorillonite and halloysite, can be used to immobilize heavy metals and organic contaminants in soil. They have a high cation-exchange capacity and can adsorb contaminants, reducing their mobility and bioavailability.

(v)**Nanoscale Metal Oxides (e.g., Fe_2O_3, MnO_2):** Nanoscale metal oxides can be used to remove heavy metals and metalloids from contaminated soil through sorption and precipitation reactions. They can be applied as amendments to the soil to enhance the removal of specific contaminants.

(vi)**Nanoscale Metal Sulfides:** Nanoscale metal sulfides, like nanoscale iron sulfides, can be used for the immobilization of heavy metals, particularly in sulfide-rich environments. They react with metal ions to form insoluble metal sulfide precipitates.

Nanoscale Bioremediation:

Nanomaterials can also be used to improve bioremediation processes in contaminated soils. For instance, Nanoparticles can serve as carriers for beneficial microorganisms or nutrients, enhancing the degradation of organic pollutants. It's important to note that the use of nanomaterials in soil remediation is an evolving field, and their environmental and health implications should be carefully considered. Regulatory agencies in different countries may have guidelines and restrictions on the use of nanomaterials in environmental remediation. Additionally, site-specific conditions and the type of contaminant present should be considered when selecting the appropriate nanomaterials and remediation approach. Monitoring and risk assessment are essential to ensure the effectiveness and safety of nanomaterials based soil remediation strategies.

NANO-ASSISTED ABIOTIC REMEDIATION OF CONTAMINATED SOILS

Nano-assisted abiotic remediation of contaminated soils is an innovative approach to cleaning up soil pollution using nanomaterials and technologies. Contaminated soils can result from various industrial activities, waste disposal, or accidental spills and they often contain harmful pollutants, such as heavy metals, organic compounds, and other toxic substances. Traditional soil remediation methods can be costly and time-consuming, making the development of more efficient and sustainable techniques essential. Nano-assisted abiotic remediation aims to address these challenges by leveraging nanotechnology for improved soil decontamination. Here are some key aspects of this approach:

Nanomaterials: Nano-assisted remediation uses engineered nanomaterials, such as Nanoparticles, nanoscale zero-valent iron (nZVI), and other nanocatalysts. These materials have a high surface area and reactivity, making them effective for chemical reactions with contaminants in the soil.

Enhanced contaminant removal: Nanomaterials are used to break down or immobilize contaminants in the soil. For example, nZVI can reduce or chemically transform certain pollutants, like chlorinated solvents or heavy metals, into less harmful forms.

Improved mobility and dispersion: Nanomaterials can be designed to disperse and move through the soil more effectively, reaching contaminants in hard-to-reach areas.

Controlled release of reactive agents: Nano-assisted remediation allows for the controlled release of reactive agents over time, minimizing the risk of secondary contamination and providing long-term treatment of polluted soils.

Reduced environmental impact: The targeted and efficient nature of nanoremediation can potentially reduce the amount of chemicals required, as well as the environmental impact of traditional remediation methods.

Precision and cost-effectiveness: This approach can result in more precise and cost-effective soil cleanup processes, leading to shorter remediation times and reduced expenses.

Despite its promise, nano-assisted abiotic remediation faces some challenges and concerns, including the potential release of nanomaterials into the environment, regulatory and safety considerations, and the need for more research to better understand the long-term effects of nanomaterials on soil and ecosystems. It's important to note that the field of nanotechnology and environmental remediation is continually evolving, and regulatory guidelines and best practices are being developed to ensure the safe and effective use of nanomaterials in soil remediation. Researchers and environmental agencies continue to study and assess the potential risks and benefits of this approach to ensure that it can be used safely and effectively in contaminated soil cleanup.

NANO-ASSISTED BIOREMEDIATION OF CONTAMINATED SOILS

Nano-assisted bioremediation of contaminated soils is an emerging approach that combines the principles of nanotechnology and bioremediation to clean up soil pollution more effectively. Bioremediation is a process that uses microorganisms, such as bacteria and fungi, to degrade or transform contaminants in the soil into less harmful forms. The integration of nanotechnology into bioremediation can enhance its efficiency and address some of its limitations. Here are key aspects of nano-assisted bioremediation:

Nanomaterials: Nanomaterials, such as Nanoparticles or nanoscale carriers, are used to enhance the delivery, stability, and effectiveness of bioremediation agents (e.g., microorganisms, enzymes, or nutrients) in contaminated soil.

Improved contaminant accessibility: Nanomaterials can increase the availability of contaminants to microorganisms by altering the soil's physical and chemical properties, making it easier for microbes to degrade or transform pollutants.

Enhanced microbial activity: Nano-assisted bioremediation can promote the growth and activity of beneficial microorganisms by providing a more hospitable environment or protecting them from adverse conditions.

Controlled release of nutrients: Nanomaterials can be engineered to slowly release nutrients, such as nitrogen or phosphorus, to support microbial growth and metabolism, optimizing the bioremediation process.

Targeted treatment: The use of nanocarriers can allow for the precise delivery of bioremediation agents to specific contaminated areas, reducing the need for excessive treatment across the entire site.

Reduced environmental impact: By enhancing the efficiency of bioremediation, this approach can potentially reduce the need for additional chemical amendments and minimize the environmental impact associated with traditional soil cleanup methods.

Despite its potential benefits, nano-assisted bioremediation also comes with challenges and considerations, including the potential ecological impact of nanomaterials and the need for safety assessments. Researchers and regulatory agencies are actively studying and developing guidelines to ensure that the use of nanomaterials in bioremediation is safe and effective. As with other applications of nanotechnology in environmental remediation, the field of nano-assisted bioremediation is evolving, and it's important to stay updated on the latest developments, regulations, and best practices when using this approach for contaminated soil cleanup.

EFFECT OF NANOMATERIALS ON SOIL ORGANIC MATTER

Nanomaterials can have various effects on soil organic matter, and these effects largely depend on the specific characteristics of the nanomaterials and how they interact with soil components. Here are some of the potential impacts of nanomaterials on soil organic matter:

Adsorption and immobilization: Nanomaterials, especially Nanoparticles with high surface areas, can adsorb and immobilize organic matter from the soil. This may lead to the sequestration of organic carbon, reducing its availability for microbial decomposition and affecting soil organic matter dynamics.

Enhanced microbial activity: Some nanomaterials, like nanocarriers or Nanoparticles, may be designed to release organic matter or nutrients gradually, which can promote microbial activity in the soil. This enhanced microbial activity can lead to increased decomposition of organic matter.

Changes in soil structure: The addition of certain nanomaterials can alter soil structure and affect the stability of soil organic matter. For example, some Nanoparticles may modify soil aggregation and enhance the protection of organic matter within aggregates, making it less susceptible to decomposition.

Organic matter degradation: In some cases, nanomaterials might accelerate the degradation of soil organic matter. For instance, reactive nanomaterials, such as certain metal Nanoparticles, can produce oxidative stress in soil microorganisms, leading to increased decomposition rates.

Organic matter protection: Depending on their characteristics, nanomaterials can help protect soil organic matter from degradation. Certain nanomaterials can serve as physical barriers or coatings, shielding organic matter from environmental factors that would otherwise promote its decomposition.

Ecological impacts: The introduction of nanomaterials into soils may have broader ecological consequences, affecting soil microbial communities and nutrient cycling. These impacts can indirectly influence the fate and stability of soil organic matter.

It's essential to note that the effects of nanomaterials on soil organic matter are context-dependent and can vary based on factors like the type of nanomaterials, its concentration, the soil type, and environmental conditions. Researchers continue to study the interactions between nanomaterials and soil organic matter to better understand the potential benefits and risks associated with the use of nanotechnology in agriculture and environmental applications. As this is an evolving field of research, it's important to stay informed about the latest findings and regulatory guidelines to ensure the safe and responsible use of nanomaterials in soil and environmental applications.

NANO-MATERIALS IN PLANT MECHANISM

Nano-materials can enter plants through their roots via passive or active uptake mechanisms. Once inside the plant, these nanomaterials can be transported via the xylem (for water and nutrient transport) or, in some cases, through the phloem (for organic compound transport). The accumulation and distribution of nanomaterials within the plant depend on their properties and the plant's physiological processes. Factors such as the nanomaterials size, charge, plant species, environmental conditions, and soil properties play a significant role in these processes. Understanding how nanomaterials are taken up, transported, and distributed in plants is crucial for assessing their potential impacts on plant health and the environment. Researchers are actively studying these mechanisms, and regulatory guidelines are being developed to ensure the responsible and safe use of nanomaterials in agriculture and other applications.

(a) Uptake and translocation mechanism

The uptake and translocation mechanisms of nanomaterials in plants are complex and depend on various factors, including the type and size of the nanomaterials, plant species, environmental conditions, and the specific route of exposure. Understanding these mechanisms is crucial for assessing the potential impacts of nanomaterials on plant health and the environment. Here are the primary mechanisms by which nanomaterials can be taken up and transported in plants:

Root Uptake:

Passive Uptake: Smaller Nanoparticles can enter plant roots passively through openings like root cell membrane pores. This process is influenced by particle size, surface charge, and the physicochemical properties of the Nanoparticles.

Active Uptake: Some nanomaterials can be actively taken up by plant roots through specific transporters and channels. For example, certain metal Nanoparticles can be transported into the plant through ion transport pathways.

Translocation:

Xylem Transport: After uptake, nanomaterials can be transported within the plant via the xylem. This typically occurs when plants are exposed to nanomaterials in the root zone. The xylem carries water and nutrients from the roots to other parts of the plant, allowing nanomaterials to move along with the water.

Phloem Transport: In some cases, nanomaterials can also be translocated through the phloem, which is responsible for transporting organic compounds, such as sugars and hormones, throughout the plant. This transport mode is less common but can occur when nanomaterials are taken up through other plant parts, like leaves.

(b) Accumulation and Distribution:

Once inside the plant, nanomaterials may accumulate in various plant tissues, including roots, stems, leaves, and reproductive organs. The distribution and accumulation patterns depend on the nanomaterial's properties and the plant's physiological processes.

Size and Charge Effects:

The size and charge of nanomaterials play a crucial role in their uptake and translocation. Smaller Nanoparticles may move more easily through plant tissues, while surface charge can affect interactions with plant cell walls and membranes.

Plant Species Variability:

Different plant species may exhibit variations in their ability to take up and translocate nanomaterials. Some plants may be more efficient at transporting certain types of nanomaterials, while others may show limited translocation.

Environmental Factors:

Environmental conditions, such as soil pH, temperature, and moisture levels, can influence the uptake and translocation of nanomaterials in plants. Soil properties can affect the bioavailability of nanomaterials.

Research in this field is ongoing, and the understanding of how nanomaterials interact with plants is continually evolving. It's important to note that the potential effects of nanomaterials on plant health and the environment depend on a complex interplay of these factors. Regulatory bodies and researchers are working to establish guidelines and safety assessments to ensure the responsible use of nanomaterials in agriculture and other applications.

INFLUENCE OF NANOMATERIALS ON PLANTS

Nanomaterials can have various influences on plants, both positive and negative. The effects of nanomaterials on plants depend on factors such as the type and characteristics of the nanomaterials, plant species, concentration, and exposure routes. Here is a summary of the key influences of nanomaterials on plants:

Positive Influences:

Nutrient Delivery: Nanomaterials can be used in nanofertilizers to enhance nutrient delivery to plants, improving nutrient uptake and crop productivity.

Pest Control: Nanopesticides can provide targeted and efficient pest control, reducing the environmental impact of traditional pesticides.

Improved Plant Health: Some nanomaterials can protect plants from stressors like drought, salinity, and UV radiation, promoting overall plant health and resilience.

Enhanced Photosynthesis: Certain nanomaterials can boost photosynthetic processes, leading to increased plant growth and yield.

Negative Influences:

Toxicity: Some nanomaterials may have toxic effects on plants, inhibiting growth and photosynthesis, and potentially accumulating in plant tissues.

Shifts in Microbial Communities: Nanomaterials can alter soil microbial communities, which can indirectly affect plant health and nutrient cycling.

Complex Interactions: The effects of nanomaterials on plants are context-dependent and can be influenced by factors like concentration, environmental conditions, and the specific nanomaterial used.

It's important to consider the potential benefits and risks of using nanomaterials in agriculture and environmental applications. Researchers are continuously studying these interactions, and regulatory guidelines are being developed to ensure the responsible and sustainable use of nanomaterials in plant-related applications.

(c) Defense mechanism in plant

Nanomaterials can play a role in enhancing the defense mechanisms of plants, aiding them in responding to various environmental stressors and potential threats. Here is a summary of how nanomaterials can contribute to plant defense mechanisms:

Stress Tolerance: Some nanomaterials can improve plant stress tolerance by acting as physical barriers or reflecting stress-inducing factors like UV radiation or excess light. This can reduce the stress on plants and enhance their resilience.

Disease Resistance: Nanomaterials, such as Nanoparticles, can be designed to carry antimicrobial agents or serve as carriers for genes that confer disease resistance. This can protect plants from pathogens and reduce the need for chemical pesticides.

Nutrient Availability: Nanomaterials in nanofertilizers can enhance nutrient uptake and utilization in plants. This improved nutrient status can make plants more robust and better able to withstand various stressors.

Enhanced Photosynthesis: Certain nanomaterials can boost photosynthetic processes in plants, increasing their energy capture and overall growth. This, in turn, can enhance the plant's ability to resist stressors.

Reduced Toxicity: In some cases, nanomaterials can help immobilize or transform toxic elements in the soil, reducing their impact on plant health. For example, nanomaterials may interact with heavy metals, making them less harmful to plants.

Controlled Delivery: Nanomaterials can deliver stress-alleviating compounds, such as antioxidants or growth regulators, in a controlled manner. This can help plants manage stress responses more effectively.

It's important to note that the effects of nanomaterials on plant defense mechanisms can vary depending on factors such as the specific nanomaterial used, its concentration, and the plant species involved. Understanding and fine-tuning the application of nanomaterials in plant defense mechanisms is an area of ongoing research, with the goal of enhancing plant resilience and reducing the need for chemical interventions in agriculture.

CONCLUSION

Nanotechnology has the potential to usher in a paradigm shift in sustainable farming by offering innovative solutions to address some of the pressing challenges in agriculture. While the field is still evolving, and regulatory considerations are essential, the benefits of nanotechnology in agriculture are becoming increasingly evident improved Resource Efficiency, Enhanced Crop Productivity, Environmental Sustainability, Plant Defense Mechanisms, Precision Agriculture, Soil Health etc. As with any emerging technology, the responsible and safe use of nanotechnology in agriculture is paramount. It's crucial to continue research and development in this field, with a focus on understanding potential risks, establishing regulatory guidelines, and addressing ethical concerns. By harnessing the power of nanotechnology, we have the opportunity to revolutionize agriculture, making it more sustainable, productive and environmentally friendly, ultimately ensuring food security for future generations. The evolving field of nanotechnology in agriculture holds great promise for a world striving to meet the challenges of a rapidly changing agricultural landscape.

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Chapter 3

ARTIFICIAL INTELLIGENCE FOR MEDICINAL CHEMISTRY AND DRUG DISCOVERY- APPLICATION AND CHALLENGES

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ABSTRACT

Artificial intelligence (AI) has infused various sectors, including the drug discovery, where it has been utilized to efficiently identify new chemical moieties with desirable properties. Conventional wet laboratory testing, validations, and synthetic procedures are costly and time-consuming for drug discovery. The future in artificial intelligence (AI) techniques has revolutionized their applications to medicinal chemistry and drug discovery. Altogether with accessible data resources, AI techniques are changing the approach of drug discovery. In previous ten years, a series of AI-based models have been developed for various steps of drug discovery. Meanwhile, the algorithms used to modify AI-based models for drug discovery is argued. Subsequently, the applications of AI techniques in pharmaceutical analysis including predicting drug toxicity, drug bioactivity, and drug physicochemical property is discussed. Furthermore, AI-based models for de novo drug design, drug-target structure prediction, drug-target interaction, and binding affinity prediction is discussed. Moreover, it is also highlighted the modern applications of AI in drug activity prediction and nano-medicine design. Finally, the challenges and future perspectives on the applications of AI to drug discovery are discussed here.

KEYWORDS: artificial intelligence, drug discovery, medicinal chemistry.

INTRODUCTION

Medicinal chemistry and drug discovery is a process through which new medications against diseases are synthesized. It involves the use of a wide variety of technologies and expertise. In general, discovering and developing a drug costs billions of rupees and time period of ten to twelve years on an average[1].The less efficacy and high-cost of conventional methods have become the hurdles of drug discovery. Therefore, developing new methods to deal with such a time-consuming and expensive task is necessary.[2]

Artificial intelligence is a field within technology, focuses on developing methods that empower devices to perform tasks typically associated with human sense, such as thinking and learning. AI is having a revolutionary impact on various fields of our lives and spreading across numerous industry sectors, with the pharmaceutical fieldtoo[3]. The value of AI is immense as it serves as a technology that can significantly reduce the extensive time and financial investments required for the discovery of a new drug. When used properly, an AI technology helps analyze large amounts of data, such as structure, functional group, and chemical information, to identify potential drug molecules and predict drug efficacy or toxicity[4]. By evaluating complex datasets and identifying hidden patterns, machine learning (ML) or deep learning (DL) algorithms can find novel targets associated with multitasking data and help find for novel chemical molecules with potent biological activities. They have not only expedited the identification of potential drug candidates but have also proven invaluable in the process of drug repurposing.[5] In the realm of medicinal chemistry, AI has shown promising results in the discovery of new chemical scaffolds with therapeutic potential. It has the capacity to scrutinize vast chemical spaces and extract meaningful patterns, thereby significantly reducing the time required for identifying potential drug candidates.[6] ML/DL algorithms can be trained to predict the biological activities, pharmacokinetic properties, and also toxicity profiles of molecules[7]. Now a day's DL methods can generate novel molecular structures that match desired therapeutic profiles[8-9]. Molecular docking, the method that predicts the interaction between a small molecule and a protein has traditionally been a computationally intensive task. Now a day, AI is being utilized to predict the likelihood of molecular binding, its strength, and the most energetically favorable position, thereby automating this critical process. In addition, it can be utilized to optimize the chemical structures of drug molecule for enhanced efficacy and reduced toxicity. While the promise of AI in medicinal chemistry is profound, the integration of AI into drug discovery pipelines presents on-going challenges[10]. Issues related to the quality and availability of data, interpretability of AI models, and regulatory considerations persist. However, as we head to the on-going digital transformation, it becomes increasingly evident that AI-based approaches hold immense ability to revolutionize drug discovery and reform the field of medicinal chemistry. The main purpose of this article is not only to outline the breakthroughs AI has facilitated but also to critically evaluate where it falls short or poses new challenges.

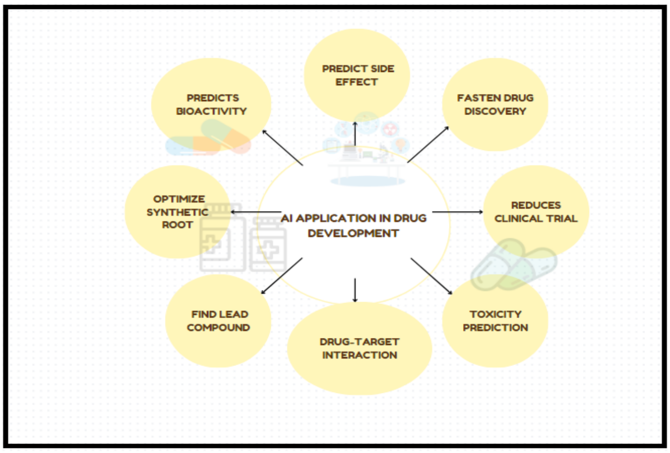

Fig. 1: AI Application in Drug Development

AI IN DRUG DISCOVERY

AI has transformed medicinal chemistry by providing novel tools and approaches for drug discovery, such as deep generative models for molecular design, as well as the extrapolation of drug–target interactions or drug toxicity.[11]

AI plays a significant role in medicinal chemistry by accelerating drug discovery and development. It can:

Drug Design: AI algorithms help design novel compounds with desired properties, reducing the time and cost of drug development.

Predictive Analytics: AI models can predict a molecule's pharmacokinetics, toxicity, and bioavailability.

Drug Repurposing: AI identifies existing drugs that can be repurposed for new medical uses. Biomarker Discovery: AI assists in identifying relevant biomarkers for disease diagnosis and prognosis.

Virtual Screening: AI-based virtual screening techniques quickly analyze large chemical databases to find potential drug candidates.

Optimization: AI optimizes chemical synthesis processes to make drug production more efficient. Personalized Medicine: AI tailors treatments based on a patient's genetic and molecular profile.AI is revolutionizing medicinal chemistry, making drug discovery more efficient and effective.

Clinical trial optimization: AI can analyze patient data from clinical trials to identify patient subgroups that may respond better to a particular drug or predict potential adverse events. This helps optimize the design and recruitment strategies for clinical trials.

AI IN MEDICINAL CHEMISTRY

It refers to the application of artificial intelligence (AI) techniques in the field of chemistry to aid in the discovery and development of new drugs. It involves the use of machine learning algorithms, data mining, and predictive modeling to analyze large datasets of chemical compounds and generate insights that can guide the design and optimization of drug molecules.

SOME WAYS IN WHICH AI IS UTILIZED IN MEDICINAL CHEMISTRY INCLUDE

Compound generation: AI algorithms can generate new chemical compounds with desired properties by predicting their structures and properties based on existing data. This helps in the exploration of chemical space and the identification of novel drug candidates.

Property prediction: AI can predict various properties of chemical compounds, such as solubility, stability, and bioactivity, based on their molecular structures. This enables researchers to prioritize and select compounds with the highest likelihood of success for further development.

Drug repurposing: AI algorithms can analyze large databases of existing drugs and their known targets to identify potential new therapeutic uses for approved drugs. This allows for the repurposing of existing drugs to treat different diseases, potentially saving time and costs compared to developing entirely new drugs.

Toxicity prediction: AI can predict the potential toxicity of chemical compounds based on their structural features and known toxicological data. This helps in identifying compounds with a lower risk of adverse effects and reducing the likelihood of drug failures during development.[13-15]

Optimization of drug properties: AI can assist in optimizing the properties of drug molecules, such as potency, selectivity, and pharmacokinetics. By analyzing large datasets of chemical and biological information, AI algorithms can suggest modifications to improve the desired properties of drug candidates.

The use of AI in medicinal chemistry has the potential to accelerate the drug discovery process by rapidly exploring vast chemical space and generating insights that can guide decision-making. It allows researchers to leverage computational power to analyze and interpret complex chemical data, leading to more efficient and effective drug discovery efforts. However, it is important to note that AI is a tool that complements human expertise and judgment in medicinal chemistry, and the final decision-making still relies on the knowledge and experience of researchers.

AUTHENTICITY IN AI

AI is often seen as a key that can be changing the methods to produce the perfect output, often regardless of input. Whether the AI challenge is to design the perfect image of a cat from a model trained on images of cats, a car that is able to drive itself without making a single mistake, or a drug that can be designed to treat a disease safely and efficaciously. While AI is not the answer to every challenge, it is a useful tool that if used correctly can help to augment current understanding and drive new discoveries. Within medicinal chemistry and drug discovery, the best AI is not necessarily that can automatically design a new drug, but one or many different AIs, that allow better understanding and the design of new inputs, throughout the drug discovery process from target selection, hit identification, lead optimization to preclinical studies and clinical trials.[12]

PREDICTION OF DRUG–TARGET INTERACTION (DTI)

Drug pharmacophore and targeted receptor cells interaction precisely should give faster and efficient output in practice. Drugs control our body's physiological activities to exert therapeutic effects, which are achieved through the interaction between the drug and its target protein, known as drug–target interaction (DTI). Conventionally, the drug discovery approach has been based on the "one molecule–one target–one disease" paradigm, where the drug yields therapeutic effects by regulating its target. In this approach, it is necessary to test whether a particular protein could be a specific drug target for treatment. The importance of DTI research is increasingly recognized, especially regarding side effects, drug repositioning, quantitative structure activity relation and drug resistance. The power of AI is apparent in this target identification and virtual screening. The research carried out on the aspects of ML-based DTIs, namely, prediction of existing ligand binding sites, binding affinity, and binding poses, is eventually aimed at bringing us faster to more efficient drug discovery.[17]

CHALLENGES

The AI techniques are not considered as resourceful tools for the discovery of drug due to the following challenges.

- The key point is the availability of high-quality data that can be used to train AI technique-based models. While the amount of chemical and biological data is increasing, the issue of poor data quality delays the full use of these data.
- Quantity of data is plays second vital role for the applications of AI techniques, the number of positive inputs is smaller than that of negative ones. The input difference problem will directly affect the predictions of the models.
- Another typical issue of AI technique-based models for drug discovery is the lack of understanding and interpretability. A model's interpretability is the degree to which humans can understand the processes it uses to arrive at its result. In most cases, the proposed models fall short in interpreting their biological and pharmaceutical meanings. Hence, trusting the predictive results obtained by AI techniques is difficult for experimental scientists.
- These issues exclude their applications to drug discovery and development. Hence, developing open-source tools or packages, which will become precious sources in the near future, is necessary some resources are shown in table 1. It is believable that AI techniques will bring innovative changes for this area.

Table 1: The resources for AI is majorly from following databases

S.N.	Database	Link
1	ChEMBL	https://chembl.gitbook.io/chembl-interface-documentation/downloads
2	Drug bank	https://go.drugbank.com/data_packages
3	PubMed Central (PMC)	https://pubmed.ncbi.nlm.nih.gov/
4	National centre for biotechnology information	https://www.nibib.nih.gov/content/national-center-biotechnology-information-ncbi
5	National library of medicine	https://www.ncbi.nlm.nih.gov/pmc/

CONCLUSIONS AND FUTURE PERSPECTIVES

Over the past few years, we have perceived the wide applications of AI techniques to various steps of our day today lives and it has changed our lifestyle unexpectedly likewise it would also change the drug discovery and development in medical field in near future undisputedly. The bang of AI techniques has made important contributions to the acceleration of drug discovery. The application of Chat Generative Pre-Trained transformer is also an encouraging topic in medicinal chemistry and development. Subsequently, AI can provide methods to identify potential target molecules, design new drugs, and optimize the pharmacodynamics of drug candidates with reduced toxicity and side effects.

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Chapter 4

FROM SEAWEEDS TO SUPERFOOD: A COMPREHENSIVE ANALYSIS OF BROWN ALGAE'S ECONOMIC IMPACT

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ABSTRACT

Brown algae, belonging to the Class Phaeophyceae, are a large group of multicellular algae that includes many algae found in cold waters of the northern hemisphere. Brown algae are the most important algae in temperate and Polar Regions. They are majorly found on rocky coasts in cooler parts of the world. The vast application potential of brown algae in the fields of renewable energy, biopharmaceuticals, cosmetics, agriculture, food, and nutraceuticals has recently received a lot of attention from around the globe. Brown algae are cheap, sustainable, and renewable sources of food components and pharmaceuticals. Numerous species have been studied in relation to their potential as high-value goods possessing unique pharmacological and biological properties. In this paper, several research done on the uses of certain species are added and these can be further exploited for large scale economic uses.

KEYWORDS: Brown algae, Phaeophyceae, hemisphere, Biopharmaceuticals.

INTRODUCTION

SEAWEEDS, KELPS AND OTHER BROWN ALGAE

The previous research done till date mainly explores the possibilities in a comprehensive way, including outlining how seaweed can be used as a source of macronutrients and micronutrients thus using it in dietary supplements, as well as nutraceuticals. The commercial value of seaweed for human consumption is increasing per year, and some countries harvest several million tons annually. Offering a comprehensive understanding of the capacity of seaweed to influence or effect angiogenesis, tumors, diabetes and glucose control, oxidative stress, fungal infections, inflammation and infection, dermatology, the gut, and the liver, this chapter goes on to highlight the qualities and effects of seaweeds and their use in the food industry. It offers a comprehensive perspective to the interaction between sea vegetables, regional cuisines, nutrition, and health by combining basic knowledge and nutritional context.

The diverse utilization of Phaeophyceae for medicinal purposes include: remedies for goiter, for intestinal afflictions, cancer, in cervix dilation, as laxative, for wound dressing, in cholesterol reduction, bleeding control [1], vermifuge, urinary tract infections, diarrhea, breast infections, tuberculosis, fevers, headaches, cardiovascular diseases, and fungal infections. Throughout the world, these have held a small but significant hold in culture and society. Harvesting large brown algae has been a challenging occupation, which produces status, luxury goods, and "peasant" food alike. Following human consumption rate and the need for good nutrition, we have found uses for the algae as feed for animals, fertilizers, housing materials, medicines, and, today, for industrial purposes. Management institutions and companies have evolved themselves to sustainably harvest these algae and reflect local cultures and traditional values in which all harvesters are recognized.

Giant kelps have long been used by farmers as a useful feed source for livestock and aquaculture, thus using them as an animal feed additive is nothing new [2]. The benefits of a diet high in seaweeds for enhancing animal immunity and general health as well as lowering the overall environmental effect of greenhouse gas emissions from ruminants are then covered. Brown algae are rich in nutrients and low in calories. They also contain fibre, proteins, unsaturated fatty acids (omega 3 and6), vitamins, and minerals. In addition, a number of seaweed byproducts have intriguing qualities for the culinary sector. Thus, this research centres on the effectiveness of a few brown algae species as a possible substitute and as a safe food source. It has high potential to be an important alternative to the world's vegetable diet. Seaweeds are utilized in many different industrial processes because of their diverse inherent properties. Because they are sensitive to heavy metals, they can be employed as a bioremediation or to balance the ecosystem by reducing eutrophication and managing nutrients. It can also be used as fresh food that is edible, a biological fertilizer for crops, etc. The need, demand, and cultivation of brown algae have expanded due to their perplexing multipurpose use and contribution. They have also long been utilized domestically as a rich source of protein that may be added to a variety of food products with additional value and used medicinally for various health benefits, among other uses. The bulk products extracted from its biomass are made into cosmetic formulations. Due to the increasing economic aspect of the cosmetic industry, and the need for harmless, efficient natural raw ingredients, which can be harvested sustainably, has become an utmost necessity. According to certain research reports, algal products used in cosmeceuticals have been known to be suitable natural alternatives for the chemical ones with positive effect even after prolonged usage. Hence diverse algal species are now being used widely for the treatment of various skin related problems worldwide.

DIFFERENT SPECIES OF BROWN ALGAE AND THEIR DIVERSE USES

Among the many vitamins and minerals found in bladder wrack (*Fucus vesiculosus*), which is a species of seaweed, are calcium, iodine, magnesium, potassium, sodium, zinc, and the vitamins A and C. It has been applied topically to treat skin conditions like cellulite, aged skin, and burns. It has a lot of phytochemicals as well. Phlorotannin and fucoxanthin are two of the health-promoting plant compounds that may reduce oxidative stress, which is caused by an imbalance in your body's free radical and antioxidant levels. Its high fiber content promotes a healthy stomach. It is also particularly rich in alginic acid and fucoidans, both of which have beneficial effects on health. It also contains a lot of iodine, a trace element that helps the thyroid produce the hormones triiodothyronine (T3) and thyroxine (T4), which are essential for the health of the thyroid gland. These hormones help in regulating your cell metabolism and it supports proper growth and neurological development of the body.

Phlorotannin, fucoxanthin, alginic acid, and fucoidans are only a few of the antioxidants that are abundant in it. Phlorotannin and fucoxanthin are particularly notable because of their strong antioxidant activity and capacity to scavenge free radicals. Free radicals are dangerous substances that can injure cells, cause chronic disease, and accelerate aging. Brown algae like bladder wrack provide promising anti-inflammatory properties, and may help lower tumor growth, blood sugar levels, and the risk of heart disease, according to several test-tube and rat studies. Seaweed, which includes components comparable to those in bladder wrack, has recently been linked to a 12% lower risk of heart disease in both men and women, according to a study. Seaweed consumption has also been linked to slight improvements in blood sugar regulation. Although bladder wrack could theoretically offer anti-inflammatory benefits and more research is needed. [3]

The species of *Ectocarpus* found in the Southeast Pacific is currently the primary experimental model of choice for the use of genomic and genetic techniques and applications related to the biology of brown algae. The genus *Ectocarpus* has been studied for a long time. It has also been utilized as a comparative model organism to comprehend broad concepts on branching morphogenesis and to study auxin function in morphogenesis among eukaryotes. Because of its relatively small cells (10–30 μm), which allow the uniseriate filaments to be developed in two dimensions and immediately attached to the surface of microscope slides, it is easy to examine under a microscope. *Ectocarpus* is ideally suited for high resolution imaging techniques because of these qualities, especially following fixation and clarity.

Tubulin in this alga can be detected using optimized techniques; however any appropriate antibody can also be used. Immunostaining techniques have been successfully used to explain the cellular alterations brought on by mutations in the pattern-forming *Ectocarpus* genes. In order to study cell wall dynamics during early *Ectocarpus* development and to describe cellular responses to osmotic stress, immunostaining with specific monoclonal antibodies directed against sulfated cell wall polysaccharides has also been used. This method is very useful for further studies and the evaluation of application in biology, changing the economic significance of this alga. [4]

Another brown alga is *Ascophyllum nodosum*. Taking this alga, as it's in the market as ProDen PlaqueOff might help to reduce the build-up of plaque on the teeth. A.N ProDenTM, a special natural substance, derived from the alga, acts through saliva to soften tartar and stop new plaque. The result is in form of visibly whiter, cleaner teeth, and fresher breath, which are usually seen within three to eight weeks with continued use. *Ascophyllum* has developed a natural defensive mechanism against bacterial biofilm. The product is made only from this seaweed and has no additives or other chemicals added. It is human grade and human tested and has a great economic value. *Ascophyllum nodosum* contains iodine, taking this alga can increase iodine levels in women who have low levels of iodine in the body. It is also used for obesity and stomach or intestinal problems [5]. It is also bioactive compound-rich brown seaweed which is demonstrated to have numerous health benefits including antimicrobial and immunomodulatory bioactivities in the pig intestine. In this research, the immunomodulating effects of extracts of brown seaweed (*Ascophyllum nodosum* and *Fucus serratus*) were evaluated on the porcine colon using a bacterial lipopolysaccharide, further studies on the same can help for antibacterial solutions against many diseases.

The protective effect of chemical constituents of the marine brown alga *Spatoglossum* variabile Figari et DE Notar (which are the taxon authors) against CCl4-induced liver damage in Wistar rats was investigated earlier. The compounds were first investigated for in vitro radical scavenging potential and were also tested for β-glucuronidase inhibition to further explore the relationship between hepatoprotection and antiradical potential. And as a result it appears that the hepatoprotection (Hepatoprotection or anti hepatotoxicity is the ability of a chemical substance to prevent damage to the liver.) afforded by these compounds was mainly due to their radical scavenging activity that protected the cells from the free radicals generated by CCl4-induced hepatotoxicity. [6]

Six merodipterpenoids (epitaondiol, epitaondiol monoacetate, diacetate of epitaondiol, stypotriol triacetate, diacetate of 14-ketostypodiol, and stypodiol) were isolated from another species of the same genus, *Stypopodium flabelliforme*, and tested for their ability to inhibit cell proliferation in five different cell lines. Human colon adenocarcinoma (Caco-2), human neuroblastoma (SH-SY5Y), mouse macrophage (RAW.267), rat basophilic leukaemia (RBL-2H3), and Chinese Hamster fibroblasts (V79) were among the cell lines examined. Additionally, *Proteus mirabilis, Bacillus cereus, Enterococcus faecalis, Micrococcus luteus,* *Salmonella typhimurium*, and *Staphylococcus aureus* were used to gauge the compounds' antibacterial activity. total in total, the compounds exhibited good activity against all cell lines; the most sensitive ones were RAW.267 and SH-SY5Y. Three compounds were found to have antibacterial activity: stipodiol, stipotriol triacetate, and epitonediol monoacetate; the former proved to be the most successful. The findings imply that these molecules deserve further studies in order to evaluate their potential as therapeutic agents and thus this alga needs to more excessively manipulated. [7]

Lobophora is a genus of thalloid brown seaweed which has a variety of natural products. There are minerals like cadmium (Cd), copper (Cu), mercury (Hg), iodine (I), nickel (Ni), lead (Pb), and zinc (Zn); Pigments including carotene, chlorophyll a, chlorophyll c, fucoxanthin; Polysaccharides or simple sugars like alginic acid, laminarin; Sugar alcohol like mannitol.[8] In addition, this property may increase its contributions in medicinal application. Sulfated polysaccharides, fucans, from algae *Lobophora variegata* were shown to have anti-inflammatory activity in acute zymosan-induced arthritis in laboratory rats. It resulted in formation of treatments by reducing cell infiltration in the synovial membrane with a decrease in the TNF-α. It was also shown that heterofucans are strong antioxidants.[9] The Heterofucans that can be extracted will exhibit good antioxidant capacity, low hydroxyl radical scavenging activity, good superoxide radical scavenging efficiency (except CC-1.0), and also excellent ferrous chelating ability. This genus also has antiprotozoal activity against parasitic protozoans like *Giardia intestinalis, Entamoeba histolytica* and *Trichomonas vaginalis*. Extract from *L. variegata* shows promising result in the treatments of protozoan mediated infections. The chloroform fraction of the extract contained a major sulfoquinovosyldiacylglycerol(SQDG), identified 1-O-palmitoyl-2-O-myristoyl-3-O-(6´´´-sulfo-a-D-quinovopyranosyl)-glycerol, together with small amounts of 1,2-di-O-palmitoyl-3-O-(6´´´-sulfo-a-D-quinovopyranosyl)-glycerol, and a new compound identified as 1-O-palmitoyl-2-O-oleoyl-3-O-(6´´´-sulfo-a-D-quinovopyranosyl)-glycerol were identified having strong antiprotozoal attributes which in turn can be used against protozoan infections in medical field .[10]

In the seaweed *Dictyota menstrualis*, people have extracted sulfated polysaccharides by proteolytic digestion, followed by separation into 5 fractions by sequential acetone precipitation. Gel electrophoresis was also done using 0.05 M 1, 3-diaminopropane-acetate buffer, pH 9.0, stained with 0.1% toluidine blue; this showed the presence of sulfated polysaccharides in all fractions. Further chemical analyses demonstrated that all fractions are composed mainly of fructose, xylose, galactose, uronic acid, and sulfate. Plant fucans have multiple biological activities, including anticoagulant and antithrombotic agents related to the structural and chemical composition of the polysaccharides. The anticoagulant activity of these heterofucans was determined by activated partial thromboplastin time (APTT) using citrate normal human plasma. This is the first report indicating the presence of a heterofucan with higher anticoagulant activity from brown seaweed. [11]

Six fucans were also isolated from *Canistrocarpus cervicornis* by scientists using a proteolytic digestion method and successive acetone precipitation. Heterofucans showed good ferrous chelating ability, good superoxide radical scavenging efficiency, low hydroxyl radical scavenging activity, and overall antioxidant capacity. These findings unequivocally demonstrated the anticoagulant and antioxidant properties of *C. cervicornis* polysaccharides. In vivo tests, more structural feature research, and purification procedures are required to assess the feasibility of their wider application as medicinal agents. [12]

Padina has adsorption capacity and has been shown to effectively accumulate many pollutants in its biomass. As an excellent bioindicator, *Padina* responds to changes in temperature, light, nutrients and other pollutants in marine ecosystems [13]. One study showed that when the cadmium concentration increased, the specific growth rate and chlorophyll content of *Padina* were adversely affected, indicating Cd contamination. [14] Hence, *Padina* are ecologically significant macroalgae which function as excellent bioindicators of aquatic pollution and potentially, remediation in marine ecosystems.[15]

As sources of different bioactive compounds, *Padina* may have potential applications on many pharmacological aspects [16] An experiment was conducted at the Crop Farm, Eastern University, Sri Lanka to assess the effects of *Padina* antrillarum extract on the flowering of roses from July to September 2020. The treatments were applied at a once-a-week interval. The experimental design was a completely randomized design with three replications. All other management practices were followed uniformly. Measurements were done at once a month. Collected data were analyzed and tabulated. The higher performances in measured parameters (plant height, leaf area, plant biomass, number of flowers per plant) were observed. It showed that once a week application of 20% seaweed liquid extract had the potential to increase growth and flower production in roses. It might be due to the presence of nutrients and the growth hormones in seaweed extract and optimum concentration of seaweed extract received by plants at second treatment. In Treatment 1 and Treatment 3, plants received sub-optimum and higher concentration respectively. This may be the reason for the worst performance of these treatments. From this experiment, it was concluded that weekly application of 20% *P. antrillarum* liquid seaweed extract increased flowering of roses. [17] *Padina minor* hexane extract inhibits the proliferation of 1140 cancer cells through topoisomerase I inhibition. Ethyl acetate extract also shows inhibition of strain 1353, which is sensitive to topoisomerase II inhibitors. The activity for the extracts is considered to be selective or specific as well as differential since the extracts do not show activity against other cell lines [16].

P. pavonica has been well studied since the beginning of the last century and is, environmentally and medically, an important alga, extensively used as a feedstock for the production of biodiesel, in heavy-metal biosorption, as a pollution bioindicator, a trace metal biomonitor, an antioxidant, an anticancer drug (by inducing apoptosis of cancer cells), an antibacterial agent, and a bioinsecticide. [18]

Another study examined interspecific differences in phosphorus (P) content, ability to withstand low salinity, and ability to produce ultraviolet (UV)-absorbing chemicals in an effort to increase the bioremediation and application potential of seaweeds in aquaculture. *Padina australis* and *Sargassum hemiphyllum*, two Phaeophyceae species, showed the greatest tolerance to low salinities, indicating that they might be a good fit for introduction into estuarine brackish water aquaculture systems. Under the usual seawater salinity of 35, *Caulerpa sertularioides* was most effective in absorbing P from the ambient saltwater when growth and P concentration were taken into account.[19]

The sperm attractant of *Zonaria angustata* has been isolated from egg secretions and identified as (+) -(3S,4S)-3[(Z)-l-butenyl]-4-vinylcyclopentene (multifidene) compound. Thus, this can be applied for fertility or IVF treatment purposes. Multifidene, the gamete attractant of the phaeophyta *Cutleria multifida*, another brown algae serves the same. [22] Multifidene has not been reported previously in the Dictyotales but it is now known to occur in the egg secretions of *Chorda tomentosa* (*Laminaria*les) also. [20]

Sulphated polysaccharides isolated from brown seaweeds *Saccharina japonica* (formerly named *Laminaria*) and *Undaria pinnatifida* have been tested successfully for their antitumour or anti-carcinogenic activity against human breast cancer T-47D and melanoma SK-MEL-28 cell lines[21]. Four phytochemicals isolated from *Halimeda stuposa* and *Dictyota sp*, xenican diterpene 4-hydroxydictiolactone (i) and diterpene dictyol E (ii), 8,11-dihydroxypachydictyol A (iii) and indole-3-carboxaldehyde (iv)., was tested for cytotoxic activity against the human and mammalian cell lines SF-268, MCF-7, H460, HT-29, and CHO-K1 and found useful for further applications. It inhibits proliferation and colony formation of breast cancer and melanoma cell lines in a dose-dependent manner.

The brown algae *S. japonica* and *U. pinnatifida* is a potential component of cancer therapy [22]. *Sargassum oligocystum* aqueous extract shows anticancer activity against human cancer cell lines such as Daudi and K562.

The outcome also indicates that this alga's cold water extract exhibits activity that is similar to that of the hot water extract. This demonstrates the heat sensitivity of bioactive chemicals. Other *Sargassum* species, such as *S. confusum, S. fusiforme, S. kjellmanianum*, and *S. lomentaria*, have been shown to have immunostimulatory qualities, induce apoptosis in tumor-bearing mice, and be cytotoxic to specific human cancer cells [23].

Biodegradable films have been created using fucoidan and fucoidan polysaccharides that are derived from brown algae, like *Sargassum natto*. [24]

Fucoidan has various biological and pharmacological activities and brown seaweeds are the main marine producers of this polymer including the following seaweed species: *Cladosiphon* sp.; *Macrocystis pyrifera; Ecklonia radiata; Seirococcus axillaris; Saccharina latissima; Fucus vesiculosus; F. serratus; Fucus evanescens; F. distichus; F. spiralis; Laminaria digitata; Dictyosiphon foeniculaceus; Dictyopteris delicatula; Undaria pinnatifida; S. japonica* (formerly known as *Laminaria japonica*); *Ascophyllum nodosum*; *Durvillaea potatorum; Sargassum sp.* and *Padina boryana* (formerly known as *Padina commersonii*).[25]

The extract of the brown alga *Taonamaria atomaria* exhibits anticancer activity due to the compound present in them, stypoldione which act as an in vitro inhibitor of microtubule polymerization and it prolongs the survival of mice injected with tumour cells due to its low toxicity [25].

In another recent study, antitumour and antimetastatic property and activities of fucoidans, isolated from the brown seaweed *Fucus evanescens* have also been successfully tested against C57Bl/6 transplanted mice with Lewis lung adenocarcinoma [26].

Phloroglucinol is an organic compound with the formula $C_6H_3(OH)_3$. It is extensively used in the synthesis of pharmaceuticals and explosives. Three phloroglucinols with a C-20 acyl side chain were isolated from the marine brown alga *Zonaria diesingiana*. They all showed antibacterial activity against *Bacillus subtilis* and *Staphylococcus aureus* and also cytotoxic activity by inhibiting the cell division in fertilized sea urchin eggs (*Echinometra mathaei*). Phloroglucinols were also demonstrated to be poisonous to rice-land shrimp (*Macrobrachium lanchesteri*), brine shrimp (*Artemia salina*), guppy fish (*Poecilia reticulata*), and the diatom *Chaetoceros gracilis*. They likely serve as chemical defences against herbivores and lessen surface fouling by epiphytic algae and larvae, indicating their dual roles as eradicators and defences in the marine ecosystem. [27]

Initial studies on the anti-Leishmania amazonensis action of aromatic acid, the main component in a lipophilic extract from the brown alga *Stypopodium zonale*, showed significant dose-dependent inhibitory effect for intracellular amastigotes. It can be utilized to fractionate the lipophilic extract because of its strong anti-Leishmania efficacy and minimal damage to host cells. Nuclear magnetic resonance (NMR) spectroscopy was used to determine the main mediterpene atomic acids in this extract as well as their methyl ester derivatives produced by the methylation process. With IC50 values of 20.2 μM (9 μg/ml) and 22.9 μM (10 μg/ml) and selectivity indices of 8.4 μM and 11.5 μM, both drugs suppressed intracellular amastigote. Both meloditerpenes' leishmanial action was unrelated to the synthesis of nitric oxide (NO), although reactive oxygen species (ROS) formation may be at least partially responsible for amastigote killing. The results suggest that the lipophilic extract of *S. zonale* may represent an important source of compounds for the development of anti-Leishmania drugs. [28]

Chloroform and methanol fractions of an ethanol extract of *Spatoglossum asperum* showed antifungal activity against the highly destructive plant pathogen, *Macrophomina phaseolina* while the n-hexane fraction showed activity against fungus *Rhizoctonia solani* which can cause Rhizoctonia root rot and *Fusarium solani* which can cause disseminated disease, osteomyelitis, skin infection, fungemia, and endophthalmitis. n-Hexane and methanol fractions of *S. asperum* also showed nematocidal activity against the plant parasitic nematode, *Meloidogyne javanica*. Oily fractions SA-I to SA-VI were obtained by column chromatography of the seaweed ethanol extract, and GC-MS analysis of these oily fractions revealed the presence of several fatty acid esters. A few of these oily components showed potent nematicidal and antifungal properties. Without adversely affecting liver or heart enzymes, oily fractions of *S. asperum* also demonstrated hypolipidaemic activity in rats that were hyperlipidaemic due to a high-fat diet, triton, or both. [29]

The primary nutrients found in brown macroalgae harvested from the central Portuguese coast, *Saccorhiza polyschides* and *Undaria pinnatifida*, were identified. The macroelements (Ca+Mg+Na+K+P) and oligoelements (Cu+Fe+Mn+Se+Zn) in the chosen species varied from 60 (*U. pinnatifida*) to 655μg g-1 (*U. pinnatifida*), according to the results, indicating a sustainable source of minerals. The low Na/K levels (0.3–3.7) indicated that certain species may be particularly beneficial nutritionally for hypertension sufferers. [27]

The highest contents of Ferrous which was of 552μg g-1 was found in *U. pinnatifida* and Se of 30μg g-1 in *S. polyschides*, suggest the increased proportion of these oligo elements can be achieved by the inclusion of macroalgal species in the diet, rather than some traditionally taken food items. The total content of proteins (15.5-24%), carbohydrates (52-62%), crude fibres (14-32%), and lipids (0.9-4.8%) indicated that the selected macroalgae were relatively low-calorie food and hence can also be used as a fitness supplement.[27]

To investigate their potential for use as inexpensive adsorbents, the removal of malachite green dye from aqueous solution by the brown algae *Ulva lactuca*, the red algae *Gracilaria corticata*, and *Sargassum crassifolium* has been proven. Under ideal circumstances, *Sargassum crassifolium* may remove a maximum of 95.6% to 98.3% of the dye. The FT-IR investigations verified that the dye binding process was primarily attributed to hydroxyl, carboxyl, amino, and carbonyl groups. Large porosity, which permits dye molecules to flow easily, was visible on the algae's surface when examined under a scanning electron microscope.

Brown algal biomass was the most effective at removing malachite green, followed by green algae and red algae, and has been suggested to be due to large pores on its surface. [28] The biosorption efficiency and capacity of methylene blue (MB) dye from aqueous solutions by untreated and pretreated (physically and chemically) brown *Nizamuddinia zanardinii* algae were studied. Of the 17 pretreatment chemicals tested, sodium thiosulfate was found to be the most effective. Various concentrations of these chemicals and sodium chloride were investigated further in the range of 0–2 M to obtain the optimal concentration for pretreatment.

Pretreatment with sodium chloride (0.1 M) may facilitate pigment removal by macroalgae. In addition, we investigated MB dye biosorption efficiency as a function of contact time in macroalgae treated with brine, initial dye concentration, and sodium chloride. Algal surface morphology was characterized by scanning electron microscopy (SEM). The results of this study showed potential advantages of using *N. zanardinii* macroalgae for MB pigment removal from water. [29]

Focusing on seaweeds that can be farmed, like *Saccharina latissima*, or gathered in the wild, such *Ascophyllum nodosum*, is crucial for overcoming environmental variables because these species develop better in aquaculture systems [29]. Seaweed aquaculture offers novel approaches to regulate or standardize the nutritional content of seaweeds because wild seaweeds have a highly variable composition due to their quick adaptation to biotic and abiotic stimuli. When opposed to wild seaweeds, nutritional qualities under aquaculture settings can be more closely regulated and standardized, making them a valuable source of food supplementation in areas stricken by malnutrition. [30]

Seaweeds are included in the “novel foods” regulations in Europe [31], and in the USA the use of brown seaweeds, named “kelp” (*Laminaria sp., Macrocystis sp.*), as human food is authorized by the Food and Drug Administration (FDA) [32]

With the exception of *Undaria pinnatida*, or "wakame," which has a higher protein level (11–24 g/100 g of dry weight), brown algae generally have the lowest protein content (7–16 g/100 g of dry weight). As a result, it makes a fantastic protein supplement. [31]

Because the storage polysaccharides have textural and stabilizing qualities, the hydrocolloid industry extracts them extensively and uses them in food applications. Alginate is the most prevalent storage polysaccharide found in brown seaweeds, accounting for up to 70% of their dry weight. Other minor polysaccharides like laminarin and fucoidan are next in line. Different brown algae species have different alginate contents. *Turbinaria conoides, Laminaria hyperborea, Sargassum silicosum, Sargassum bacularia*, and *Sargassum aquifolium* (formerly known as *Sargassum binderi*) all have an alginate output of 26.7%, 38.7%, 40.8%, 41.4%, and 49.9%, respectively. Therefore, it can be used as a source for extracting algin. [36.37]

Table 1: Nutrient composition of selected edible seaweed (% dry weight), adapted from [33] which can be inculcated in the diet.

Species	Protein	carbohydrate	Dietary fiber	lipid
Fucus vesiculosus	3–14	46.8	45–59	1.9
Saccharina japonica	7–8	51.9	10–41	1.0–1.9
Sargassum fusiforme	11.6	30.6	17–69	1.4
Undaria pinnatifida	12–23	45–51	16–51	1.1–4.5

Good fats are polyunsaturated fats, sometimes known as polyunsaturated fatty acids, or PUFA. This kind of fat is beneficial to heart health. For human health, both ω-3 and ω-6 polyunsaturated fatty acids (PUFAs) must come from a balanced diet. The optimal ω-6:ω-3 ratio is linked to improved brain and immune system performance, as well as a lower risk of cardiovascular and other chronic diseases like diabetes. It should be between 3:1 and 5:1. This ratio typically falls between 0.2 and 2.4 in brown algal species. [33,34,35] Thus, as a promotion of health benefiting components, consumption of seaweed products should be encouraged.

Sodium alginate is often extracted from *Saccharina japonica* and *Laminaria*. Similar to other algins, sodium alginate forms viscous solutions and gels when dissolved in water hence can be used in gel medium preparations, or in confectionery and bakery [39]. All brown algae include sodium alginate in its intercellular matrix and cell wall, which allows it to chelate metal ions and absorb water rapidly. The elasticity and mechanical strength that macroalgae require to live in the ocean are provided by sodium alginate. In order to maintain the smooth texture of frozen foods and enhance the look of bakery goods, sodium alginate is frequently employed as a viscosity modifier in the food sector. In order to improve the look of dairy goods, canned meals, and water retention, it is even dehydrated. Brown algae are essential to the food sector since it is frequently used to stabilize beer foam. [40,41]

Brown algae by-products are often used as dietary supplements for broilers. Adding 0.5% of brown algae by products to broiler diets can increase body weight, improve serum levels, immune responses and reduce mortality [31]

Brown seaweeds, such as *Saccharina latissima* and *Laminaria digitata*, were rich in I (respectively, 4600 and 10,000 mg/Kg of dry seaweed). Seaweeds, which contain more of these chemicals than terrestrial or freshwater food products, are essential to the human diet because of their capacity to absorb and collect these components from their ecosystem. Dietary iodine excess can cause hyperthyroidism and thyrotoxicosis. Therefore, one must use caution when consuming seaweeds, especially brown ones with greater concentrations of I. [31]

Dieckol (a hexamer) is a phlorotannin present in the brown seaweeds *Ecklonia* species. It is isolated from *Ecklonia cava* which exhibits antioxidant, hepatoprotective and anticoagulant activities. [42]

Typically, hijiki alga is marketed to make salads, soups, and Korean vegetable dishes. It is typically served as an appetiser or starter in Japanese or Korean restaurants. In East Asia, the antiproliferative properties of fucoidan were also studied on three regional hijiki (*Hizikia fusiforme*) samples (from China and Korea). To reduce the amount of heavy metals in hijiki, 1% citric acid was used during processing. Using diethylaminoethyl cellulose ion-exchange chromatography, the JH sample was divided into four active fractions (JHCF1-JHCF4). High-performance liquid chromatography was then used to determine the monosaccharide content of these fractions. Using Fourier transform infrared spectroscopy, the structures of the crude polysaccharide and the four fucoidan fractions were examined. In 48 hours, JHCF4 had the highest fucose and sulphate content and the lowest growth of Hep3B cells and with a half-maximal inhibitory concentration of 33.53 ± 2.50 μg/ml, which represented the strongest anticancer activity. [43] Customers were cautioned by a number of government food safety bodies not to eat Hijiki seaweed. According to Test 41's results, the seaweed's inorganic arsenic levels were considerably greater than those of other varieties, rendering it unfit for human consumption. [44]

Farmers, gardeners, and horticulturists are using more and more liquid extracts and dried or fresh seaweeds as fertilizers. Seashore plants benefit greatly from the fertilizing properties of giant kelps, or *Laminaria*. These days, seaweed extracts can be bought commercially under the names cytokine, maxi crop, seasol, SM3, and kelpak. The microelements and plant growth regulators like cytokinin included in seaweed extract are what give it its effects. Seaweed extract is applied to soil, used as a foliar spray, and used to soak seeds before to planting. It improves seed germination, boosts nutrient intake by plants, and confers resistance against fungal and frost diseases. Extracts from seaweed are applied topically, applied topically in the soil, and used to soak seeds prior to planting. It increases resistance to frost and fungal diseases, boosts seed germination, and increases plant intake of nutrients.

Algae extracts are effective in fruit ripening, extend product shelf life, improve product quality and act as excellent soil conditioners. Extracts of brown algae such as *Ecklonia radiata, Fucus serratus, Laminaria digitata* and *Macrocystis pyrifera* are commonly used in the production of plant growth promoters in agriculture and horticulture. [45]

Stems and stalks of *Durvillaea antarctica* and *D. incurvata* are harvested offshore Chile and used in Chilean cuisine in a variety of recipes, including salads and stews. [46] Together with *D. poha, D. antarctica* blades are used to make traditional pōhā bags used for transporting and storing food and fresh water, breeding live shellfish, and making sports clothing and equipment. [47].

Talking about, skincare and cosmetology, *Chnoospora minima*, *Ecklonia cava*, *Ecklonia kurome, Ecklonia Stolonifera, Eisenia arborea, Eisenia bicyclis, Halopteris scoparia, Ishige okamurae, Padina tetrastromatic, Petalonia binghamiae, Sargassum hemiphyllum, Sargassum horneri* are important. These algal species show anti inflammatory activity and hence is used in cosmetology by producing fucoidan, dieckol, phlorotannins etc.[48]

The phlorotannins found in *Macrocystis pyrifera* and the alginate, fucoidan, and laminarin found in *Turbinaria conoides*, are the secondary metabolites of brown algae that function as antioxidants to delay the ageing process of the skin. [49] Research has also revealed that the methanol extract of *Macrocystis pyrifera*, also referred to as big kelp or bladder kelp, contains hyaluronic acid and improved the synthesis of syndecan-4, a protein that is helpful in the synthesis of anti-aging products and is a component of the extracellular matrix. [50]

In tests conducted on UVA-irradiated dermal fibroblasts, the *Sargassum horneri* compound sarga-chromanol E was found to protect against UVA-induced collagen degradation by suppressing MMP production. *Sarga chromanol* E has been shown to be useful in avoiding skin aging and may have use in cosmetics due to its ability to reduce the generation of ROS and lipid peroxidation. [51]

The tyrosinase enzyme is responsible for pigmentation. Brown seaweeds that is rich in phloroglucinol, has tyrosinase inhibitor activities which can chelate copper in this enzyme. (52) Apart from that, phlorotannin (7-phloroeckol) from *Ecklonia cava* and zeaxanthin from *Nannochloropsis oculata* have skin whitening activities by inhibiting tyrosinase [53,54] Another bioactive compound, fucoxanthin from *Laminaria japonica*, has been treated on UVB-irradiated guinea pigs and melanogenesis in UVB irradiated mice. It was reported that this compound had reduced the tyrosinase activity. [54]

The results obtained in another study reveals that the potential of brown macroalgae is a promising alternative source of antimicrobial compounds as functional ingredients for its vast application in industrial fields. Three species, *Bifurcaria bifurcata, Ericaria selaginoides*, and *Dictyota dichotoma* from the Dictyotaceae family, all exhibited antibacterial action when mid-polarity extracts from brown macroalgae used in this study were applied. Regardless of the species under consideration, all the extracts displayed the same range of antimicrobial activity against six Gram-positive bacteria, including spoilage microorganisms like *Geobacillus stearothermophilus*, spore-forming bacteria that continue to pose a significant challenge in the dairy industry, the opportunistic pathogen *Staphylococcus haemolyticus*, and the spore-forming bacterias and spore-forming fungi. The MIC/MBC values obtained for *E. selaginoides* and *B. bifurcate* showed that each macroalgae extract had a different overall quantitative antibacterial potential profile against the six target microorganisms despite having the same antimicrobial spectrum. The MIC/MBC values could not be estimated due to the rarity of *D. dichotoma* along Spain's northern coast. [55]

Depolymerized fucoidans exhibit more superior antibacterial activity than unprocessed fucoidans, which is enhanced by their low molecular weight and strong anionic characteristics. While native fucoidan lacked any antibacterial activity, depolymerized fucoidan from *L. japonica* successfully reduced the growth of *Escherichia coli* and *Staphylococcus aureus*.

By concentrating on the membrane proteins, the depolymerized fucoidan breaks down the biomembranes, altering membrane fluidity and/or activating autophagocytosis.

By exerting a synergistic effect, fucoidans can improve the pharmacological action of other therapeutic molecules in the fight against pathogenic microorganisms [56]. When combined with ampicillin and gentamicin, fucoidans isolated from a variety of brown algae species were found to have antibacterial activity against cariogenic and periodonto-pathogenic bacterial strains, according to Lee *et al.* [57]. When used in synergism with fucoidans, antibiotics demonstrated a larger reduction in bacterial growth than when used alone.

In the studies related to phaeophyceae as biocontrol agents, Brown algae (*Leathesia nana*) and red algae (*Rhodomela confervoides*) contain bromophenol bis(2,3 dibrom-4,5- dihydroxybenzyl) ether which is an antifungal substance which reduced *B. cinerea* growth and *Colletotrichum gloeosporioides*.[58]

Strawberries can be treated with bromophenol (BDDE), a substance obtained from brown and red algae, to reduce *B. cinerea*-caused illness. Many plant species have been effectively tested using extracts from brown algae (*A. nodosum*), particularly carrot against *Alternaria radicina* [59] and cucumber against *F. oxysporum*, *Alternaria cucumerinum*, and *B. cinerea*[60].

Due to their ability to fight off drug-resistant infections, marine macroalgae are used in the pharmaceutical industry [61]. By inhibiting efflux pumps, the macroalgal compounds can either increase the effectiveness of other antimicrobial compounds or have inherent antibacterial capabilities [62]. The antibacterial activity of seaweed polysaccharides is influenced by molecular weight, charge density, sulfated content, structural features, and conformation, just as other biological functions [63]. Protein leakage and membrane instability are caused by interactions between the antimicrobial polysaccharides from macroalgae and the glyco-receptors of bacterial cell walls and membranes [64].

Treatment with fucoidan can decrease the elevated levels of TNF- and IL-1 caused by alcohol while increasing the levels of IL-10 and TGF-. Fucoidan inhibits the activation of microglia cells, which are the main cells implicated in the inflammatory response associated to neurotoxicity brought on by alcohol use, upregulates the expression of CD68 in the hippocampus, down regulates the TLR4/MyD88/NF-B p65 pathway, and raises the expression of CD68 in the hippocampus. By modifying the gut-microbiota-brain axis, fucoidan treatment reduces the depressive-like behaviors brought on by alcohol use [65].

Fucoidan from *Turbinaria decurrens* has been shown in immunohistochemistry and immunoblotting studies in Parkinson's disease-induced mice to have neuroprotective effects on dopaminergic neurons by increasing levels of antioxidants, dopamine, dopamine transporter, and tyrosine hydroxylase[67]. Parkinson's disease is brought on by the neurotoxin MPTP (1-methyl-4-phenyl-1, 2, 3, 6-tetrahydropyridine), which kills the dopaminergic neurons in the substantia nigra and corpus striatum of the brain.

It has been claimed that the fucoidan that has been commercially isolated from the brown seaweed *F. vesiculosus* has anti-adipogenic and lipolytic properties. Fucoidan was isolated from *F. vesiculosus* in four separate fractions (F0.5/F0.9/F1.1/F2.0), all of which demonstrated lipolytic effects on adipocytes. Additionally, the expression of crucial adipogenic proteins (C/EBP, C/EBP, and PPAR) was inhibited by the F1.1 and F2.0 fractions, impeding the development of pre-adipocytes. The other two fractions, F0.5 and F0.9, on the other hand, exhibited an adipogenic effect. The F2.0 fraction can be employed as an anti-obesogenic agent since it has anti-adipogenic effect and three times more lipolytic action than the other fractions.[66]

It was also found that oral administration of fucoidan from *Cladosiphon okamuranus* greatly increased the activation of natural killer cells in male cancer survivors. This was replicated in another clinical investigation on cancer survivors.[68] Fucoidan's anticancer properties and effectiveness in inducing apoptosis point to the possibility of its development as a robust treatment regimen against several cancer cell types [69].

CONCLUSION

This review chapter is an attempt to highlight the vast potential and versatility of brown algae as a valuable resource in various industries. Brown algae, with its diverse marine genera, offer not only food and fodder but also a rich source of secondary metabolites and chemical compounds. It stands out as a main representative of polysaccharides and fucoidans, which are responsible for remarkable biological activities. The up gradation of algal fuel and bioproducts technology from pilot scale to commercial level in agriculture, cosmetology, food, and medical fields is not only feasible but essential. To achieve this transition, we must address the associated challenges and limitations by implementing more innovative and manipulative methods and conducting further research and usage experimentation.

This chapter has extensively reviewed published research and studies on the economically important applications of brown algae, revealing that while some processes are already in use, many others are ripe for exploration. Future studies should focus on manipulation, product design, optimization, availability, and intensification to fully unlock the potential of brown algae in various industries. In essence, this comprehensive and critical literature review of the functional properties of brown algae serves as a valuable resource for researchers and professionals in their pursuit of sustainable and innovative solutions. By harnessing the potential of brown algae, we can address the growing demand for environmentally friendly products and contribute to the betterment of humankind.

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Chapter
5

A REVIEW ON SYNTHESIS OF SELENIUM NANOPARTICLE AND ITS BIO-ACTIVITY

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ABSTRACT

Selenium nanoparticles (SeNPs) are well-known bioactive compounds with essential micronutrient element. Various chemical, physical and biological methods have been applied to SeNPs synthesis. Selenium is an important dietary micronutrient required for the normal physiology and metabolism of humans and animals. The biological properties of selenium nano particle depend on their size and forms. Selenium nanoparticles have many biomedical applications as both therapeutic agents and delivery systems.

KEYWORDS: Selenium nanoparticles, SeNP synthesis, biomedical applications.

INTRODUCTION

Elemental selenium (Se) has great importance in the fields of physics, chemistry, and biology. Obviously, selenium exists in two forms: inorganic (selenite and selenate) and organic (selenomethionine and selenocysteine). Selenium is found in the form of both crystalline and amorphus polymorphic structures in the nature. Selenium is an essential element in human and animal body in low concentration. It is a necessary dietary constituent of at least 25 human selenoproteins and enzymes containing selenocysteine (Zhang and Spallholz, 2011).

Selenium is an essential micronutrient element in the body that play a key role as an antioxidant, anticarcinogen, antiviral and immune response enhancer through its incorporation into selenoproteins in the form of the redox-active amino acid selenocysteine (Lei, 2022). In recent years, several studies have pointed out the ability of selenium nanoparticles to exhibit anticancer, antioxidant, antibacterial and anti-biofilm properties. So far, evidences have been proven to displayed remarkable antimicrobial activity of them against pathogenic bacteria, fungi and yeasts (Mahsa and Tahereh, 2020).

Selenium NPs have high photoconductivity, catalytic action in hydration and oxidation reactions! (Stroyuk *et al.*, 2008), and they have high piezoelectric, thermo electric, and non linear optical responses! (Chen *et al.*, 2010). Selenium, a nutrient element that has a massive function in biological systems, is one of the interesting compounds to integrate with antibacterial agents. Selenium is an essential trace element in the diet, required for maintenance of health and growth (Skalickova, *et al.*, 2017).

The Mechanisms underlying the Protective Actions of Selenium Nanoparticles against Ischemia/Re oxygenation are mediated by the Activation of the Ca2+ Signaling System of astrocytes and reactive astrogliosis!!! (Varlamova *et al.*,2021). Selenium supplements are promoted to offer several benefits, including boosting immune function, improving hair and nail health, and supporting a healthy thyroid. Selenium nanoparticles have gained attention in the electronics and optics industries for their special physical characteristics; such as photoelectric, X-ray sensing properties, and catalytic properties. (Chaudhary *et al.*, 2016). The SeNPs bear numerous outstanding biomedical features and shows enhanced biocompatibility and degradability when compared to other metal nanoparticles (Zhang *et al.*, 2021; Kumar, 2022).

They are sometimes combined with other antioxidant vitamins such as vitamin E or C (Mahsa and Tahereh 2020). Besides improving the photosynthetic activity, increasing the direct quenching of ROS, and up regulating both the enzymatic and no enzymatic parts of the antioxidant defense system, Se can helps to decrease plant cell membrane damage. (Lqra*et al.*, 2021). Nanostructured selenium increases the surface area available to interact with and kill bacteria in addition to changing the surface morphology to ultimately inhibit the attachment of bacteria. Additionally, SeNPs have shown a sevenfold lower acute toxicity than sodium selenite in mice showing less prooxidative effects.

Mahsa and Tahereh 2020 highlighted the design of nanohybrid systems with synergistic antibacterial properties to overcome the emerging antibiotic resistance as well as to define fruitful applications in biomedicine and food safety. They chemically synthesized mono disperse SeNPs *using* Ascorbic acid with biocompatibility and good reducing properties. Selenium oxyanion (SeO32) was formed in aqueous medium. When this solution reacted with ascorbic acid, selenium was reduced to elemental selenium (Se0). Zhizeng et al 2018 established a simple, rapid and convenient method for the preparation of selenium nanoparticles that can be used as labels in Lateral flow immunoassays (LFIAs). LFIAs had been applying widely in clinical diagnosis, food safety, drug abuse, environmental monitoring and other fields due to their characteristics of rapidity, sensitivity, stability and low cost.

Mohamed *et al.*, 2021 obtained the SeNPs from Lacticaseibacillusparacasei HM1 could be used to prepared biological antifungal formulations effective against major animal pathogenic fungi. In vivo studies showing the antagonistic effect of SeNPs on pathogenic fungi are underway to demonstrate the potential of a therapeutic agent to treat animals against major infectious fungal diseases. Deepa *et al.*, (2022) synthesized Selenium NPs from aqueous flower extract of CassicaAuriculata and assessed its bioactive potential for anti-microbial, antioxidant, and anti-diabetic behavior. Neha *et al.*, (2022) synthesized methods employed for their preparation and highlighted their applications in the biomedical field such as in the treatment of fungal, bacterial, and parasitic infections, cancer, and diabetes. They can also act as chemo preventive agents, anti-inflammatory agents, and antioxidants.

Beheshti *et al.*, (2013) reported that in vitro and in vivo effectiveness of biogenic SeNPs, biosynthesized by Bacillus sp. MSh-1, against Leishmania major (MRHO/IR/75/ER). Dobias *et al.*, (2011) conducted a proteomic study and compared proteins associated with biogenic SeNPs produced by *E. coli* to chemically synthesized SeNPs as well as magnetite nanoparticles and their results support the assertion that protein may become an important tool in the industrial-scale synthesis of SeNPs of uniform size and properties.

Husen (2014) analyzed in depth, the biogenic synthesized of SeNPs, their characterized and transformed into t-Se, m-Se, Se-nanoballs, Se-nanowires and Se-hollow spheres in an innocuous way preventing the environment from pollution. Their shape, size, FTIR, UV–Vis, Raman spectra, SEM, TEM images and XRD pattern have been analyzed. The weak forces involved in aggregation and transformation of one nano structure into the other have been carefully resolved. Lenz *et al.* (2009) alternated approaches to classical synthesis were investigated, producing selenium nanospheres biologically during treatment of contaminated water.

Sani *et al.*, (2022) SeNPs synthesized by using sodium salt of selenium and Solanumlycopersicum (tomato) fruit juice and seeds extract. The plant extracts were used as a reducing agent in ratio 1:4 i.e. sodium selenite salt (Na2SeO3).

Overall, selenium nanoparticles have shown great potential in various applications including antibacterial properties, treatment of fungal and animal pathogenic infections, and as antioxidants. The synthesis methods for SeNPs are diverse, ranging from chemical synthesis to biogenic synthesis using plant extracts. Further research and development in this field can lead to significant advancements in biomedicine and other related fields.

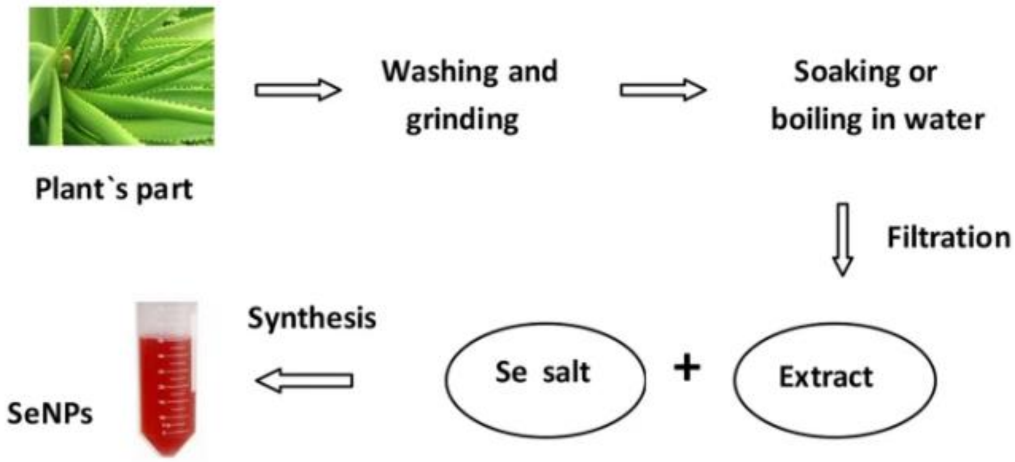

Fig. 1: Selenium Nanoparticle synthesis from plants (Krystyna et al 2022)

Cuong (2021) synthesized SeNPs from selenite by Shewanella sp. HN-41 demonstrated that particle size depended on the reaction time and biomass of cells. Shewanella sp. HN-41 was introduced into the anode of a no external circuit bio electrochemical system (nec_BES) to convert chemical energy from lactate to low electron current to the cathode, where selenite was reduced. Natwar *et al.* (2022) synthesized RMLP-SeNPs by using a polysaccharide (RMLP) that was previously isolated from mangrove Rhizophoramucronataleaves. Characterized by UV-Vis, HR-TEM, and DLS, FTIR, and TGA-DSC analysis. In addition to this, in vitro antibacterial activity of RMLP- SeNPs was determined by using the disk diffusion method according to the standard protocols.

Chinnaraj (2022) reported that biosynthesis of SeNPs from *Goniothalamuswightii* (*Gw*-SeNPs) and characterized were performed on UV–vis spectroscopy showed at 265 nm, it was primarily confirmed the biosynthesis of SeNPs. Soflaei *et al.* 2014 Studied antileishmanial effect of selenium dioxide and selenium nanoparticles synthesized by green technique on Leishmania infantum. In vitro promastigote toxicity was evaluated at concentrations, 2.5, 5, 10, 25, 50, and 100 μg mL−1 for both the selected selenium formulations and assessed in peritoneal macrophages of BALB/c mice. In addition, cytotoxic effect of the SeNPs and selenium dioxide was evaluated on noninfected macrophages. SeNPs showed less toxicity and comparatively higher inhibition of growth of promastigote as well as intramacrophage amastigotes of Leishmania infantum.

BIOACTIVITY OF SELENIUM NANOPARTICLE

Chaudhary *et al.*, (2016) isolated Se-reducing bacteria (LY5201) showing tolerance to selenite (173 mmol/L, 30 g/L) from Chinese Sauerkraut. They found that SeNPs synthesized by Paenibacillusmotobuensis LY5201 efficiently under sodium selenite (Na_2SeO_3) stress in anaerobic conditions. Hereafter, the cytotoxicity of SeNPs was investigated as a promising drug for anticancer. Ola *et al.*, (2020) evaluated the efficacy of synthesized SeNPs capped with glucose and polyvinyl-pyrrolidone (PVP) on the hyperglycemia and prooxidants/antioxidants imbalance present in model streptozotocin (STZ)-induced diabetic rats.

Chinnaraj (2022) biosynthesized of SeNPs from *Goniothalamuswightii* (*Gw*-SeNPs and characterized were performed on UV–vis spectroscopy showed at 265 nm. Abdel-Moneim *et al.*, (2022) investigated the antimicrobial and antioxidant activity of three Spirulina extracts (methanol, acetone, and hexane) and the biological SeNPs fabricated by *Bacillus subtilis* AL43. It exhibited antimicrobial activity against tested pathogens. Kasi Anu *et al.*, (2020) highlights the importance of selenium nanoparticles, results addressed herein very well reveal that functionalization of SeNPs as anti-cancerous nanomaterial has been achieved with biomolecule reductant without any capping molecules. Hossein *et al.*, (2014) indicated that biogenic SeNPs at all concentrations have potent scolicidal effects especially at concentrations 500 and 250 mg/ml after 10 and 20 min of application, respectively. They findings of present study prevent that SeNPs have potent scolicidaleffects, therefore may be used in CE surgery. However, the in vivo efficacy of these NPs remains to be explore.

Lucas *et al.*, (2022) reported antimicrobial activity and low hemolytic concentration indicated the possibility of use against Gram-positive bacteria, including multidrug-resistant ones, opening a wide variety of options for their application. Xin *et al.*, (2014) evaluated the prophylactic effect of intra peritoneal administration of selenium, an essential trace element and aputative chemo preventive agent, on peritoneal implantation no f cancer cells. Se concentration sin the cancer cells and tissues, as well as the efficacy of proliferation inhibition and safety, were evaluated.

Iranifam*et al.*, (2013) In the present study, it was found that direct reaction of DNBP with potassium permanganate (KMnO4) in the acidic mediums elicited light emission, which was greatly enhanced by selenium nanoparticles. Kazempour*et al.*, (2013) evaluated freshly prepared SeNPs produced by *Klebsiella* pneumonia were purified and characterized by transmission electron microscopy and Energy-Dispersive X-ray spectroscopy (EDS) and its post antifungal effects for two fungi.

Lampis et al (2014) discussed the reduction of selenite to SeNPs by a strain of Bacillus sp., SeITE01, isolated from the rhizosphere of the Se-hyper accumulator legume Astragalusbisulcatus. Luo *et al.*, (2012) suggested that nano Se (0) may be more helpful in cancer chemoprevention as a potential anticancer drug. In vitro ant proliferative effects of selenium nanoparticles nano Se (0), 10-40 μmol/L) on HeLa (human cervical carcinoma) cells and MDA-MB-231 (human breast carcinoma) cells were examined by optical microscopic inspection and MTT assay. Yang (2012) investigated of the underlying mechanisms revealed that SPS-SeNPs inhibited cancer cell growth through induction of apoptosis, as evidenced by an increase in sub-G (1) cell population, deoxyribonucleic acid fragmentation, chromatin condensation, and phosphatidylserine translocation. SPS-SeNPs may be a potential candidate for further evaluated as a chemo preventive and chemotherapeutic agent against human cancers.

Chen *et al.*, (2008) studied the intracellular mechanisms found that Nano-Se treatment triggered apoptotic cell death in A375 cells with the involvement of oxidative stress and mitochondrial dysfunction. It suggested that Nano-Se may be a candidate for further evaluation as a chemo preventive and chemotherapeutic agent for human cancers, especially melanoma cancer. Rohan *et al.*, 2016 suggested that a higher hydraulic retention time (HRT) or different reactor configurations need to be applied for selenium-removing activated sludge processes. Mahsa *et al.* (2020) highlighted design of nanohybrid systems with synergistic antibacterial properties to overcome the emerging antibiotic resistance as well as to define fruitful applications in biomedicine and food safety. Eleonora *et al*., (2016) analyzed biogenic SeNPs of bacterial origin to determine their antimicrobial activity against selected pathogens in their planktonic and biofilm states.

Qian *et al*., (2023) reported selenium-enriched strain with highly selenite-resistant (up to 173 mmol/L) was isolated from the local specialty food of longevity area and identified as Paenibacillusmotobuensis (P. motobuensis) LY5201. Most of the SeNPs were accumulated extracellular. It is suggested that Paenibacillusmotobuensis LY5201could be a suitable and robust biocatalyst for SeNPs synthesis. Ahmed *et al*., (2017) delineated to explore the efficacy of selenium nanoparticles delivered in liposomes (L-Se) in the mitigation of type-2 diabetes mellitus. compelling evidence favoring the antidiabetic potency of elemental selenium nanoparticles delivered in liposomes through preservation of pancreatic β cell integrity with consequent increment of insulin secretion and in turn glucose depletion, repression of oxidative stress, potentiation of the antioxidant defense system, and inhibition of pancreatic inflammation.

Al-Quraishy*et al*., (2015) investigated the anti-hyperglycemic activity of SeNPs in streptozotocin-induced diabetic rats. This study suggested that SeNPs can alleviate hyperglycemia and hyperlipidemia in streptozotocin-induced diabetic rats, possibly by eliciting insulin-mimetic activity. Alipour et al 2021 biosynthesized of SeNPs using sodium selenite and Spirulina platens has been developed. The SeNP performed at different cultivation condition including pH and illumination schedule variation. Prokischet al., (2008) developed and patented a technology to produce nano-sized (100-500nm) elemental selenium by using prebiotic yogurt bacteria in a fermentation procedure. This technique is the first to use lacticacidbacteria and other probioticbacteria Species of Lactobacillus and Bifidobacteria, nanospheres.

Fiona and Moganavelli (2016) they suggested that FSeNP's low cytotoxicity coupled with their small particle size and surface properties, make them suitable non-viral gene delivery vectors. However further engineering and modifications of the FSeNPs may be required to enable *in vivo* gene delivery. The use of SeNPs has opened a new direction for synergistic treatment of cancer with higher efficiency and reduced side effects. Rajesh and Mohan (2022) reported that eco-friendly synthesis of SeNPs by using *Allamandacathartica* extract as a reducing/capping agent and selenium dioxide as a precursor. The method used here is free of any toxic reducing agents and organic solvents. Mingshi*et al*., (2022) isolated selenite-resistant strain (up to 500 mM), from lateritic red soil, had identified as *Proteus penneri* LAB-1. Remarkably, isolate LAB-1 reduced nearly 2 mM of selenite within 18 h with the production of selenium nanoparticles (SeNPs) at the beginning of the exponential phase.

Nahid (2021) synthesized the SeNPs employing vitamin C as a biocompatible and low toxic reducing agent. The results of the DPPH free radical scavenging assay demonstrated strong potentials to scavenge the free radicals and cytotoxicity against MCF-7 and Raji Burkitt's lymphoma cancer cell lines. Amit *et al*., 2019 reported SeNPs in pharmacological protection against various inflammatory and oxidative stress mediated conditions is presented. However, it is largely unknown how SeNPs may affect the pharmacokinetics and pharmacodynamics of selenoproteins.

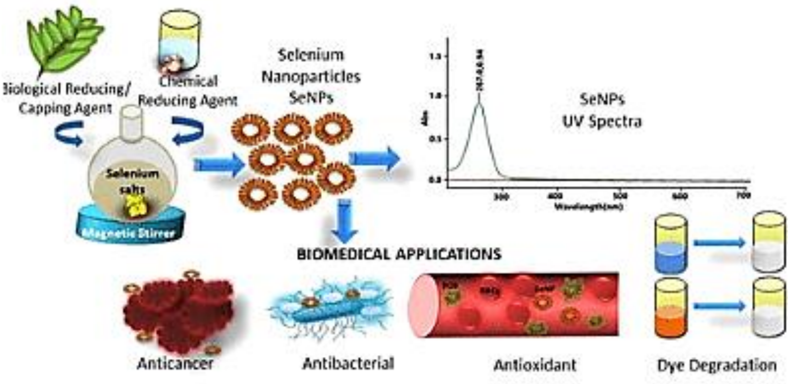

Fig. 2: Selenium Nanoparticle synthesis (Gagan *et al.*, 2021)

Table 1: Synthesis of Selenium Nanoparticle and its Bioactivity

Source	Synthesis method	Nanoparticle	Size	Bioactivity	Reference
Aspergillus Fumigates, Candida albicans	Chemical	Metal Nanoparticle	120- to 140-nm	antifungal activity	Mojitaba *et al.*, 2015
Bacillus subtilis	Biological	Green nanotechnology	65.23 nm	antimicrobial and antioxidant activity	Abdel *et al.*, 2022
Spirulina platensis	chemical and biological	-	145 ± 6 and 171 ± 13 nm	antioxidant activity	Alipoure *et al.*, 2021
Shewanella sp	Biological	Metal nanoparticles.	30–60 nm	antimicrobial activities	Cuong *et al.*, 2021
Spirulina polysaccharides	Biological	-	20 nm to 50 nm	anticancer activity	Yang *et al.*, 2012
yeast, Saccharomyces cerevisiae	Bilogical	Metal	30 to 100 nm size.	antimicrobial activity	Hariharan *et al.*, 2012
Cassia auriculata	Biological	-	10–20 nm	anti cancer	Kasi *et al.*, 2020
Aspergillus niger and *Candida albicans*	Chemical	Biogenic Se NPs	90- 320 nm	antifungal activity	Kazempour *et al.*, 2013
Rhizophora mucronate	Chemical	-	31.82 nm	antimicrobial and antibiofilm activity	Natwar *et al.*, 2022
E. coli and *Staphylococcus*	Chemical	-	35.6 ± 7.5 nm.	antimicrobial	Mahsa and Tahereh, 2020

CONCLUSION

Selenium has come a long way and risen from a toxin to a nutrient with chemotherapeutic applications. Se, owing to its antioxidant, pro-oxidant, and apoptotic activities, ameliorates the proliferation of cancer cells and homeostasis. SeNPs, due to their different mechanisms of action on cancer and normal cells, become a platform of choice to administer antimitotic drugs at the target site. SeNPs possess enhanced cytotoxicity against cancer cells and induce apoptosis via different pathways such as cell cycle arrest at different phases, mitochondrial membrane dysfunction, and activation of caspases. The review, therefore, highlights the potential of SeNPs as a potential candidate for a targeted and effective strategy for drug delivery.

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Chapter 6

TOXICOLOGY AND ITS CLINICAL APPLICATIONS

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ABSTRACT

Clinical toxicology encompasses the research, treatment and prevention of various syndromestriggered by drugs, chemicals and toxins. Special consideration is paid to the extent and intensities of chemical contact and to the results of that exposure may have on persons. Clinical toxicology is specificallyworthwhile when handling persons who are either poisoned or who are overdosed, so it is advantageous for medical specialists and first respondents. Clinical toxicology is divided into two parts: clinical chemistry and toxicology. Clinical toxicologists may improve new techniques of estimating the destructive effects of drugs and chemicals, in addition to how much dosage is causing such effects. Clinical toxicologists 'further-more work on the study of definite drugs and chemicals and in what way they can be handled safely.

KEYWORDS: Clinical toxicology, toxins, handling.

INTRODUCTION

Toxicology is the scientific methodical discipline that explores the adversarial effects of chemical agents, physical agents, or biological agents on the living organisms and the surrounding environs. It is a multi-disciplinary arena that draws acquaintance from biology, pharmacology, physiology, chemistry, environmental sciences, and additional connected disciplines. The prime aim of toxicology is to comprehend the impending risks and hazards concomitant with exposure to toxic materials and to develop approaches for their managing and inhibition. (1)

BASIC CONCEPTIONS IN TOXICOLOGY

Toxicants: Toxicants are materials that have the potential ability to cause damage to living organisms. These comprise chemicals originating in industrial produces, domestic substances, pharmaceutical preparations, pesticides, natural toxins, and environmental contaminants.

Dose-Response Correlation: One of the very basic principles in toxicology is the dose-response correlation, according to which, the degree of the toxic effect is directly linked to the doses (amount) of the toxicant administered or come across the system. This opinion is made concise in the eminent proclamation by Paracelsus, "The dose creates the poison," implies that any constituent can be toxic at a high ample dose.

Routes of Exposure: Toxicants pass in the body through several ways, comprising ingestion, breathing, skin contact, and injection (Parenteral). The route of introduction ominously influences the toxic properties of a material.

Absorption, Distribution, Metabolism, and Excretion (ADME): Once a toxicant arrives in the body, it goes through courses of absorption into the circulation, distribution to many organs and tissues, metabolism or undergoes biotransformation to less potentially toxic or more toxic systems, and elimination from the body. Understanding processes of ADME is essential for envisaging how a toxicant may affect the body.

Target Organs and Systems: Diverse toxicants have definite affinities for certain organs or structures inside the body. For instance, some toxicants might largely affect the liver, nervous system, reproductive organs, or kidneys.

THE HISTORY OF TOXICOLOGY

The background of toxicology dates back to antediluvian times when publics commenced to identify the damaging effects of definite materials on human beings as well as animals. Here is an outline of the significant milestones in the progress of toxicology:

Ancient Eras: The geneses of toxicology can be outlined to initial civilizations, comprising the Greeks, Romans and Egyptians. These ancient people witnessed and noted the toxic effects of several matters, for example poisonous plants and venomous creatures, and used this understanding for medicinal and vindictive purposes.

Middle Ages: For the period of the middle Ages, the usage of toxic materials turned into further prominent, frequently for menacing purposes like poisoning opponents or political foes. This headed to the occurrence of the conception of "poisons" and the establishment of initial forensic toxicology to identify poisoning incidents.

16th to 19th Century: The arena of toxicology sustained to grow, predominantly with progresses in chemistry and the documentation of new toxic constituents. Paracelsus, a Swiss doctor of medicine and alchemist, is deliberated one of the instituting fathers of toxicology. He suggested the conception of "the dose creates the poison," affirming that any constituent might be toxic if the dose is high enough.

Industrial Revolution: The fast industrial development for the duration of the 18th and 19th centuries span presented novel chemicals and materials into the environs and the place of work, heading to an upsurge in poisoning instances. This epoch witnessed the emergence of professional toxicology, centering on the healthiness effects of workstation exposures.

20th Century: The 20th century time span observed noteworthy improvements in toxicology owing to the expansion of sophisticated analytical instruments and techniques and a deeper considerate of cellular level and molecular level appliances. Toxicologists began to study the special effects of synthetic chemicals, pharmaceutical drugs, pesticides, and environmental impurities. This period also witnessed the instituting of regulatory organizations, such as the Food and Drug Administration (FDA) in the USA, to assess and cope up the safety of chemicals and byproducts.

Late 20th to 21st Century Span: Toxicology developed further integrated with new technical disciplines, like molecular biology and genetics. The growth of in vitro and in vivo testing approaches, as well as computer models, contributed to further precise and effective toxicological assessments. Furthermore, ecological toxicology increased eminence as worries about pollution and its influence on bionetworks rose.

All over the ancient eras, toxicology is advanced from a practical acquaintance of poisons to a sophisticated scientific technology plays a critical role in shielding public healthiness, gauging chemical safety, and maintaining the environs. As our knowledge of toxicology lingers to develop, we are superior fortified to discourse the encounters posed by the complex interactions amid chemicals and living organisms. (2)

NEED FOR THE STUDY OF TOXICOLOGY

Studying toxicology is vital for various reasons, as it offers essential information and understanding about the adversative effects of various chemicals, different drugs, and further toxic materials on the living organisms and environment. At this point are some important motives why toxicology is imperative:

Community Health Safety: Toxicology aids to recognize and evaluate potential health threats connected with exposure to toxic constituents. This data is decisive in developing safety regulations, setting up the exposure limits, and shielding civic health.

Drug Safety and Development: Aforenovel drugs can be permitted for humanoid usage; toxicology studies are performed to assess their safety summaries and potential adversarial effects. This certifies that medicaments are effectual and have tolerable risk-benefit balances.

Environmental Safeguard: Toxicology studies play an important part in the assessment of the influence of pollutants, contaminants, impurities and hazardous materials on bionetworks and ecosystems including wildlife. Consideration of the biological effects aids in the formulation of rules and policies and actions to safeguard the environs.

Occupational Safety: Toxicologists also study workstation menaces and measure the hazards confronted by workforces wide-open to the exposure to several chemicals and substances. This information is critical for forming safety guiding principles and defending worker's healthiness.

Hazardous Material Management: Toxicology is employed to assess the safety of chemicals used in consumer goods, manufacturing processes, and agricultural processes. It assists in recognizing and handling hazardous materials to avoid harm to human being and the atmosphere.

Emergency Response: In cases of poisoning, environmental incidents, or accidental contacts, toxicologists deliver proficiency to medical specialists and emergency respondents, guaranteeing well-timed and suitable action.

Risk Valuation: Toxicology databases are used to perform threat assessments, which comprise gauging potential vulnerabilities and exposure situations to make conversant resolutions about the grade of tolerable risk.

Regulatory Compliance: Toxicological information make available critical statistics for regulatory organizations to fix safety guidelines, permit new materials, and observe agreement with current regulations.

Forensic Research: Forensic toxicology is essential in defining the reason of death in circumstances of poisoning or drug-toxicity events. This data supports legal measures and justice.

Product Development and Innovation: Understanding toxicological databases permits investigators and manufacturers to create improved, safer and much ecological products, decreasing potential harms to consumers and the atmosphere.

To summarize, toxicology is an introductory science that enlightens resolutions across several divisions, starting from healthcare to environmental sustainability and product safety. By learning toxicology, we can well understand and be able to manage the risks connected with toxic materials, supporting community health, environmental sustainability, and global well-being. (3)

BRANCHES OF TOXICOLOGY

Toxicology comprises of quite a few focused branches that put emphasis on particular features of toxicological exploration and applications:

CLINICAL TOXICOLOGY:

Clinical toxicology is a specific branch of toxicology that emphases on the diagnosis, treatment, and supervision of poisonous and adverse effects of chemicals, drugs, and other toxic materials on humanoid health. It includes the assessment of patients who have been exposed to toxic substances, either purposefully or accidentally, and purposes to afford proper remedial care to alleviate the toxic effects and stimulate recovery. Clinical toxicology includes:

Poisoning Assessment: Clinical toxicologists estimate patients who are existent with signs or symptoms of poisoning. This valuation includes procurement of an exhaustive account of the exposure, together with the category of toxicant, course of exposure, timing, and extent of quantity. Moreover, facts and figures about the patient's health history, concurrent medicaments and underlying conditions of health are necessary for correct diagnostic analysis and treatment.

Clinical Demonstration: The indications and clinical indicators of poisoning may differ extensively depending on the kind of toxicant and the dosage received. Some of the common indications include diarrhea, nausea, vomiting, confusion, headache, dizziness, seizures, respiratory distress, and unconsciousness. Clinical toxicologists are proficient to diagnose these signs and symptoms and correlate with particular toxic substances.

Toxicological Testing: In several instances, toxicological testing is decisive to endorse the manifestation of exact toxicants in the patient's body. Urine, blood, and occasionally other body-fluids like saliva, sweat or tissues are collected and examined by means of few analytical investigative techniques, such as gas chromatography-mass spectrometry (GC-MS) and immunological assays, to detect and estimate the toxic materials.

De-contamination: When the toxic acquaintance is recognized, clinical toxicologists start decontamination processes to avoid further absorption of the toxicant. General de-contamination techniques comprise gastric lavage (evacuation of stomach), activated charcoal administration through oral route, and entire irrigation of bowel.

Supportive Care: Patients with severe poisoning frequently need supportive attention to stabilize critical functions and cope up with complications. This usually includes oxygen therapy and airway management, fluid revitalization, and restoration of electrolytic imbalances.

Administration of Antidotes: In several cases, particular antidotes or neutralizing agents are employed to counteract the toxic properties of certain constituents. For instance, naloxone is an antidote substance used for reversing opioid over-doses, and acetylcysteine or activated charcoal is used for acetaminophen poisoning cases.

Poison Control Centers: Clinical toxicology facilities are regularly providing through poison control centers, which have steadfast facilities and functioned with toxicology specialists who offer instant supervision to healthcare workers and the community in the cases of poisoning crises.

Monitoring and Follow-up: After primary management, patients are watchfully observed to assess their reaction to therapy and to manage any deferred or progressive toxic effects. Longstanding follow-up may also be essential to address impending complications or persistent health related concerns. (4)

APPLICATIONS OF CLINICAL TOXICOLOGY

Clinical toxicology has quite a lot of useful practical applications, including:

Acute Poisoning Management: Clinical toxicologists have a crucial responsibility in handling serious poisoning incidents in emergency units and intensive care units (ICU), making sure suitable and timely diagnosis and treatment.

Overdose Management: Clinical toxicology is indispensable in handling drug overdoses, comprising those concerning prescription medicaments, energetic drugs, and over-the-counter substances.

Substance Abuse and Addiction: Clinical toxicologists work along with addiction experts to cope up with the cases of drug substance abuse and addiction, extending medical backing and assistance throughout detoxification and recovery process.

Occupational and Environmental Exposure: Clinical toxicologists are also involved in evaluating and supervision of the incidents of toxic exposure in the place of work or community, mostly in conditions where multiple persons are affected.

Public Health Response: Clinical toxicology expertise is critical in responding to mass poisoning incidents, bioterrorism events, or chemical accidents that pose significant public health risks.

In conclusion, clinical toxicology is a central arena of medicine that discourses the adverse effects of poisonous toxic substances on social health. By providing focused care and proficiency, clinical toxicologists have a noteworthy part in diagnosing and management of cases of poisoning and toxic acquaintance, thus protecting and saving lives and supporting the welfare of suffering people.

ENVIRONMENTAL TOXICOLOGY

This branch is applied to the study of effect of environmental contaminants on ecology and living creatures including biota and plant life.

ANALYTICAL TOXICOLOGY

It encompasses the development and application of analytical techniques to identification and quantification of toxic materials in environmental, biological, and drug or food samples.

FORENSIC TOXICOLOGY

Related with analysis of toxic constituents in post-mortem and autopsy checkups to decide the reason of death in situations of poisoning or overdose of drug.

OCCUPATIONAL TOXICOLOGY

It emphases on evaluating and treatment of the exposure of personnel to toxic constituents in the place of work to make sure their safety and health.

REGULATORY TOXICOLOGY

It includes estimating the safety of chemicals and drug products and setting satisfactory exposure parameters to safeguard human health and the surroundings.

IMPORTANCE OF TOXICOLOGY

Toxicology plays a crucial role in various fields and has numerous practical applications:

Drug Development and Safety: Toxicological studies are conducted during the preclinical phase of drug development to assess the safety and potential side effects of new drugs before human trials.

Risk Assessment: Toxicologists evaluate the potential risks associated with exposure to chemicals and pollutants, directing the establishment of safety standards and guidelines.

Environmental Protection: Toxicological exploration helps ascertain and apprehend the effects of ecological pollutants on bionetworks and biota, supporting exertions for ecological preservation.

Product Safety Testing: Toxicology plays an important role in assessing the safety of several customer products, such as drugs and cosmetics, household chemicals, and food additives etc.

Poison Control: Medical toxicologists offer supervision in managing incidents of poisoning, providing critical attention and treatment.

Regulatory Compliance: Toxicological documents are essential for regulatory organizations to conclude the safety of chemical products and drugsafore they are presented into the market. (5)

To conclude, toxicology is a vibrant scientific discipline that aids us comprehending the potential hazards brought by toxic materials to living creatures and the atmosphere. By learning toxicology, research scholars, policy-makers, and medical specialists can collaborate to develop advanced strategies for alleviating these hazards and protecting community health and the surrounding environment.

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Chapter
7

ANTI CARIOGENIC ATTRIBUTES OF MEDICINAL PLANTS – A REVIEW

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ABSTRACT

Medicinal plants or medicinal herbs are plants that exhibit therapeutic features and exert pharmacological effects on humans and animals. They have long been used in traditional medicine as well and are always found to play a significant and prominent role in the preparation of drug led compounds. The varied biological properties of medicinal plants are on the verge of being discovered, documented and explored more and more day by day. According to the International Union of Conservation of Nature and the World Wildlife Fund, about 50,000 - 80,000 of flowering plants are used because of their medicinal properties. The drastic rise in human population and the demand for natural medicines have increased the loss of medicinal plant species, 100 - 1000 times the rate of natural extinction. The rising demand for medicinal plant products has revived interest in the biomedical industry in the production of herbal health care products, herbal based aesthetic products and healthy herbal supplements. About 80% of the world's population is dependent on conventional or herbal medicine for the treatment of various illnesses, because most of these have relatively no adverse or toxic side effects when consumed by humans. As medicinal plants are a reservoir of various biologically active components with curative properties, they are widely accepted by a vast number of people across the globe for various diseases like muscle cramps, osteoarthritis, skin health, eye disorders, bronchitis, oral health, cardiac health, digestive health, prostate health, uterine health etc.

Among the various health disorders and diseases commonly faced by people across the world on a larger scale, oral diseases or oral health disorders are quite predominant and require immediate and instant solutions for a healthy and hygienic lifestyle, as any compromise in oral health will influence the quality of life and may lead to chronic dieases and infections at a later stage. Oral diseases are major health issues resulting in dental caries or tooth decay and various other periodontal diseases.

The current review article will focus on the anti cariogenic properties of medicinal herbs and their phytochemicals, thereby proving to be effective alternatives to several commercially available oral healthcare products.

KEYWORDS: Medicinal plants, curative properties, anti cariogenic property, oral health, dental caries.

INTRODUCTION

Herbal plants have always been a store house of medicines in a large scale since ancient times. The various parts of plants, like leaves, twigs, stems, bark, roots, flowers, petals, seeds produce innumerable biologically active molecules called secondary metabolites, which provide the plant with healing properties for an end number of health disorders. Oral health is the most important aspect of an individual's healthy lifestyle. Various microbes like Lactobacillus acidophilus, Streptococcus mutans, Staphylococcus aureus, Lacobacilluscasei are inhabitants of teeth structures, causing dental caries or tooth decay in a long run, leading to demineralization of teeth and damaging oral health to a greater level if left untreated or not treated properly in time. Loss of teeth due to poor oral health may lead to adverse conditions like premature death and significant morbidity (Petersen PE, 2003). Herbal plant extracts or phytochemicals have been identified to inhibit the spread of oral pathogens, thereby reducing the formation of biofilms and dental caries. Nearly, 750 species of bacteria inhabit the mouth and a number of these bacteria are implicated in the cause of oral diseases (Jenkinson HF, 2005). The global need for alternative prevention and safe, economic and effective treatment options for various oral diseases is due to the high incidence of the oral disease and due to the resistance developed by the bacteria against currently used antibiotics and chemotherapeutics (Badria FA, 2004).

Though a number of agents are commercially available for the maintenance of oral health, the chemicals present in the oral healthcare products have been found to be associated with unanticipated side effects like vomiting, diarrhoea, staining of teeth and few of them have been linked to oral cancer as well (Neumegen RA, 2005). Thus, the search for alternative plant products continues and the natural phytochemicals isolated from herbal plants are considered as a good alternative to synthetic chemicals (Prabu GR, 2006).

Dental disorders are a threat to oral health, as dental care and oral hygiene is an integral part of health and, when neglected, can cause several oral health problems.

CONVENTIONAL PLANT BASED DRUGS

The usage of medicinal plants as conventional treatments for various human diseases has been in practice over many years. In many parts of the globe, especially in the rural areas, the medicinal plants have effectively proven as a primary source of medicine (Chitme HR, 2003). The antimicrobial activities of many medicinal plants have been reviewed during the early days, thereby proving their efficacy in the therapeutics side. As approximately out of 500,000 thousand plant species worldwide, only 1% of the plants have been evaluated phytochemically, paving way for the identification of novel bioactive phytochemical compounds of therapeutic value. The prime aspect of seeking medicinal plants for treatment purposes lies in the fact that, the incidence of microbial infections which is at a peak, resulting in the usage of antibiotics or antimicrobial agents at an increased rate, which later results in the development of resistance by the microbes to the conventional chemotherapy. This leads to an urge in seeking the novel anti-infective agents from medicinal plants.

IDENTIFICATION AND EVALUATION OF MEDICINAL PLANTS

Various conventional medicinal plants have been evaluated for their potential aspects in the treatment of numerous diseases. The purpose of evaluating medicinal plants is to identify and determine the purity and quality of an herb, thereby paving the way for its utility as a prominent drug in the treatment of various diseases. Drug assessment and standardization involves the detection of common impurities or adulterants present in the plants by taking into consideration various parameters like morphological, physical, microscopical, chemical and biological observations. Each and every herbal drug needs to be evaluated due to the following aspects like any variation biochemically may arise in the drug, there may be some kind of deterioration due to improper storage and processing conditions or there may be presence of some unwanted impurities in the form of adulterants.

WHO is committed to develop adverse measures with updated guidelines with respect to the safety and quality assurance of herbal medicines? The major rand prime objective of the WHO guidelines focus on the safety assessment of efficacy by studying the pharmacology of drugs and evaluating their biological activity.

The different methods of standardization of herbal plants comprises authentication, which relies primely on various evaluation parameters like identification of the plant parts collected, their biological source, regional status, family, species identification and chemical constituents. Organoleptic or morphologic evaluation of herbal plants includes color, shape, size, odour, taste, texture. The microscopic evaluation relies on the various qualitative and quantitative assessments of the plant features like stomatal number, leaf constant, powder microscopy, measurement of number of fibres, the physical evaluation of herbal plants relies on the solubility, moisture content, optical rotation, refractive index, ash value, melting point whereas the chemical parameters involve the various chemical tests and chemical assays like HPTLC, HPLC, GLC fingerprinting. The biological evaluation criteria involve the determination of microbial contamination, pathogens, aflatoxin content, total viable count, the pharmacological evaluation like hemolytic activity, foaming index, bitterness value and then the toxicological evaluation like testing the pesticide, insecticide residues and heavy metals.

HERBS IN ORAL HEALTH CARE

Oral hygiene is important to an individual's well being and overall health, and oral diseases have become one of the major health concerns globally in recent days. The most prominent and significant oral diseases globally are dental caries and oral cancers (Beaglehole R, 2009). In India, medicinal plants have been utilized for over a thousand years as conventional medicine in the treatment of oral diseases. Herbs like Azadirachta indica and Acacia nilotica have been reported to be utilized in the maintenance of oral health and hygiene (Farnsworth N S, 1988). Herbal extracts have been proved to be effective as they are found to interact with specific chemical receptors inside the body and produce fewer side effects compared to conventional medicines. Herbal materials are proven effective in the treatment of severe stages of gingivitis, mucositis, mycosal infections, superficial periodontitis and toxic inflammation of oral cavity. The herbs are mainly opted in medicine due to the abundance of bioactive compounds like flavonoids, resine, terpenes, phytoesters, tannins, coumarins, carotenoids, cholines, essential oils and mineral salts in their phytochemistry.

ALOEVERA (*ALOE BARBEDENSIS* MILLER)

Aloevera is composed of active constituents like beta carotene, Vitamin B12, folic acid, choline, minerals, sugars, enzymes, salicylic acids, saponins and amino acids. Aloe vera is highly moisturizing in nature, besides that it also has powerful anti-inflammatory effect. It is been known to reduce the loss of thinning of the tooth enamel and helps in preventing gingivitis, gum abscesses, dry tooth socket, migratory glossitis, burning mouth syndrome, candidiasis and other peridontal tissue related issues.

GREEN TEA (*CAMELLIA SINENSIS*)

The Green tea is composed of wide variety of bioactive compounds like proteins, amino acids (serine, aspartic acid, threonine, tryptophan, arginine, lysine), polyphenols andcatechin (Epigallocatechin-3-gallate). It is a very well known fact that, the green tea possesses anti-microbial, anti-oxidant, carcinogenic and anti-inflammatory properties. It has been suggested that it regulates oral health by suppressing inflammation, preventing bone resorption and reduces the growth of bacteria responsible for oral health deterioration. Several studies have indicated that consuming green tea fights dental cavities and supports the prevention of tooth decay.

CHAMOMILE (*MATRICARIA CHAMOMILLA*)

Chamomile has long been known for containing bioactive like flavonoids, terpenes, volatile oils, steroids, polysaccharides, organic acids, coumarins, polyacetylenes and polyphenols. Chamomile has a soothing effect on the lining of the mouth and helps fight against gingivitis and canker sores in thebuccal cavity, due to its anti inflammatory, analgesic, sedative and anti microbial properties.

CARAWAY (*CARUM CARVI*)

Caraway is also known as Persian fennel or Meridian cumin. It is rich in essential oils like carvone, limonene and anethole. It is basically a spice with many culinary and medical benefits. It has been known to alleviate bad breath and keep the mouth fresh.

CLOVE (*SYZYGIUM AROMATICUM*)

Clove is mainly composed of volatile oils, resin, euginine or cariophyllin, tanin and gum. The anaesthetic and anti bacterial activity of clove is attributed to the presence of eugenol, which has long been used in dentistry for the effective alleviation of tooth ache, dental caries and pyorrhea. It has been found that the clove buds suppress the microorganisms in the oral cavity by about 70%, which makes it a main ingredient in commercially available tooth pastes as well.

NEEM (*AZADIRACHTA INDICA*)

Neem has long been utilized in almost every household in India because of its varied benefits, ranging from tooth brush (twigs), soap (oil); medicine (leaves), healing gum disease (bark). The most important and active constituents of neem are azadirachtin, nimbin, nimbidin, sodium nimbinate, gedunin, salannin and quercitin.

TURMERIC (*CURCUMA LONGA*)

Turmeric is composed of volatile oils like (tumerone, atlantone, and zingiberone), resins, sugars and proteins. Studies claim that turmeric is responsible for the reduction of dental plaque, gingivitis, halitosis and inflammation, owing to its anticarcinogenic, antimutagenic, antibacterial and antioxidant properties.

TRIPHALA

Triphala is a familiar polyherbal medicine, comprising the dried fruits of three plant species namely, *Emblica officinalis, Terminalia bellerica* and *Terminalia chebula*. The prime constituents of triphala include riboflavin, niacin, thiamine, ascorbic acid, beta sitosterol, gallic acid, ellagic acid, chebulinic acid and corilagin. Owing to its antimicrobial and antioxidant properties, it is extensively used in the treatment of dental caries, bleeding andinflammated gums.

TULSI (*OCIMUM SANCTUM*)

Phytochemical analysis of *Ocimum sanctum* has revealed the presence of ursolic acid, oleanolic acid, rosmarinic acid, linalool, carvacrol and eugenol. It has antipyretic, analgesic, antihelminthic, antiinflammatory, antimicrobial and antiulcerative properties. Tulsi has long been incorporated in herbal formulations for targeting comprehensive oral health care and hygiene.

ANISE (*PIMPINELLA ANISUM*)

Aniseeds are composed of proteins, crude fiber, fatty oils, sugar, starch and ash. Studies have revealed that aniseed is a powerful antibacterial and antiinflammatory agent with astringent properties. It is used as a powerful home therapy for maintenance of oral hygiene and is a good remedy for bad breath.

ADVERSE REACTIONS OF PHYTOMEDICINE

It is a widely believed and well-known fact that herbal medicines do not have any side effects on human health (Little, 2004), and there has been an increasing concern about the use of these herbal medicines in oral health care and dentistry. In very rare cases, phytomedicine may bring about adverse reactions like hypersensitivity, gastro intestinal disturbances, central nervous system effects and other less common general effects. Studies need to be clearly carried on so as to hinder the side effects of herbal medicine at all levels.

CONCLUSION

The usage of herbal medicine for maintenance of oral health care is increasing day by day, and people have started relying on the phytomedicine at a larger scale. The bioactive compounds of plants may be incorporated into recent oral health and hygiene practices and there is a need for the professionals in dentistry to rely on natural medicines for oral healthcare treatment, as herbs serve a wide range of purposes varying from pills, infusions, syrups to pastes as well. Relying on herbal medicine for oral healthcare may make dentistry even more fruitful and better than before, as herbal formulations are much more affordable, safer, reliable and more accessible among low socio-economic groups.

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Chapter 8

PHYTOCHEMICALS - AN OVERVIEW

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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.

KEYWORDS: Phytochemicals, traditional medicine, bio nutrients, chronic diseases**.**

INTRODUCTION

Phytochemistry can be considered a subfield of herbal science or science. Exercises can be driven in greenhouses or in the wild with the guide of ethno botany. Phytochemical studies coordinated toward human (for example drug revelation) use might fall under the discipline of pharmacognosy, though phytochemical concentrates on zeroed in on the natural capabilities and development of phytochemicals probably fall under the discipline of synthetic environment. Phytochemistry additionally has significance to the field of plant physiology.

The investigation of phytochemicals, which are synthetics gotten from plants. Phytochemists endeavor to portray the designs of the huge number of auxiliary metabolites tracked down in plants, the elements of these mixtures in human and plant science, and the biosynthesis of these mixtures. Phytochemists endeavor to portray the designs of the huge number of auxiliary metabolites tracked down in plants, the elements of these mixtures in human and plant science, and the biosynthesis of these mixtures.

Phytochemicals by first removing and disconnecting compounds from the beginning plant, trailed by characterizing their construction or testing in research center model frameworks, for example, in vitro examinations utilizing cell lines or in vivo examinations utilizing lab creatures.

A few examples of well-known phytochemicals are the flavonoids, phenolic acids, isoflavones, curcumin, isothiocyanates, and carotenoids. Lowers the risks of chronic diseases such as cardiovascular diseases and obesity. Phytochemicals including carotenoid, flavonoids, anthocyanin, isothiocyanates, and zeaxanthin helps in inhibiting the growth of cancer cells and lowers the occurrence of cardiovascular diseases. Phytochemicals are plant-based bioactive mixtures created by plants for their assurance. They can be gotten from different sources like entire grains, organic products, vegetables, nuts, and spices, and in excess of 1,000 phytochemicals have been found to date.

They for the most part have natural movement in the plant host and assume a part in plant development or protection against contenders, microorganisms, or hunters. Can be characterized into significant classifications, like carotenoids and polyphenols, which incorporate phenolic acids, flavonoids, stilbenes or lignans. Flavonoids can be additionally isolated into bunches in light of their comparative substance structure, for example, anthocyanins, flavones, flavanones, isoflavones, and flavanols. Flavanols are additionally named catechins, epicatechins, and proanthocyanidins. Altogether, somewhere in the range of 50,000 and 130,000 phytochemicals have been found. Plants make synthetic compounds for some reasons, including protection and fascination. Having their own consciousness, plants will incorporate synthetics that repulse or kill bugs and creatures benefiting from them and successfully manage viral, bacterial, and contagious contaminations, to give some examples. Plants share data with one another, as a matter of fact. Not only one tree to one more of similar animal categories, however interspecies. Trees share supplements through their foundations, which contact the underlying foundations of different plants. A more established tree will impart supplements to youthful trees, bearing the cost of them a superior possibility developing to development. The extraction strategies are imperatively significant in the examination of phytochemicals. There are some traditional extraction techniques and high level extraction strategy. The cutting-edge advancement in the instrumental procedures of examination and chromatographically strategies has added various perplexing and uncommon normal items to the arsenal of Phytomedicine.

Phytochemists have responded to green science bits of knowledge beginning around 1990, the year when the U.S. Environmental Protection Agency launched the "Pollution Prevention Act". For each year in the period 1990 to 2019, three extraordinarily alluded to photochemistry papers that gave adequate information about the preliminary techniques utilized were analyzed.

A few ebb and flow drives toward a more practical phytochemical research considering perspectives other than just solvents are featured. Albeit a few advances have been accomplished, it is accepted that normal items scientists can assume a significant part in fostering an original biological worldview in science.

TECHNIQUES FOR SCREENING OF PHYTOCHEMICALS FROM PLANTS EXTRACTION METHODS

1. Maceration
2. Percolation
3. Soxhlet extractions.
4. Decoction
5. Digestion
6. Infusion
7. Plant tissue homogenization

QUALITATIVE AND QUANTITATIVE ANALYSIS OF PHYTOCHEMICALS

1. Gas chromatography,
2. Mass spectroscopy (GCMS). GC-MS can be applied to solid, liquid and gaseous samples.

METHODS OF DETECTION

Spectroscopy is used in the detection of phytochemicals.

1. UV Spectroscopy
2. IR Spectroscopy
3. Mass Spectroscopy

4. Nuclear Magnetic Resonance Spectroscopy: (NMR)
5. X-Ray Crystallography

ADVANCED METHODS

1. Supercritical fluid extraction
2. Microwave Assisted Extraction (MAE)
3. Accelerated solvent extraction
4. Ultrasound assisted extraction

NEW TREND METHODS

1. Phytochemical genomics
2. Up-to-date technology advance in metabolomics
3. Plant Tissue Culture
4. Biochromatography

FEW 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 is also called isoprenoids, are a class of naturally happening natural synthetic substances got from the 5-carbon compound isoprene and its subsidiaries called terpenes, diterpenes, and so forth.

Flavonoids are a class of polyphenolic secondary metabolites tracked down in plants, and in this way ordinarily consumed in the eating regimens of people. Synthetically, flavonoids have the general design of a 15-carbon skeleton, which comprises of two phenyl rings and a heterocyclic ring. This carbon construction can be curtailed C6-C3-C6.

Lutein is a xanthophyll and one of 600 known normally happening carotenoids. Lutein is combined exclusively by plants, and like different xanthophylls is found in high amounts in green leafy vegetables like spinach, kale and yellow carrots.

Biflavonoids are found in citrus natural products. Carotenoids are viewed as in dull yellow, orange, and dark green leafy foods like 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.

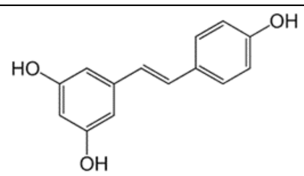
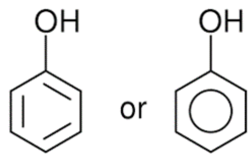
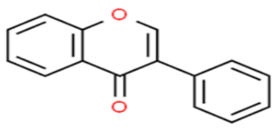
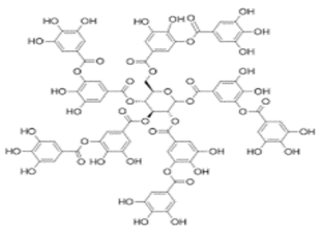
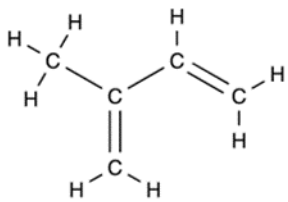
Anthocyanidins are normal plant pigments, the aglycones of anthocyanins. They depend on the flavyliumcation, an oxonium ion, with different gatherings fill in for its hydrogen atoms. They by and large change colour from red through purple, blue, and somewhat blueish green as a component of pH.

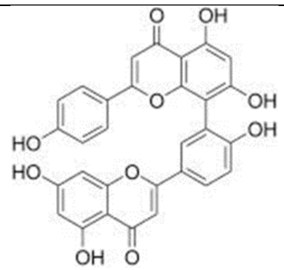
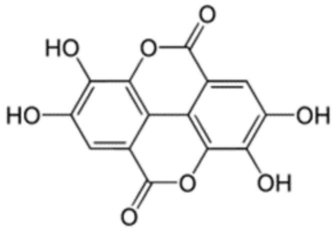
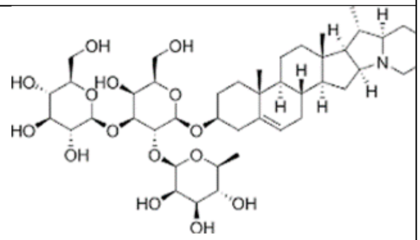
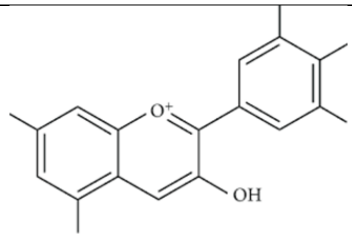
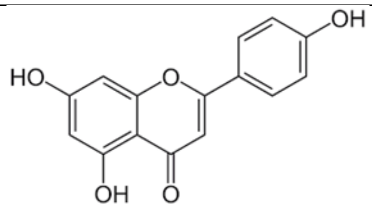
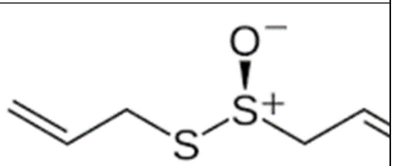
Apigenin, tracked down in many plants, is a characteristic item having a place with the flavone class that is the aglycone of a few normally happening glycosides. A yellow glasslike strong has been utilized to color fleece.

Phytosterols are phytosteroids, like cholesterol, that act as primary parts of organic layers of plants. They incorporate plant sterols and stanols. In excess of 250 sterols and related compounds have been distinguished.

Allicin is an organo sulfur compound gotten from garlic. At the point when new garlic is squashed, the compound alliinase changes over alliin into allicin, which is responsible for the fragrance of new garlic. Allicinis rapidly changes into a progression of other sulfur-containing mixtures, for example, diallyldisulfide.

Table 1: 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	Anthocyanidins	
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 flavour 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.

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Chapter
9

A BRIEF REVIEW ON NANOPARTICLES: APPLICATIONS IN ORGANIC SYNTHESIS

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ABSTRACT

Nanoparticles (NPs) chemistry is a rather earlier branch of chemical studies. For over hundred years, transition metal nanoparticles were generally utilized as heterogeneous catalyst and created great incomes for chemistry. Nanoparticles are significant in the evolution of technology due to light of their enhanced performance beyond their parent material and their flexible nature. Nanoparticles happen broadly in nature and are objects of study in numerous sciences such as chemistry, physics, and biology. Being on the transition among bulk materials and atomic or molecular systems, they regularly showcase phenomena that aren't found at either scale. They may be an essential thing of atmospheric pollutants, and key substances in many industrialized products together with paints, plastics, metals, ceramics, and magnetic products. The manufacturing of nanoparticles with unique homes is a division of nanotechnology. This review briefly features a few significant responses did by using NPs in organic synthesis.

KEYWORDS: Nanoparticles, organic synthesis, heterogeneous catalysts.

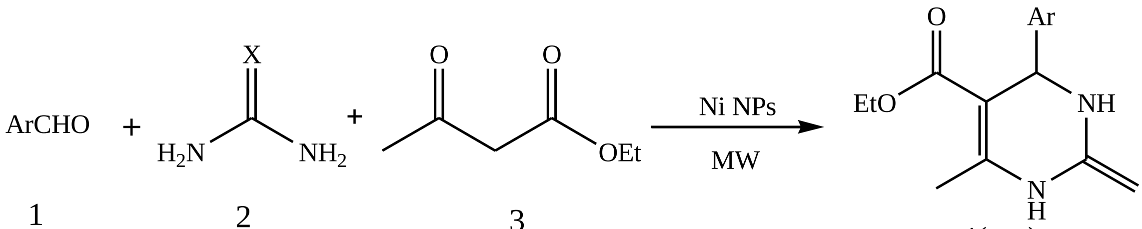
INTRODUCTION

Nanotechnology advanced as the success of technology in the twenty first century. The synthesis and application of these materials with a size smaller than one hundred nm fall beneath the interdisciplinary umbrella of this discipline. A nanoparticle is a small particle that range among 1 to 100 nanometers (nm) in diameter. Undetectable by using the human eye, nanoparticles can show off drastically unique physical and chemical homes to their large fabric opposite numbers.[1, 2]

Nanoparticles have tremendous applications in special sectors including the environment, agriculture, food, biotechnology, biomedical, medicines, etc such as like; for treatment of waste water,[3] environment monitoring,[4] as a functional food additives,[5] and as a antimicrobial agents.[6]Imaginative properties of NPs, for example, nature, biocompatibility, anti-inflammatory and antibacterial action, effective drug delivery, bioactivity, bioavailability, cancer focusing on, and bio-retention have prompted a development in the biotechnological, and applied microbiological utilizations of NPs. Nanoparticles regularly exhibit unique size-dependent features, often because of their tiny size and tremendous surface place. The periodic boundary situations of the crystalline particle are destroyed while the size of a particle tactics the nano-scale with the feature period scale near or smaller than the de Broglie wavelength or the wavelength of light.[7] Because of due to this a number of the physical characteristics of nanoparticles vary extensively from those of bulk materials, leading to a wide variety in their novel uses.

Recently, the efficiency of heterogeneous catalysis in organic synthesis can be enhanced by using nanosized catalysts due to their extremely small size and large surface to volume ratio. Now days, it has been proved that Ni nanoparticles as catalysts offer great opportunities for a wide range of applications in organic synthesis and chemical manufacturing processes because nanoparticles inside the shape of nanocatalysts have emerged as possible alternative to conventional materials in numerous area of chemistry and attracted astonishing interest of chemists. Also, nanoparticles have the potential for improving the efficiency, selectivity, and yield of catalytic strategies.

Sapkal *et al.*[8] have reported the use of Ni NPs as an effective catalyst has been demonstrated for the efficient cyclocondensation of aromatic/heteroaromatic/aliphatic aldehydes, urea/thiourea and ethyl acetoacetate under microwave irradiation for the preparation of 3,4-dihydropyrimidine-2(1H)-ones via Biginelli reaction with excellent yield (Figure 1).



1 2 3 4(a-v)

Fig. 1: Biginelli Reaction

Pereira *et al.*[9] have developed Gold Supported on Strontium Surface-Enriched CoFe2O4 Nanoparticles for the Selective Oxidation of Benzyl Alcohol(Figure 2).

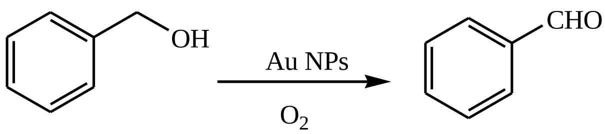


Fig. 2: Oxidation of Benzyl Alcohol

An efficient photo catalytic procedure for the synthesis of substituted biaryls from phenyl boronicacid by Suzuki cross-coupling reactions on Au-Pd alloy nanoparticles under visible light irradiation in good yields has been developed by Xiao et al[10](Figure 3).

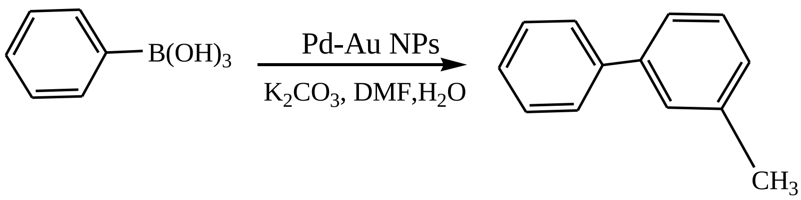


Fig. 3: synthesis of substituted biaryls

Murugesan*et al.* [11] has proposed rapid method for the stereo- and chemo selective hydrogenation of Aromatic ring to Alicyclic by using monodisperse Ru-nanoparticles (Figure 4).

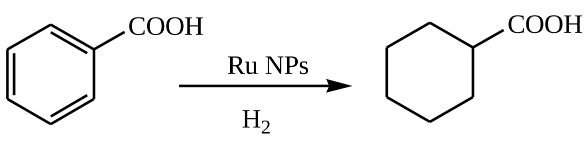


Fig. 4: hydrogenation of Aromatic ring to Alicyclic

Polshettiwar et al [12] have described nanoparticle-supported and attractively reusable ruthenium hydroxide catalyst for hydration of nitriles to amides in aqueous medium (Figure 5).

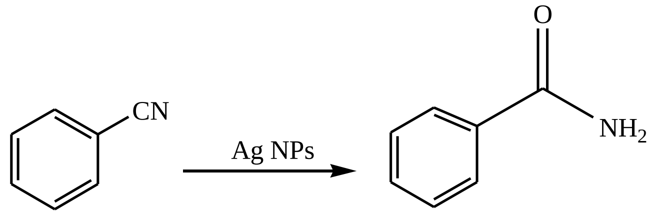


Fig. 5: hydration of nitriles to amides

Karimiet al[13]have proposed Ullmann reaction catalyzed by Cu NPs supported on periodic mesoporous organosilicain good yields (Figure6).

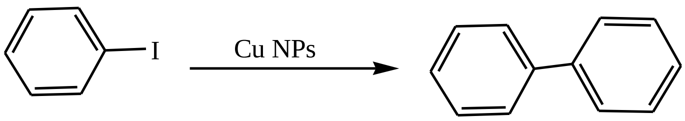


Fig. 6: Ullmann reaction

Sapkal et al[14]have been prepared efficiently polyhydroquinoline derivatives in a via Hantzsch condensation using nanosized Nickel as a heterogeneous catalyst with remarkable advantages such as the shortest reaction time, good yields, simple work-up procedure, and purification of products (Figure7).

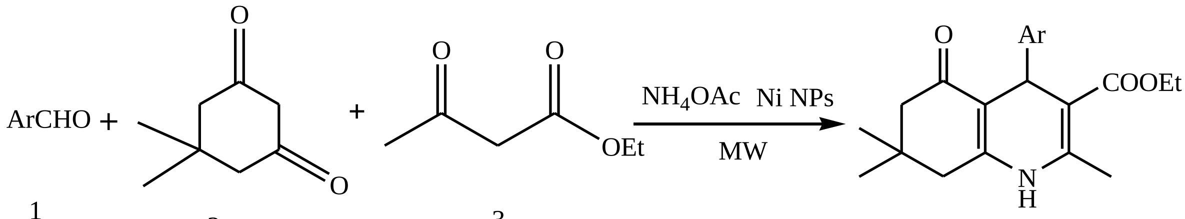


Fig. 7: Hantzsch condensation

CONCLUSION

In our study we have focused the application of the nanoparticles as catalysis for the organic synthesis. Numerous organic reactions have been reported on wide range of application of various supported nanoparticles in catalysis including Au, Ru, Ni, Ag, Pt, Cu, Pd etc. Nanoparticles have potential for improving the efficiency, selectivity and yield of catalytic processes. Higher choosiness of the nanoparticles to response continues through less waste and less contaminations which could prompt more secure procedure and decreased ecological effect. This review provides a comprehensive understanding on organic reactions which are catalyzed using green and environmentally friendly nanocatalysts as well as developments in green catalytic reactions.

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Chapter
10

PHARMACEUTICAL APPLICATIONS OF CERTAIN MEMBERS OF ORDER NOSTOCALES

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ABSTRACT

Cyanobacteria are a group of prokaryotes that are blue-green Gram-negative and photosynthetic bacteria. They are recognized to play critical roles in the universal nutrient cycle due to their ability to repair gaseous nitrogen and carbon dioxide to organic molecules. Cyanobacteria has emerged as one of the most potential resources for combating global warming, disease outbreaks, food shortages, energy crises, and ongoing human population growth. Cyanobacteria have been used as a supplement to poultry feed and as a vitamin and protein supplement in aquatic life. They are effectively used to deal with numerous tasks in various fields of biotechnology, such as agricultural (including aquaculture), industrial (food and dairy products), environmental (pollution control), biofuel (bioenergy), and pharmaceutical biotechnology (such as antimicrobial, anti-inflammatory, immunosuppressant, anticoagulant, and antitumor); recently, there has been a growing interest in using them as biocatalysts. We expand on the great potential of marine cyanobacterial bio-active for improving human health and identify future research areas to support their development as medicines.

KEYWORDS: Cyanobacteria, Gram-negative, photosynthetic bacteria.

INTRODUCTION

The *Nostoc*ales are filamentous cyanophycean (Cyanophyta) representatives with or without sheath, heterocystous or non-heterocystous, unbranched, or with false branching if branched. Members of this group are practically everywhere, but tropical rice fields and damp soil are ideal settings for their occurrence. Members of the order *Nostoc*ales are *Nodularia, Nostoc, Anabeana, Isocystis, Trichormus, Anabeanopsis, Cylinderospermum, Aulosira, Rivularia, Calothrix, Gloeotrichia, Scytonema, Tolypothrix, Microchaete* etc.

One of the leading causes of cancer-related deaths worldwide is lung cancer, which affects both men and women equally. Though decades of research and development have produced novel chemotherapeutic drugs and immunotherapies, lung cancer outcomes and long-term survival have only slightly improved (Edward *et al.,* 2004). Improving lung cancer therapy may therefore depend on investigating novel and unusual sources of bioactive compounds with potential anti-cancer properties. Members of the order *Nostoc*ales may contain chemicals that have therapeutic potential to treat malignant diseases like cancer because of their diverse forms (Burja *et al.,* 2001). Numerous bioactive compounds with significant biological potential are produced by the different metabolic pathways. It has been demonstrated that these substances are effective against a range of illnesses.

ANTI-CANCER PROPERTY

Gastric cancer is one of the most frequent malignant cancers of the digestive tract, with the second highest fatality rate of any malignant cancer. As a result, it is critical to identify chemicals that can disrupt signaling pathways linked to cancer migration.

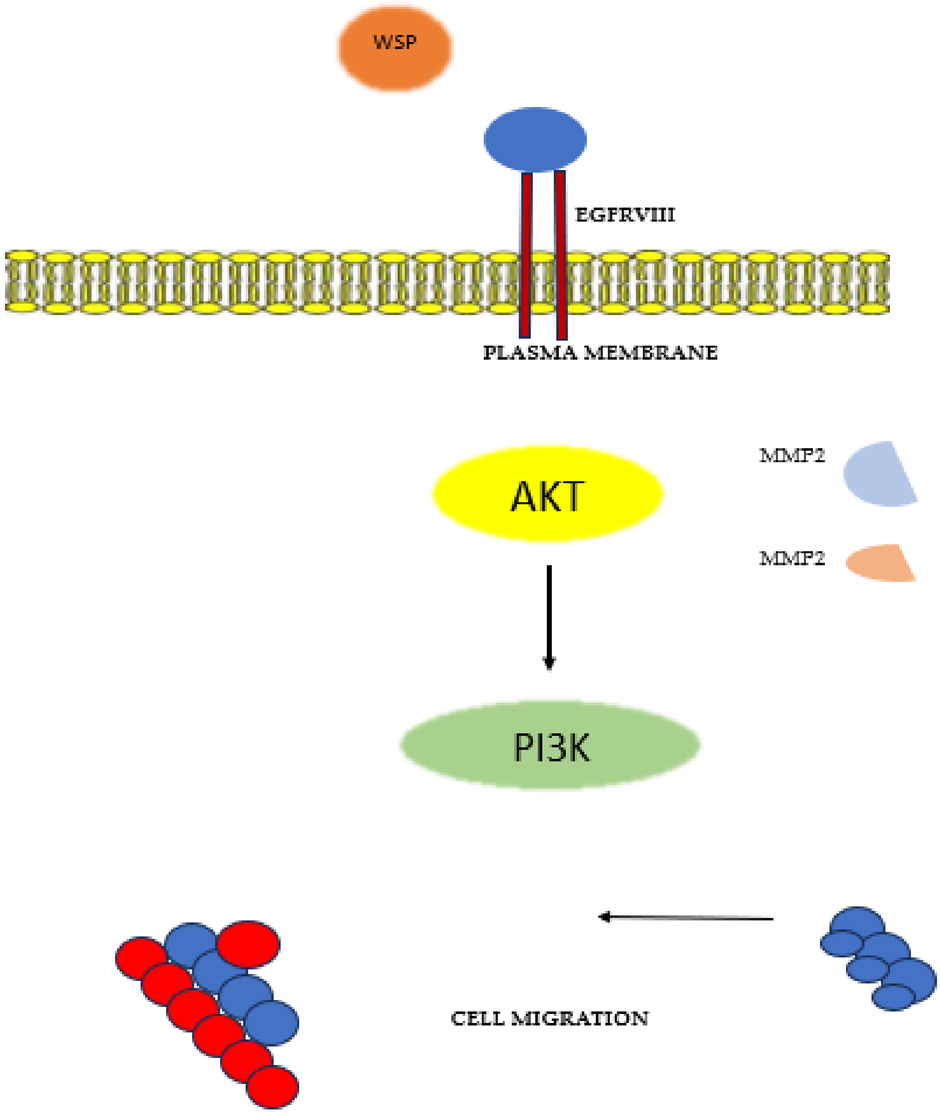

Fig. 1: Mechanism of WSP Gene of *Nostoc commune* (Guo *et al.*, 2022)

ANTIOXIDANT PROPERTY

The increasing health and wellness business necessitates using alternative and sustainable bioactive resources. Cyanobacteria are ancient photosynthetic microorganisms found in aquatic habitats that have been heralded as the next generation of sustainable bioactive cell manufacturers. Spirulina-derived health products, for example, are household names due to their widespread use in supplements, feed, and food. Microalgae grow 10 times quicker than terrestrial crops and do not compete with land to flourish. This competitive advantage emphasizes their ability to address global concerns, such as sustaining and feeding a growing human population Cyanobacteria are known as cell manufacturers because they produce their own macronutrients (protein, carbohydrates, and lipids) and micronutrients (phycobiliproteins, beta-carotene, tiny bioactive compounds, and so on). Previous research found that bioactive cyanobacteria, such as phycobiliproteins from *Spirulina platensis* and *Oscillatoria sp.*, and *Nostoc commune* have antioxidant properties (Sanab *et al.*, 2012, Carlos *et al.*, 2021, Tseng *et al.*, 2021).

ANTIBIOTIC PROPERTY

Recent years have seen a significant increase in interest in cyanobacteria due to their potential as a source of novel antibiotics. It has been discovered that cyanobacteria produce a wide range of bioactive substances with antiviral, antimicrobial, and anticancer characteristics (Tan, 2007). Recent years have seen a lot of interest in marine cyanobacteria due to their potential as a source of novel antibiotics. Numerous bioactive substances with strong antimicrobial, antiviral, and anticancer properties are known to be produced by cyanobacteria (Tan, 2007). But it has been discovered that marine cyanobacteria create distinct substances that are absent from their terrestrial counterparts (Dittmann & Wiegand, 2006). According to Tan (2007), these substances show encouraging antibacterial properties against a variety of harmful bacteria, including strains that are resistant to medications. One of the most promising classes of antibiotics produced by marine cyanobacteria is the cyanobacterial peptides. These peptides are cyclic and contain a range of unique amino acid residues, making them structurally diverse and bioactive. For example, it has been shown that from the cyanobacterium *Nostoc* sp. isolated cyclic peptide *Nostoc* cyclopeptide an exhibits antibacterial activity against several Gram-positive bacteria (Fidor *et al.*, 2021). Likewise, it has been demonstrated that the cyanobacterium *Lyngbya majuscula* produces the cyclic peptide microcyclamide 7806A, which exhibits strong anti-methicillin activity against *Staphylococcus aureus* (MRSA) (Dahiya *et al.*, 2020). Another class of antibiotics produced by marine cyanobacteria is the fatty acid derivatives. These compounds are derived from polyunsaturated fatty acids and have been shown to have antibacterial, antifungal, and antiviral activity. For example, it has been shown that the cyanobacterium *Thalassospira* sp. isolated fatty acid derivatives Thalassospiramides A and B exhibit potent activity against Gram-negative bacteria (Abad *et al.*, 2011). Similarly, it has been shown that the cyanobacterium *Scytonema* sp. produced polyketide scytophycin A is active against several drug-resistant bacteria, including MRSA and vancomycin-resistant Enterococcus (VRE) (Smith *et al.*, 1993). Cyanobacteria are photosynthetic and oxygen-releasing organisms, found in various freshwater and marine ecosystems. They produce many secondary metabolites with antimicrobial properties (Nawaz *et al.*, 2023). These metabolites act against pathogenic bacteria, fungi, algae, and some also have antiviral effects. As drug resistance in microorganism's increases, cyanobacterial secondary metabolites cyanobacteria play a key role in the development of new drugs. This review explores the antibacterial, antifungal, antialgal, and antiviral properties of cyanobacterial metabolites (Singh *et al.*, 2020). Antibiotic-resistant bacteria pose a serious public health concern, affecting both clinical and industrial fields. Finding new antibiotics is crucial, but traditional sources have limited potential for discovery. Antarctic bacteria have been identified as a potential source for novel antimicrobial compounds due to their extreme environment. This review explores how adaptation to polar conditions has enabled Antarctic bacteria to produce diverse antibiotic molecules, supporting biotechnology applications and enhancing our understanding of polar ecosystems (Núñez-Montero & Barrientos, 2018). Cyanobacteria contain a wide range of bioactive compounds, including a recently identified antibacterial compound that was extracted using chromatographic methods from the cyanobacterium *Nostoc* sp. MGL001. The compound known as EMTAHDCA, which had not been previously reported, was examined through the use of NMR and electrospray ionisation mass spectroscopy (ESIMS) methods. It demonstrated strong growth-inhibiting properties, mostly against strains of Gram-negative bacteria. The compound's capacity to bind to the OmpF porin protein and the 30S ribosomal fragment was assessed through in silico studies.

Comparative molecular docking analysis revealed that EMTAHDCA has a strong binding affinity to these particular targets, indicating that it functions similarly to pharmaceuticals that are sold commercially (Niveshika *et al.*, 2016). In summary, marine cyanobacteria are a promising source of novel antibiotics, and several studies have reported the isolation and characterization of these compounds. The structurally diverse and bioactive cyanobacterial peptides and fatty acid derivatives, as well as other secondary metabolites, have shown potent activity against a range of bacterial pathogens, including drug-resistant strains. Further research on these compounds and their mechanisms of action is needed to fully realize their potential as new antibiotics.

***MRSA** - Methicillin-resistant Staphylococcus aureus

***VRE** - Vancomycin-resistant enterococci

***EMTAHDCA** -thyliminomethyl-12 (morpholin-4-ylmethoxy)-5, 8, 13, 16-tetraaza-hexacene-2, 3-dicarboxylic acid

Fig 2: Different Pharmaceutical Properties of Algae

https://www.healthy-holistic-living.com/wcontent/uploads/2014/02/microalgeacancer.gif

ANTIFUNGAL PROPERTY

The fungicidal synthesis of cyanobacteria has been documented since the turn of the century and has been shown to support the survival of life on Earth. These metabolites mediate a great deal of cyan bacteria's interactions with other species and may serve as defense mechanisms against parasites and predators (Preisitsch *et al.,* 2015). It is well known that fungi, particularly those in the cheered group, are primarily in charge of controlling the population of cyanobacteria (Preisitsch *et al.,* 2014). The existence of chemotactic zoospores and the growth of rhizoids, which are able to locate targets and extract nutrients, respectively, are responsible for the pathogen's capacity to infect these photosynthetic bacteria (Preisitsch *et al.,* 2016). The various susceptibility levels within the species can be explained by the molecular repertoire of each strain of cyanobacteria (Preisitsch *et al.,* 2016). Certain substances have the ability to impede essential functions of the fungi, hence averting infection. Additionally, they have the ability to hunt down other living things, including some bacteria and cyanobacteria, which can function as rivals and predators, respectively.

On reviewing many articles, it is found that several enzymes, phycobiliproteins, and polysaccharides in addition to 106 secondary metabolites of cyanobacterial origin having antifungal activity. These chemicals were primarily derived from terrestrial strains. These cyanobacteria were primarily found to contain hapalindole-type alkaloids. These substances that contain nitrogen never exist by themselves. They are made up of a combination of different alkaloids from the same group. As a result, it is common to see many hapalindole-type alkaloids produced by a single cyanobacterium. When compared to other ecosystems, terrestrial ecosystems typically exhibit a higher degree of variability, which is indicative of an exceptionally high stress level. Cyanobacteria isolated from these environments typically utilize the insertion of new gene families as a method, which results in a bigger genome compared to freshwater and marine strains. A few integrated genes are linked to the synthesis of natural compounds (Preisitsch *et al.*, 2016). Freshwater and terrestrial cyanobacteria produced five metabolites in common, including members of the Scytophycin, Laxaphycin, and carbamidocyclophane families. Just two and one of the thirty-one compounds that were isolated from marine strains, respectively, are common to freshwater and terrestrial strains.

CONCLUSION

This review has shown that cyanobacteria are a prospective source of various primary and secondary metabolites with known biological activity. Nonetheless, in order to improve the usefulness of cyanobacteria for human and animal exploitation, substantial research is required for characterizing cyanobacterial secondary metabolites, which are widely used in various nations in the fields of nutraceuticals and pharmaceuticals.

To present, the bulk of marine cyanobacterial compounds identified have been optimized for biological activities rather than drug-like qualities. To improve bioavailability, stability, and pharmacokinetic features of marine cyanobacterial compounds, more optimization is required. Another difficulty is a lack of knowledge about the mechanisms of action of marine cyanobacterial bio-actives. Despite tremendous progress in finding marine cyanobacterial substances with medicinal potential, their methods of action remain unknown. More study on how to properly exploit cyanobacteria employing green technological breakthroughs, as well as efficient insights on cyanobacteria usage on larger scales, is required. Future research that is likewise promising is required to investigate more positive effects of cyanobacteria.

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Chapter

11

COPPER COMPLEXES CONTANING BENZIMIDAZOLE DERIVATES - A REVIEW

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ABSTRACT

Nitrogen-containing heterocycles of benzimidazole derivatives and its corresponding copper complexes. Mostly all the reaction conditions are in 1:1 stoichiometric ratio. But all the complexes are in unexpected formation with two different oxidation states Cu(I/II). All the complexes are structurally characterized. Both ligand and complexes are subjected to biological studies.

KEYWORDS: Benzimidazole derivatives, Copper complexes, Biological studies.

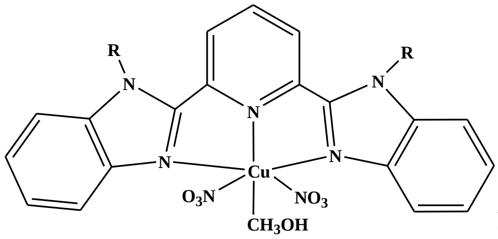
INTRODUCTION

Among the various nitrogen-containing heterocycles, various benzimidazole derivatives are common building blocks in biologically active compounds. They exhibit significant pharmacological and biological activities such as anticancer, antioxidant, antihypertensive, antibacterial and antihistaminic properties.[1–5] in addition, the derivatives of benzimidazole is employed in other fields, such as sensors [6], dyes [7]and fluorescence. [8] Their synthesis is one of the most electrifying themes in practical organic synthesis. A number of synthetic methods have been developed in recent years to cover a variety of new reagents for the synthesis of 2-substituted benzimidazoles. [9-14]Among the bridging ligands, NaN_3 (Sodium azide) and pseudohalides (such as cyanide ion, inorganic acids and hydrogen cyanide) are good choice, because of versatile coordination behaviour depending upon the steric and electronic demands of coligands. [15,16] On the other hand, such nature of bridged complexes is of great importance for biologists and bioinorganic chemists investigating the structure and role of active sites in proteins and for physical inorganic chemists seeking to design new magnetic materials. [17,18]

Copper complexes play an important role in the active sites of metalloproteins in biological systems and potential application for numerous catalytic processes in living organisms that involve electron transfer reactions or activation of some antitumor substance.[19]A number of Cu(II) chelate complexes exhibit cytotoxic activity through apoptosis or enzyme inhibition.[20]

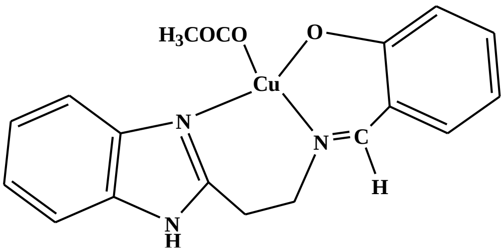
LITERATURE REVIEW

Xu etal. have reported a few pincer type ligands, 1,3-bis(2' -benzimidazolyl)benzene (L1), 2,6-bis(2' -benzimidazolyl)- pyridine (L2), and their N-alkylated derivatives. They were characterized by IR and ^1H-NMR spectroscopy. The N-alkylated benzimidazolyl ligands, 2,6-bis(N-benzylbenzimidazolyl)pyridine (L3), 2,6-bis(N-allylbenzimidazolyl)pyridine (L4), and 1,3-bis(N-allylbenzimidazolyl)benzene (L5) form 1 : 1 complexes with copper nitrate. X-ray diffraction studies showed that $[Cu (NO_3) (MeOH) (L_4)] (NO_3)$ and $[Cu (NO_3)_2(L_3)]$ are mononuclear in nature, whereas $[Cu (NO_3)_2(L_5)]$. 2DMF exhibited one-dimensional zigzag form.[21]

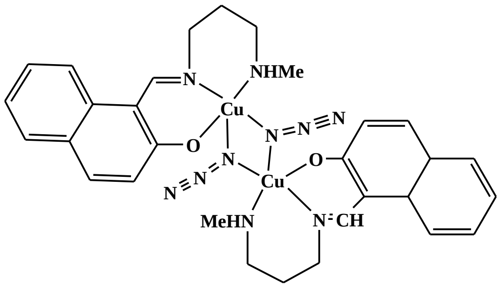


R=Allyl

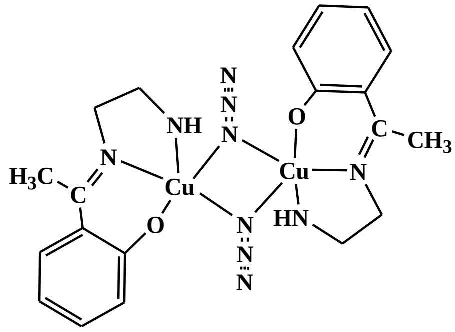
Kumar etal. Have reported three new Cu (II) complexes of a Schiff base ligand, 2-[2-(1H-benzo[d]imadazol-2-yl) ethylimino) methyl] phenol, (HL), derived from 2-aminoethylbenzimidazolyl and salicylaldehyde, the complexes have been synthesized and characterized by elemental analyses, electronic and IR spectroscopy. Results showed that HL acted as tridentate ligand and coordinates through the imine nitrogen of benzimidazole ring, the azomethine nitrogen and a deprotonated phenolic oxygen of the Schiff base. One of the complexes with the composition [Cu (L) CH3COO] has been structurally characterized. The copper (II) ion adopted a distorted square planner geometry involving the N, N and O atoms of L and an O atom of acetate anion.[22]



Copper(II) complexes $[Cu_2L_2(\mu\text{-}_{1,1}\text{-}N_3)_2]\cdot 2CH_2Cl_2$ (**1**) and $[CuL(\mu_{1,5}\text{-dca})]_n$(dca = dicyanamide) (**2**) have been synthesized by using a tridentate Schiff base ligand, 1-[(3-methylamino-propylimino)-methyl]-naphthalen-2-ol (HL) and azide or dicyanamide as co-ligand.[23] Both the complexes are characterized by elemental analyses, IR, UV–Vis spectroscopy and single crystal X-ray diffraction studies. The coordination geometry around the copper center in complex **1** was found elongated (4 + 1) square pyramid whereas, complex **2** square planar geometry with the tridentate Schiff base ligand in the basal plane. Complex **1**, a centrosymmetric dimer in which metal centers are connected by the double μ-1,1-azido bridges. On the other hand, complex **2** is a 1D zigzag chain in which metal centers are connected by μ-1,5-$N(CN)_2$ ligands.



Zbirietal. have reported a new rare variety asymmetric μ-1,1-azido bridged copper(II) complex and was structurally characterized. The complex $[Cu_2L2(\mu_2\text{-}1,1\text{-}N_3)_2]$. H_2O. CH_3OH (L = 1-(N-ortho-hydroxyacetophenimine)-2-aminoethane) (1), crystallized in monoclinic space group, $P2_1/n$. A strong ferromagnetic interaction between the metal centers was found in the complex. To rationalize this paradoxical magnetic behavior, DFT calculation of this and other four complexes with very similar structures have been performed within broken symmetry framework. [24]

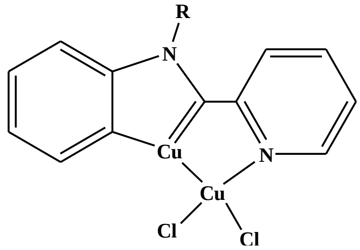


Yang etal. have reported three metal complexes based on the flexible bis(benzimidazole) derivatives, namely $[Co_2(L1)_4(pydc)_2]·2H_2O$ (1), $\{[Cu(L1)(pydc)]·0.75H_2O\}n$ (2), and $[Co_2(L2)_2(pydc)_2]·8H_2O$ (3), [L1 = 1,2-bis(5,6-dimethylbenzimidazol-1-ylmethyl)benzene, H2pydc = 2,6-pyridinedicarboxylic acid, L2 = 1,4-bis(5-methylbenzimidazol1-ylmethyl)benzene] were hydrothermally synthesized and characterized by IR spectra, elemental analyses, UV/Vis diffuse refraction spectroscopy, and X-ray single-crystal diffraction. Complexes 1 and 3 exhibited a dinuclear structure composed of two central cobalt atoms bridged by flexible bis(benzimidazole) ligands and 3 finally packed into a two-dimensional supramolecular network through π···π stacking interaction. Complex 2 showed an one-dimensional zigzag chains motif, which further extended into a 2D supramolecular layer by face-to-face π···π stacking interactions. The luminescence properties of complexes 1–3 in the solid state at room temperature were described. Moreover, complexes 1 and 2 showed higher catalytic activity than complex 3 for degradation of congo red azo dye in a Fenton-like process.[25]

Lewis etal. have reported the synthesis and characterization of two copper(II) complexes containing 2-(2-pyridyl)benzimidazole (PyBIm) with the biological activity of these two complexes and a third Cu(II) complex containing 2-(2- pyridyl)benzothiazole (PyBTh). Complex 1, $[Cu(PyBIm)(NO_3)(H_2O)](NO_3)$, is a four coordinate, distorted square planar geometry with one ligand (N,N), nitrate and water bound to Cu(II). The $[Cu(PyBIm)_3](BF_4)_2$ complex 2 has distorted octahedral geometry with a 3:1 Py(BIm) ligand to metal ratio. The distorted trigonal bi-pyramidal geometry of compound 3, $[Cu(PyBTh)_2(H_2O)](BF_4)_2$, is comprised of two PyBTh ligands and one water. Biological activity of the complexes 1–3 has been assessed by analyzing DNA interaction, nuclease ability, cytotoxic activity and antibacterial properties. Complex 3 exhibited potent concentration dependent SC-DNA cleavage forming single- and double-nicked DNA in contrast to the weak activity of complexes 1 and 2. The interaction between the complexes 1–3 and DNA was investigated using fluorescence emission spectroscopy and the results revealed all complexes strongly intercalate with DNA having Kapp values of 2.65×10^6, 1.85×10^6 and 2.72×10^6 M^{-1} respectively. Cytotoxic effects of complexes 1–3 were examined using HeLa and K562 cells and show cell death in the micromolar range with the activity of 1 ≈ 2 and were slightly higher than 3. Similar reactivity was observed in the antibacterial studies with E. coli and S. aureus. [26]

Devereux etal., have reported a series of copper complexes such as, Cu(BZA)2(EtOH)0.5 (1). The complexes prepared by the reaction of copper(II) hydroxide with benzoic acid (BZAH). [Cu (TBZH) 2(BZA)]- (BZA). 0.5TBZH. H_2O (2) and [Cu (2-PyBZIMH) (2-PyBZIM) (BZA)].1.66EtOH (3) were obtained when 1 reacted with thiabendazole (TBZH) and 2-(2-pyridyl) benzimidazole (2-PyBZIMH), respectively. $[Cu (BZA)_2(phen)(H_2O)]$ (4) Was isolated from the reaction of benzoic acid and 1, 10-phenanthroline (phen) with copper (II) acetate dihydrate. Molecular structures of 2, 3 and 4 were determined crystallographically. The complexes 2 and 3 are hydrogen bonded dimers and trimers, respectively. The copper centres in complexes 2 and 3 are bis-chelate derivatives that have N_4O ligation and their geometry is very similar being approximately square-pyramidal. However, in complex 2 both TBZH ligands were neutral and in complex 3 one of the 2-PyBZIMH chelators is deprotonated on each copper. Complexes 1–4, the metal free ligands and a simple copper (II) salt were assessed for their chemotherapeutic potential against the hepatocellular carcinoma (Hep-G2) and kidney adenocarcinoma (A-498) cell lines.[27]

Prosser etal. have reported the Cu(II) complex $CuCl_2$(pbzH), pbzH = 2-(2-pyridyl)benzimidazole and derivatives modified at the non-coordinated nitrogen of the benzimidazole fragment, and also studied for anticancer agents. These compounds showed promising cytotoxicity against A549 adenocarcinomic alveolar basal epithelial cells with IC_{50} values in the range of 5–10 μM. Importantly, this activity was found to higher than either $CuCl_2 \cdot 2H_2O$ or the individual ligands. Further DNA cleavage studies using agarose gel electrophoresis demonstrated strand cleavage by the complexes in the presence of ascorbate which was mediated by reactive oxygen species (ROS). Through a fluorescence-based in vitro assay, intracellular ROS generation in the A549 cell line was observed in which the damage by ROS is responsible for the observed activity of the complexes.[28]



Adhikaryetal., have reported three copper(II) tridentate (NNO) Schiff base azido complexes, $[Cu(L^1)(N_3)]$ (1), $[Cu_2(L^2)_2(\mu\text{-}1,1\text{-}N_3)_2]$ $[Cu(L^2)(N_3)]$ (2) and $[Cu(L^3)(N_3)]$ (3). [where HL^1 = 1-(N-5-methoxy-ortho-hydroxyacetophenimino)-2, 2-dimethyl-aminoethane], HL^2 = 1-(N-ortho-hydroxyacetophenimine)-2, 2-diethyl-aminoethane and HL^3 = 1-(N-salicylideneimino)-2-(N, N-diethyl)-aminoethane]. The structure of complex (1) has been determined by single crystal X-ray diffraction analysis. In 1, out of four coordination sites of copper (II) ion, three are occupied by the NNO donor atoms of a tridentate Schiff base ligand, HL1 and the remaining site is occupied by terminal nitrogen of azido moiety. All the complexes exhibited high catalytic activity in epoxidation reactions of a variety of olefins with tert-butyl-hydroperoxide in acetonitrile. Antimicrobial activity of the ligand and copper(II) complexes were carried out.[29]

Manikandanetal., have prepared a copper(II) azide complexes of three tridentate ligands namely 2,6-(3,5-dimethylpyrazol-1-ylmethyl)pyridine (L), 2,6-(pyrazol-1-ylmethyl)pyridine (L′), and dipropylene triamine (dpt) with different azide-binding modes. The ligand L formed two end-on-end (μ-1,3) diazido-bridged binuclear complexes, $[CuL(\mu\text{-}N_3)]_2(ClO_4)_2$ (1) and $[CuL(\mu\text{-}N_3)(ClO_4)]_2 \cdot 2CH_3CN$ (2), and L′ formed a perchlorato-bridged quasi-one-dimensional chain complex and $[CuL'(N_3)(ClO_4)]_n$ (3) with monodentateazide coordination. The ligation of dipropylene triamine (dpt) gave an end-on (μ-1, 1) diazido-bridged binuclear copper complex $[Cu\ (dpt)\ (\mu\text{-}N_3)]_2(ClO_4)_2$ (4). The crystal and molecular structures of these complexes have been solved.[30]

Goheretal., have prepared the first polymeric copper(I) complex with a μ-1,1,3-N_3 bridge $[Cu(pyza)(\mu\text{-}1,1,3\text{-}N_3)]_\infty$ (pyza 5 pyrazinecarboxamide). The reaction between copper (I) azide and pyrazinecarboxamide resulted in the formation of a deep red-brown complex in high yield.[31]

CONCLUSION

Herein, we have concluded the various coordination behaviors of copper complexes containing Nitrogen-containing heterocycles of benzimidazole derivatives. Most of complexes were confirmed by single crystal X-ray diffraction studies. From the X-ray study copper complexes exhibited diverse natures in geometry. Further, in vitro cytotoxicity of copper complexes against different cancer cell lines by MTT assay and cytological changes observed by staining method as compared with standard cisplatin.

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Chapter
12

EFFECT OF TEMPERATURE ON MOLECULAR INTERACTIONS INLIQUID MIXTURES AT ATMOSPHERIC PRESSURE

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ABSTRACT

Ultrasonic investigation of binary liquid mixtures has become an important tool for determination of internal structures of pure liquids and their associates. In order to perform such investigation ultrasonic velocity was computed by statistical liquids state model of Flory from 298.15-308.15K temperatures over the entire range of mole fractions for dodecane+1- butanol and +2-butanol and compared with the literature values.

KEYWORDS: Ultrasonic, associates, Flory, interaction behavior

INTRODUCTION

Ultrasonic investigations of multicomponent liquid mixtures are considerable importance in understanding the molecular interactions between component molecules. Various thermodynamic properties of liquid mixtures can be easily determined by the help of ultrasonic velocity Dael *et al.* (1968), which are not determined by other means. Successful attempts have been made by number of workers on the measurements and theoretical evaluation of sound velocity in binary liquid mixture by using various empirical theoretical models. Intermolecular free lengths in liquids were determined using the knowledge of ultrasonic velocity by Jacobson *et al.* (1952) Nomoto *et al.* (1958) proposed an empirical relation for sound velocity in liquid mixtures. Theoretical prediction of various thermo physical properties from pure liquids was carried out by Pandey *et al.* (1999). Speed of sound and isentropic compressibility of weakly interacting liquids from various models at different temperature was determined by Shukla *et al.* (2017).). Ultrasonic study of various liquid state models using Protic and Aprotic solvents from 298.15 to 318.15K by Awasthi *et al.* (2021). In the continuation of previously published work Prediction of molecular interactions in binary system from 288.15 to 318.15K by ultrasonic speed and isentropic compressibility Awasthi *et al.* (2021), this book chapter is concerned with theoretical investigation of ultrasonic velocity of aforementioned liquid mixtures at different temperatures by Flory *et al.* (1965) and these computed results were compared with the measured work of Peleteiro et al (2004). The values of β_s and Zcan also are calculated by the computed values of ultrasonic velocity to analyze the behavior of liquid mixtures at different temperatures. The main objective of this work is to analyze the interaction behavior of weakly interacting liquids at different temperatures.

Table 1: Density and ultrasonic velocity of pure liquids at 298.15K

	T/K	α X10^3	β_T x10^{12}	V	ϱ_{exp}	ϱ_{lit}	U_{exp}	U_{lit}
Dodecane	298.15	1.3298	123.13	228.59	0.7452	0.7453	1278.2	1278
1-Butanol	298.15	1.3111	118.00	91.98	0.8059	0.8057	1239.29	-
2-Butanol	298.15	1.3342	124.34	92.40	0.8022	0.8026	1210.98	1212

Theoretical

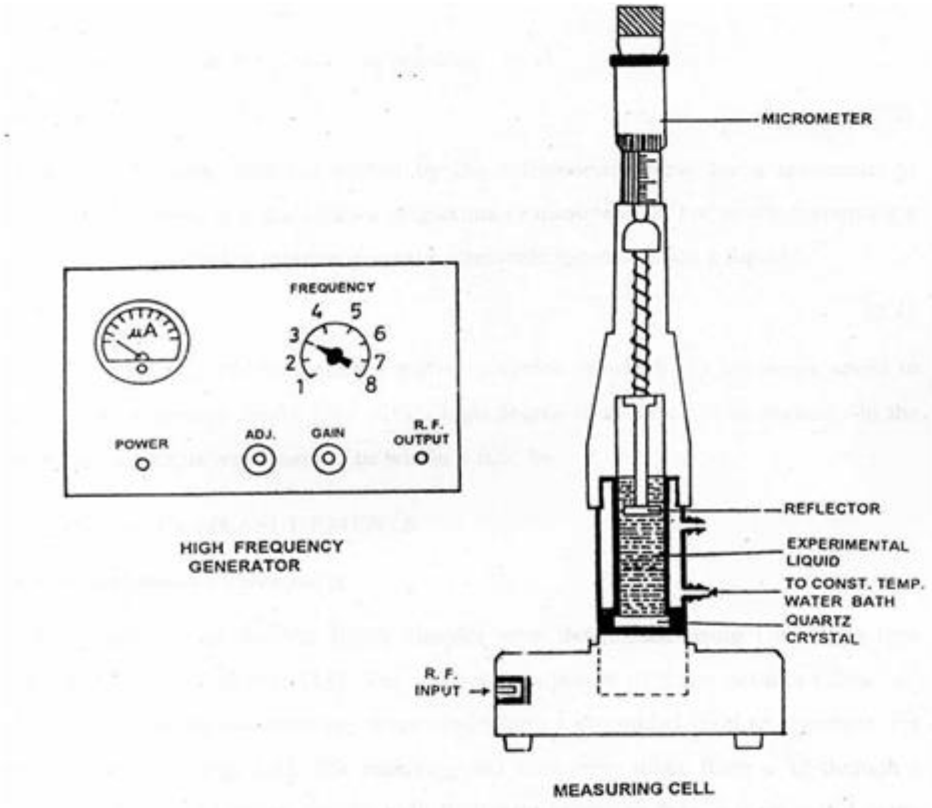

Fig. 1: Ultrasonic interferometer

PRIGOGINE-FLORY-PATTERSON MODEL

The original cell model of Prigogine *et al.* (1952) for chain molecule liquids uses a dependence of the configurational energy on volume equivalent to the Lennard-Jones (6-12) energy distance;

$$\tilde{u}(\tilde{v}) = -2\tilde{v}^{-2} + \tilde{v}^{-4} \qquad (1)$$

More generally for an (m, n) potential,

$$\tilde{u} = \frac{(-n\tilde{v}^{-m/3} + m\tilde{v}^{-n/3})}{(n-m)} \qquad (2)$$

This leads to the following equation of state

$$\frac{\tilde{P}\tilde{v}}{\tilde{T}} = (1 - b\tilde{v}^{1/3})^{-1} + \frac{mn}{3(m-n)}(\tilde{v}^{-n/3} - \tilde{v}^{-m/3}) \qquad (3)$$

Where b is a packing factor and equals to $(m/n)^{1/(n-m)}$

$$\sigma^{*} = k^{1/3} p^{*2/3} T^{*1/3} \qquad (4)$$

$$\frac{\phi_{surface}}{\phi_{Bulk}} = \frac{(\tilde{v}^{1/3} - 0.5b)}{(\tilde{v}^{1/3} - b)} \qquad (5)$$

$$b = \frac{m^{1/(n-m)}}{n}$$

$$\tilde{\sigma}(\tilde{v})^{2/3} = -M\tilde{u}(\tilde{v}) - T\ln\frac{(\tilde{v}^{1/3} - 0.5b)}{(\tilde{v}^{1/3} - b)} \quad (6)$$

The surface energy and entropy are given by;

$$\tilde{\sigma}_U = -M\tilde{u}(\tilde{v}); \qquad \tilde{\sigma}_S = \ln\frac{(\tilde{v}^{1/3} - 0.5b)}{(\tilde{v}^{1/3} - b)} \quad (7)$$

$$\tilde{\sigma}(\tilde{v}) = M\tilde{v}^{5/3} - \frac{(\tilde{v}^{1/3} - 1)}{(\tilde{v}^{2})}\ln\frac{(\tilde{v}^{1/3} - 0.5)}{(\tilde{v}^{1/3} - 1)} \quad (8)$$

Flory's statistical theory has no direct link with ultrasonic velocity. So, the evaluation of ultrasonic velocity of binary liquid mixture through Flory's statistical theory requires the use of well known and well tested Auerbach relation which is expressed as

$$U = \left(\frac{\sigma}{6.3\times10^{-4}\rho}\right)^{2/3} \quad (9)$$

Where U, σ and ρ denote the ultrasonic velocity, surface tension and density of binary liquid mixture respectively. This procedure has been developed recently to evaluate the sound velocity in pure liquids and liquid mixtures. The validity of Auerbach relation has also been tested. Thus on the basis of Flory theory, surface tension of binary liquid mixture is given by the expression,

$$\sigma = \sigma^{*}\tilde{\sigma}(\tilde{v}) \quad (10)$$

The intermolecular energy E_0 for the liquid is expressed by,

$$E_0 = \frac{NrS\eta}{2V} \quad (11)$$

Where N: number of molecules,
V: volume per segment
rS: number of contact sites
η: Constant characterizing the energy of interaction for a pair of neighbouring sites.

The reduced equation of state derived from the resulting partition function is given by,

$$\frac{\tilde{P}\tilde{v}}{\tilde{T}} = \frac{\tilde{v}^{1/3}}{\tilde{v}^{1/3} - 1} - \frac{1}{\tilde{v}\tilde{T}} \quad (12)$$

The reduced quantities $\tilde{P}, \tilde{V}$ and $\tilde{T}$ are given by

$$\tilde{P} = \frac{p}{p*} = 2pv^{*}/S_{\eta} \tag{13}$$

$$\tilde{T} = \frac{T}{T*} = 2v^{*}ckT/S\eta \tag{14}$$

$$\tilde{v} = v/v* = V/V* \tag{15}$$

Thus

$$P^{*} = ckT^{*}/v^{*} \tag{16}$$

$$T^{*} = \frac{T\tilde{v}^{4/3}}{(\tilde{v}^{1/3} - 1)} \tag{17}$$

From which:

$$\tilde{v} = \left[\frac{\alpha T}{(3+3\alpha T)} + 1\right]^{3} \tag{18}$$

Whereα is the thermal expansion coefficient at P=0 (or without appreciable error at 1 atm). The temperature derivative of eq. (12) at constant volume evaluated for P=0 gives

$$P^{*} = \frac{\alpha}{\beta_T} T\tilde{v}^{2} = \gamma T\tilde{v}^{2} \tag{19}$$

$$-E_0 = (A_{11}\eta_{11} + A_{22}\eta_{22} + A_{12}\eta_{12})/v \tag{20}$$

In the light of the above assumption and definitions set forth in eq.(11), it is possible to write

$$A_{12} + 2A_{11} = s_1 r_1 N_1$$

$$A_{21} + 2A_{22} = s_2 r_2 N_2 \tag{21}$$

From which the intermolecular energy may be written as

$$-E_0 = [(s_1 r_1 N_1 \eta_{11} + s_2 r_2 N_2 \eta_{22})$$

$$-(\Delta\eta_1 A_{12} + \Delta\eta_2 A_{21}]/2v \tag{22}$$

Where

$$\Delta\eta_1 = \eta_{11} + \eta_{22} - 2\eta_{12}$$

$$\Delta\eta_2 = \eta_{22} + \eta_{11} - 2\eta_{21} \tag{23}$$

It will be assumed that random mixing of two components is taking place. Furthermore, it is also assumed that a species of kind i neighbours any given site to be equal to its site fraction θ_i which is defined for binary mixture as follows.

$$\theta_1 = 1 - \theta_2 = s_1 r_1 N_1 / s\bar{r} N \tag{24}$$

Where

$$\bar{r} = (\bar{r}_1 N_1 + \bar{r}_2 N_2)/N \tag{25}$$

$$S = (S_1 r_1 N_1 + S_2 r_2 N_2) / \bar{r} N \quad (26)$$

N=N_1+N_2

Substituting the values of $\bar{r}$ and S from eq. (25) & (26) in eq. (24) considering the assumption,

i.e., $$\frac{S_i}{S_j} = (\frac{r_i}{r_j})^{-1/3} = (\frac{v_i^*}{v_j^*})^{-1/3}$$

We get the final expressions for θ_2 &θ_1 for binary liquid mixtures:

$$\theta_2 = \frac{(S_2 r_2 N_2)\bar{r}}{(S_1 r_1 N_1 + S_2 r_2 N_2)\bar{r} N}$$

$$\theta_1 = \frac{(S_1 r_1 N_1)\bar{r}}{(S_1 r_1 N_1 + S_2 r_2 N_2)\bar{r} N}$$

Dividing the above expression by S_2r_2 for θ_2 and S_1r_1 for θ_1 and considering the N=number of segment, we get the final expressions which are used throughout the calculations;

$$\theta_2 = \frac{\psi_2}{\psi_2 + \psi_1 (v_2^* / v_1^*)^{1/3}}$$

$$\theta_1 = [1 - \theta_2] \quad (28)$$

On this basis

$$A_{12} = S_1 r_1 N_1 \theta_2 = S_2 r_2 N_2 \theta_1 \quad (29)$$

By substituting eq.(24) and eq. (29) into eq.(20) we have

$$\frac{-E_0}{\bar{r} N} = \frac{S}{2v} [\theta_1 \eta_{11} + \theta_2 \eta_{22} - \theta_1 \theta_2 \Delta \eta_1] \quad (30)$$

Defining the segment fractions ψ_2 and ψ_1 by

$$\psi_2 = 1 - \psi_1 = r_2 N_2 / \bar{r} N$$

$$\psi_1 = 1 - \psi_2 = r_1 N_1 / \bar{r} N \quad (31)$$

Substituting the values of $\bar{r}$ and N from eq.(25) and (26) to eq. (31) we get the expression

$$\psi_2 = \frac{r_2 N_2}{r_1 N_1 + r_2 N_2} \quad (32)$$

$$\psi_1 = \frac{r_1 N_1}{r_1 N_1 + r_2 N_2}$$

Dividing the above by r_2 for ψ_2 and r_1 for ψ_1 and applying the assumption;

$$\frac{r_i}{r_j} = \frac{v_i^*}{v_j^*}$$

We get the final expression used throughout the calculation:

$$\psi_2 = \frac{x_2}{x_2 + x_1(v_1^* / v_2^*)} \tag{33}$$

$$\psi_1 = [1 - \psi_2]$$

Sum of the segment, site and mole fraction is taken as unity in derivation

We have

$$1/\bar{r} = \psi_1 / r_1 + \psi_2 / r_2$$

$$S = \psi_1 S_1 + \psi_2 S_2 \tag{34}$$

$$\theta_{i=}\psi_i S_i / S$$

The characteristic pressures for the pure components are given by eq.(13) to be

$$P_1^* = \frac{S_1 \eta_{11}}{2v^{*2}}, \quad P_2^* = \frac{S_2 \eta_{22}}{2v^{*2}} \tag{35}$$

By analogy we define (assuming $x_{ij}=x_{ji}$)

$$X_{12} = \frac{S_1 \Delta \eta_1}{2v^{*2}} \tag{36}$$

Substituting the values from eq. (35) into eq. (30), we have

$$\frac{-E_0}{\bar{r}N} = \frac{S}{2v}[\theta_1 \frac{P_1^* 2v^{*2}}{S_1} + \theta_2 \frac{P_2^* 2v^{*2}}{S_2} - \frac{\theta_1 \theta_2 X_{12} 2v^{*2}}{S_1}] \tag{37}$$

$$\frac{-E_0}{\bar{r}N} = \frac{S}{v}[\frac{\theta_1}{S_1} P_1^* + \frac{\theta_2}{S_2} P_2^* - \frac{\theta_1 \theta_2 X_{12}}{S_1}]v^{*2} \tag{38}$$

On simplification, one gets

$$\frac{-E_0}{\bar{r}N} = [\psi_1 P_1^* + \psi_2 P_2^* - \psi_1 \theta_2 X_{12}]v^* / \tilde{v} \tag{39}$$

By the analogy with the energy for a pure component we define

$$\frac{-E_0}{\bar{r}N} = P^* v^* / \tilde{v} = ckT^* / \tilde{v} \tag{40}$$

For the binary mixture, where

$$U = (U_1 r_1 N_1 + U_2 r_2 N_2) / \bar{r}N \tag{41}$$

$$U = \psi_1 U_1 + \psi_2 U_2 \tag{42}$$

Comparing eq. (39) and eq. (40), one obtains

$$P^* = \psi_1 P_1^* + \psi_2 P_2^* - \psi_1 \theta_2 X_{12} \tag{43}$$

On the basis of eq. (39) to (43), the characteristic temperature T* for the binary mixture is **given by**

$$T^* = P^* / (\frac{\psi_1 P_1^*}{T_1^*} + \frac{\psi_2 P_2^*}{T_2^*}) \tag{44}$$

Where the characteristic temperature T* is defined in accordance with eq. (14).

Assuming the volume reduction parameter of the binary liquid mixture to be linear in mole fractions of the components, we have,

$$v^* = X_1 v_1^* + X_2 v_2^* \qquad (45)$$

$$\tilde{v} = v / (X_1 v_1^* + X_2 v_2^*) \qquad (46)$$

Where v is the molar volume of binary mixture, adopting the familiar Berthelot relationship

$$\eta_{ij} = (\eta_{ii}\eta_{jj})^{1/2}$$

For homopolar species, the interaction parameter X_{12}, can be readily computed from eq. (23) and (36) as;

$$X_{12} = P_1^*[1-(P_2^*/P_1^*)^{1/2}(v_2^*/v_1^*)^{1/6}]^2 \qquad (47)$$

Thus it is possible to calculate the ultrasonic velocity of the binary liquid mixture using eq. (9) in the light of eq. (43), (44) and (46).

RESULT AND DISCUSSION

Table1 represents thermal expansion coefficient (α), isentropic compressibility (β_T) , density and ultrasonic velocity of pure liquids at 298.15K.Theoretical values of ultrasonic velocity and their percentage deviations (%Δ) with experimental values computed by aforementioned statistical model from 298.15-308.15K over the entire range of mole fraction of binary liquid systems is recorded in Table2.

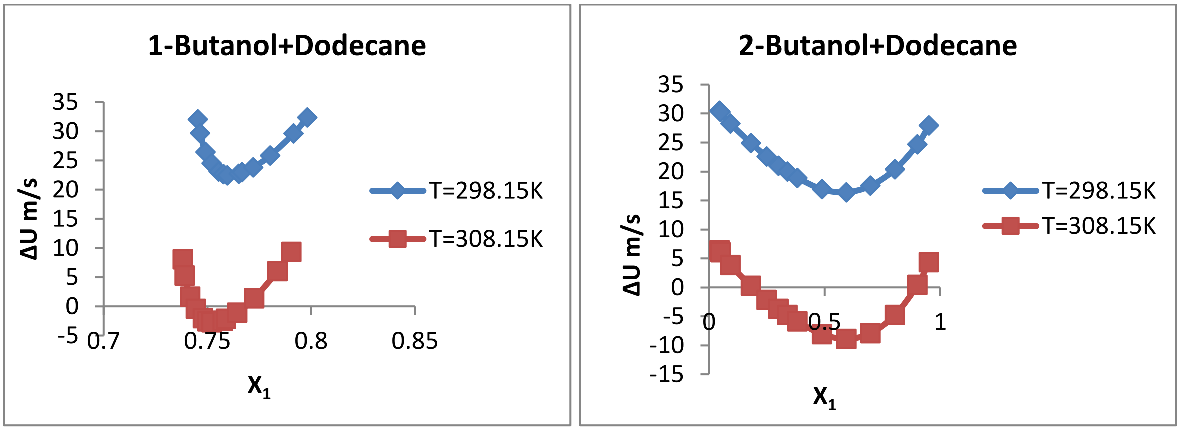

Fig. 2: Deviation in ultrasonic velocity with mole fraction at different temperatures

A close perusal of Table 2 reveals that density of both the binary system linearly increases as mole fraction increases but decreases with increase in temperature for both the system indicating weak molecular interactions between the binary components. Theoretical values of ultrasonic velocity show positive and negative deviation from experimental findings at different temperatures as shown in fig.(2), indicative of associating behaviors depending on magnitude of deviation. Negative deviation shows strong dipolar-dipolar molecular interaction and positive deviation shows weak dispersion force of interactions between the like and unlike components of liquid mixtures.

Table2: Theoretical and experimental values of ultrasonic velocity from 298.15-308.15K

X_1	ρ_{Mix}	U_{exp}	U_{Flory}	%ΔU
1- Butanol + Dodecane		T=298.15K		
0.02749	0.74549	1275.72	1243.705	2.50958
0.08048	0.74651	1272.6	1242.959	2.329186

0.19017	0.74912	1267.38	1240.952	2.085284
0.28812	0.75204	1263.17	1238.649	1.941224
0.38654	0.75551	1259.03	1235.938	1.834082
0.44097	0.75773	1256.85	1234.221	1.800468
0.4835	0.75962	1255.23	1232.779	1.788625
0.58849	0.76509	1251.4	1228.682	1.81544
0.61515	0.76672	1250.47	1227.476	1.83882
0.69605	0.77204	1247.52	1223.723	1.907516
0.79594	0.7802	1244.06	1218.245	2.075041
0.90295	0.79157	1240.79	1211.187	2.385794
0.95321	0.79815	1239.77	1207.407	2.610423
		T=308.15K		
0.02749	0.73818	1237.32	1229.271	0.650528
0.08048	0.73913	1234	1228.717	0.428156
0.19017	0.74167	1228.68	1227.032	0.134165
0.28812	0.74451	1224.6	1225.047	-0.03647
0.38654	0.74793	1220.59	1222.633	-0.16737
0.44097	0.75012	1218.52	1221.088	-0.21072
0.4835	0.752	1217.02	1219.769	-0.22584
0.58849	0.7574	1213.58	1216.036	-0.20241
0.61515	0.75903	1212.77	1214.908	-0.17626
0.69605	0.76436	1210.28	1211.386	-0.09136
0.79594	0.7725	1207.63	1206.247	0.114548
0.90295	0.78388	1205.58	1199.547	0.500397
0.95321	0.79048	1205.26	1195.931	0.77403
2- Butanol +Dodecane		T=298.15K		
0.04602	0.74546	1273.46	1242.966	2.394562
0.0507	0.74551	1273.1	1242.851	2.375972
0.09287	0.74619	1269.82	1241.562	2.225361
0.18128	0.74797	1263.38	1238.466	1.972013
0.24985	0.74959	1258.36	1235.81	1.792044
0.30044	0.75094	1254.67	1233.691	1.67205
0.33974	0.75215	1251.84	1231.88	1.594466
0.38271	0.75351	1248.76	1229.874	1.512415
0.48939	0.75762	1241.13	1224.196	1.364416
0.59429	0.76272	1234.11	1217.701	1.329639
0.69831	0.7692	1227.66	1210.133	1.427643
0.80469	0.7778	1221.36	1201.005	1.666617
0.90245	0.78821	1215.73	1191.052	2.02989
0.95177	0.79474	1213.24	1185.306	2.302402

		T=308.15K		
0.04602	0.73806	1234.92	1228.56	0.515032
0.0507	0.73811	1234.48	1228.444	0.488985
0.09287	0.73872	1231.07	1227.219	0.312858
0.18128	0.74036	1224.51	1224.249	0.021328
0.24985	0.7419	1219.48	1221.657	-0.17853
0.30044	0.74322	1215.85	1219.554	-0.30462
0.33974	0.74436	1213.01	1217.804	-0.39524
0.38271	0.74569	1209.91	1215.814	-0.48798
0.48939	0.74962	1202.2	1210.286	-0.67262
0.59429	0.75456	1195.02	1203.911	-0.74403
0.69831	0.76088	1188.52	1196.452	-0.66742
0.80469	0.76939	1182.58	1187.342	-0.40264
0.90245	0.77973	1177.79	1177.374	0.035358
0.95177	0.78627	1175.92	1171.566	0.370276

CONCLUSION

It may be concluded that density and ultrasonic velocity are very effective parameters for the analysis of molecular integrations between the binary components. Linear and non-linear variation in density of binary mixture at different temperatures provides significant information regarding the weak and strong molecular interaction between the binary components respectively. Positive deviation in ultrasonic velocity is responsible for weak molecular interactions and negative deviation is responsible for strong molecular interactions. In both cases interactions becomes strong at higher temperature.

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Chapter 13

KERATINOLYTIC MICROBES: AN ECO-FRIENDLY TOOL FOR THE MANAGEMENT OF CHICKEN FEATHER WASTE

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ABSTRACT

Chicken feather waste management is an important topic that has gained attention recently. Enormous feather waste is generated each year which is not disposed of properly leading to environmental pollution. This waste is generated from poultry, slaughter houses, and food industries. Traditional and modern methods for the degradation of feather waste are expensive and harmful to the environment also they end up destroying essential amino acids which could be a cheap source of raw material for many industries. Keratinolytic microbes like bacteria, fungi, and actinomycetes can produce keratinase enzymes which can degrade the feathers and can be an eco-friendly alternative for the management of feather waste.

Recycled keratin wastes are used for low-cost fertilizers and additives to the soil because they include organic matter, which is a crucial component of soils that are biologically active and productive. This chapter discusses the use of microorganisms for the management of feather waste to ensure environmental safety.

KEYWORDS: Fertilizers, Keratinase, Recalcitrant, Waste management.

INTRODUCTION

Chicken is an excellent source of nutrition and is a popular protein of choice for many people around the World. Chicken is rich in high-quality protein and contains various essential nutrients, minerals, B vitamins such as B6 and niacin, phosphorus and selenium. These nutrients are important in energy metabolism, immune function and bone health. The poultry sector plays a significant role in reducing malnutrition, poverty and unemployment. Chicken feathers are a byproduct of the poultry industry and can pose a significant waste management challenge due to their high volume and low degradation rate. According to the survey of United States Department of Agriculture, about 100.5 million tons of meat was produced in 2020 and as an outcome, more than 4.7 million tons of chicken feathers were generated around the World (Bharietal., 2021). In India, there are about 3430 million population of poultry with waste generation of 3.30 million tonnes per year (https://www.agritech.tnau.ac.in). This chicken feather waste which is accumulating at a higher rate is a by-product of slaughter houses & commercial poultry processing plants. Feathers alone constitute nearly 8.5% of the total weight of chicken. The major concern lies in managing this poultry solid waste which results in wastage of protein and results in environmental pollution. Also, due to use of hazardous chemicals in agricultural activities has led to the depletion of soil fertility. Also, the World population is projected to grow from 7 to 9 billion in 2050 (Sypka *et al.*, 2021) & hence agricultural productivity needs to increase by 60% in 2030-2050 relative to the production level in

2005-2007. In this view, this review mainly focuses on the use of different keratinolytic microbes for the management of feather waste.

THE PHYSICAL STRUCTURE AND COMPOSITION OF CHICKEN FEATHERS

According to Belarmino *et al.* (2012) and Njoku *et al.* (2019), the feathers are complex structures found in birds that serve various functions including insulation, protection and aiding in flight. Feather consists of a central axis known as a rachis that is attached to the calamus body of a bird. The barbs branch out from the rachis. Barbules branch out from barbs and have hooklets at their end. The chicken feathers contain crude lipid (0.83%), NFE (1.02%), ash (1.49%), crude fiber (2.15%), crude protein (82.36%), and moisture content (12.33%). The ultimate analysis showed: carbon (64.47%), nitrogen (10.41%), oxygen (22.34%), and sulphur (2.64%). Naturally, feathers are a rich source of keratin protein containing a high percentage of cysteine, serine, proline, and glutamine amino acids and low levels of histidine, tryptophan, glycine and glutamic acid (Tesfaye *et al.*, 2017).

Keratin is a type of protein that is present in the feathers of chickens. Keratin belongs to a family of fibrous structural proteins and is ubiquitously present in nature after chitin & cellulose. Its strength and robustness is due to tightly packed α-helixes & β-sheets configurations. Super coiling of micro- and macro-filaments of keratin results in the formation of tetramers and octamers supported by disulfide bonds, inter or intra-molecular hydrogen bonding and hydrophobic interactions of polypeptides. The disulfide bond ranges from 2% in soft keratin and up to 22% in hard keratin (Bhari *et al.*, 2021). Keratins are characterized based on their secondary structures (mainly α-helixes, β-sheets, ϒ-keratin), sulfur content (soft & hard), amino acid composition (basic, acidic, neutral), molecular weight & source of origin (Sypka *et al.*, 2021).

Table 1: Types of keratin protein and their characteristics

Types	α- keratin	β-keratin	γ-keratin
Source	Mammals, Birds, Reptiles, Fish, Amphibians	Birds, Reptiles	Mammals
Tissue type	Hair, Nail, Horn, Wool, Hooves, Epidermis, Fibers	Feathers, Claws, Beak, Scales, Cuticle, Epidermis	Epidermis, Fibrils, Matrix, Cortex, Fiber
Amino Acids	Hydrophobic Amino Acids Methionine, Phenylalanine, Valine, Isoleucine, Alanine	Cysteine, Glycine, Proline	Cysteine, Glycine, Tyrosine
Molecular weight (kDa)	40-80	10-22	7-35
Protein type	Filament	Filament	Globular
Sulfur Content	1% Sulfur	1-5% Sulfur	>5%

TRADITIONAL AND MODERN APPROACHES FOR DISPOSAL OF CHICKEN FEATHER WASTE

In traditional methods, physical and chemical treatment is used for the disposal of feather waste. This waste is incinerated, dumped in landfills, or processed for making animal feed. These methods require very high energy consumption and expensive operating cost which results in the loss of valuable resources and limit to their extensive use (Kumawat *et al.*, 2018). In conventional methods, feathers are cooked under high temperatures and pressure to produce feather meal used as an animal dietary ingredient. Feather waste management by incineration at elevated temperatures releases harmful environmental pollutants, so its use is limited. The currently applied in cineration process also raises the emission of some gases like CO, SO_2, Volatile Organic Compounds (VOCs) and NO into the environment (https://www.azocleantech.com/aboutus.aspx). Consequently, these pollutants have been known to cause respiratory diseases, cardiovascular diseases and cancer, among other illnesses (Anbesaw, 2022).

Landfills are commonly used for waste disposal, but they can cause environmental problems such as landfill leachate and greenhouse gas emissions. (Adelere and Lateef, 2016) mentioned leachate can increase the levels of nitrogen and phosphorus in nearby water bodies, leading to algal blooms, toxicity to aquatic animals and acidification of surface water. These issues can result in methemoglobinemia in newborns and even stomach cancer in adults. The composting of keratinous waste results in the emission of unpleasant odors, which have a slow degradation rate and can also promote the growth of pathogens. The large amount of discarded feathers not only pollutes the soil and air, but also causes various human ailments such as chlorosis, mycoplasmosis, and fowl cholera (Shah *et al.,* 2019). The keratinous waste is treated by hydrothermal methods, chemical methods and biological methods. Keratin waste undergoes hydrothermal treatment at high pressure and temperature, which generates non-nutritive amino acids such as lysinoalanine and lanthionine. The acid, alkali or solvents are added in chemical treatment which causes a reduction in the content of amino acids and digestibility values of feather meal (Bhari *et al.,* 2021). Ningthoujam *et al.* (2018) discussed that in biological methods, proteolytic microbes are used for the degradation of feather waste. Microbes such as bacteria, fungi, and actinomycetes produce proteolytic enzymes such as keratinase that are capable of degrading chicken feather waste. Efficient bioconversion of keratinous waste by keratinolytic microorganisms provides a superior and environmentally friendly approach (Bhari *et al.,* 2021).

MANAGEMENT OF FEATHER WASTE BY MICROORGANISMS

According to Adelere & Lateef, (2016) the several microbes possess the ability to hydrolyze the keratin present in feathers and can be used as an eco-friendly approach for waste management. A feasible substitute and environmentally beneficial way for managing feather waste is to use keratinase-producing microbes in feather waste management that can convert this abundant waste into affordable and value-added products. The microbial feather degradation generates toxic-free by-products and is more efficient than physical and chemical degradation methods. The scientific research community has recently emphasized biological feather degradation in this context (Agrahari & Wadhwa, 2012).

KERATINASE PRODUCING MICROORGANISMS

Microorganisms that produce keratinase are ubiquitously present in nature and can be easily isolated from diverse sources. Various microorganisms including bacteria, actinomycetes, halophilic microorganisms and keratinolytic fungi can utilize keratin as a substrate for the production of keratinases. Bacillus sp. are predominantly found to produce keratinase enzymes viz. *Bacillus subtilis, Bacillus pumilus, Bacillus lichenifomis*, and *Bacillus cereus* (Bhari *et al.,* 2021). Keratinolytic microbe *Bacillus thuringensis* FDB-10 isolated from a local tea plantation, a new *Bacillus spp.* Having dual production of keratinases and cellulase have been found in habiting the gut of cockroaches (Hassan *et al.*, 2020). *Bacillus megaterium* SN1 is used to produce animal feed protein concentrate (Agrahari & Wadhwa, 2012). *Amycolatopsis* sp. MBRL, *Chryseo bacteriumsediminis* RCM-SSR-7, *Ochrobactrum intermedium* used in biofertilizers (Sharma & Kango, 2021). Microbes reported in the recycling of keratin-rich waste are *Bacillus sp.* CL18, (Sobucki *et al.,* 2017). *Bacillus cytotoxicus* LT-1 and *Bacillus cytotoxicus* O11-15 are reported in the recycling of keratin-rich waste hide dehairing and feather degradation. They also have applications in the detergent formulation as well as scavenging activity in feather protein hydrolysate (Cavello *et al.,* 2021; Sypka *et al.*, 2021). Feather degradation with the production of feather protein hydrolysate with high antioxidant activity was shown by a novel psychrotolerant Antartic bacterium *Pedobacter* sp. 3.14.7 (Bezus *et al.*, 2021).

Li (2021) revealed the isolation of fungi from tissues of humans and animals that was able to produce keratinase which showed the capacity to degrade the feather keratin. These keratinase-producing fungi may be responsible for the fungal infection. High keratinolytic activity is also reported by fungus of genus including *Aspergillus, Paecilomyces, Chrysosporium, Alternaria, Geotrichum, Onygena, Microsporum, Candida, Arthroderma, Trichophyton, Gymnoascoideus, Scopulariopsis, Tritirachium, Doratomyces, Myrothecium, Fusarium* and *Curvularia* (Bohacz & Korniłłowicz-Kowalska, 2019; Peng *et al.*, 2019). *Streptomyces* sp. 2M21 scales up the production by utilizing chicken feathers as substrate (Demir *et al.*, 2015). The most common actinobacterium that is capable of producing keratinases is *Streptomyces*. Keratinase-producing actinobacterial can be isolated from various environmental sources and some of them can produce thermostable enzymes that have potential applications in industries. Quite a few species of alkali gens are reported for degradation of feathers. (Yusuf *et al.*, 2016) newly reported bacterium *Alcaligenes* sp. AQ05-001 shows multi heavy metal tolerant ability.

Table 2: Chicken feather degrading microbes

Sr. no.	Name of microbes	Collection site	M.W. (kDa)	Keratinase type	References
1	*Fervidobacterium pennivorans*	Hot spring	130	serine	Kim *et al.*, 2004
2	*Bacillus cereus*	Soil	80	serine	Ghosh *et al.*, 2009
3	*Bacillus subtilis*	Poultry soil	-	serine	Gupta and Singh, 2013
4	*Stenotrophomonas maltophilia*	Poultry farm	48	serine	Fang *et al.*, 2014
5	*Thermo actinomyces sp. CDF*	Campus soil	30	serine	Wang *et al.*, 2015
6	*Bacillus subtilis FTC02PR1*	-	30	serine	Ferraris *et al.*, 2016
7	*Bacillus pumilus*	Compost	38	serine	Fellahi *et al.*, 2016
8	*Streptomyces albidoflavus*	Poultry soil	36	serine	Ma *et al.*, 2017
9	*Bacillus licheniformis ALW1*	Feathers	-	metallo	Fattah *et al.*, 2018
10	*Bacillus amyloliquefaciens S13*	Brown algae Z. tournefortii	28	serine	Hamiche *et al.*, 2019
11	*Bacillus pumilus AR57*	Slaughter house soil	-	serine	Jagadeesan *et al.*, 2020

KERATINASES AND THEIR MECHANISM OF ACTION

Keratinases are classified based on the sequence of amino acids and conserved domains in the MEROPS protease family. Li (2021) mentioned that keratinase is distributed into 14 protein families, which correspond to their substrate preferences. Keratinolytic enzymes are either serine proteases or metalloproteases. keratinases are distinguished based on their mechanism of action that is, whether they function through endo-attack, exo-attack, or enzymatic activity on peptide oligomers. Members of the families S1, S9, S8, S10, and S16 are among the serine proteases; members of the families M3, M4, M14, M16, M28, M32, M36, M38 and M55 are among the metalloproteases (Qiu *et al.*, 2020).

Keratinase enzyme can degrade feather keratin by cleaving the peptide bonds (Gupta & Ramnani,2006). Keratin is a robust structure due to disulfide bonds present in them. The disulfide bond present in the protein can be reduced by certain chemicals or enzymes so that proteases can easily access the keratin protein for cleaving the peptide bonds. Serine and metalloproteases can recognize the hydrophobic substrate and affect the disulfide bonds which results in breakage of peptide bonds. Many of the keratinases are dependent on other enzymes for breaking the disulfide bonds. Therefore keratin degradation contains two important steps, the first step is to break the disulfide bond and to release the peptide while the second step is degradation of this polypeptide into amino acids. Chemicals such as reducing agents or enzymes such as disulfide reductase can catalyze the reduction reaction. As mentioned earlier keratin can be degraded by many protease families (Qiu *et al.,* 2020). Keratinase is an inducible enzyme so in the presence of keratin substrate, many of microbial keratinase enzymes are secreted outside the medium. Certain microbes also can concurrently produce intracellular and extracellular keratinase, additionally cell-bound keratinase is also found. Keratinase enzyme can also be immobilized on the cell surface and used for various applications (Li, 2021).

CONCLUSION

According to the above mentioned data, using microbial keratinases to handle keratinous waste represents an appealing biological strategy. Keratinases are helpful enzymes with a wide range of commercial applications, including waste management, pharmaceuticals, the manufacture of detergents, biocontrol agents, biogas, bioplastics, fabrications, animal feed, and the leather and textile industries. In the agriculture sector, keratinase is also used in the production of fertilizers and the recycling of wool waste. The feathers can also be used as a substrate for the production of keratinase enzymes. keratinolytic microorganisms play an important role in feather degradation and its recycling (Kumawat *et al.,* 2018). This area of research demands the search for keratinolytic bacteria and their enzymes with higher efficiency.

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Chapter
14

BRYOPHYTES: MEDICINAL POTENTIAL AND SECONDARY METABOLITES

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ABSTRACT

This chapter discusses the usage of bryophytes, which are valuable medicinal plants with the ability to cure a wide range of illnesses. Bryophytes also include bioactive chemicals that have therapeutic significance and their role as secondary metabolites. After angiosperms, bryophytes are the second largest category of terrestrial plants. From ancient times, bryophytes have been utilized as medicine to treat many ailments. Since many decades ago, the majority of research on the possible use of bryophytes as a source of biologically active compounds has been carried out; nevertheless, these studies have primarily focused on liverworts, with mosses and hornworts getting a lesser amount of research. Bryophytes are a rich source of secondary metabolites and medicinal uses. Additionally possessing antipyretic and diuretic qualities, many forms of bryophytes have been employed as remedies for skin conditions, heart conditions, neurasthenia, cancer, pulmonary TB, fever, burns, wounds and other ailments. In addition to their commercial value, bryophytes are employed in horticulture, gardening, nurseries and ornamental plantings. Bryophytes are significant therapeutic agents in the prevention of various illnesses. Secondary metabolites are the most significant group of molecules among the many plant derivatives, exhibiting a wide range of antimicrobial activities.

KEYWORDS: Alkaloids, Cardiovascular, Moss, Therapeutic uses, Terpenoids.

INTRODUCTION

Bryophytes are one of the most significant groups of plants consisting of approximately 24,000 species and were divided into three separate groups namely mosses with 15,000 species, liverworts with 8,500 species and hornworts with about 100 species widely spreading worldwide (Tabassum *et al.,* 2020; Azuelo *et al.,* 2010; Azuelo *et al.,* 2011; Asakawa, 1999; Bandyopadhyay *et al.,* 2022). In India, there are 1786 species of Bryopsida reported with 355 genera, 675 species of Hepaticopsida and 121 genera and Anthoceropsida 25 species with 6 genera. There are a total of 133 endangered species in India, belonging to infrequent groups. Out of 78 moss species, 53 are liverworts and 2 are hornworts. Additionally, 14 species of bryophytes, belonging to different groups, are reported to be rare in India (Chandra *et al.,* 2017).

The bioactive compounds in bryophytes that have been studied for their potential agricultural, medicinal, cosmetic, pharmacological and chemical applications. Liverworts, with over 800 species collected from various regions such as South and North America, India, Pakistan, Australia, Taiwan, North and South Africa, Europe, Japan and New Zealand are a major source of these compounds (Asakawa, 1999).

In North America and Europe between the 16th and 19th centuries, bryophyte knowledge of medicine was used in ethnomedicinal and pharmaceutical works (Drobnik and Stebel, 2021). Plants are a valuable resource for the production of novel pharmaceutical products and their secondary metabolites are great sources of medicines, nutritional supplements, flavor as well as other industrial applications (Tiwari and Rana, 2015). There are now over 20,000 secondary metabolites known and their isolation and characterization are in progress at a continued rate (Waterman, 2007).

Liverworts as well as bryophytes have produced a wide range of secondary metabolites. Terpenoids, flavonoids, unsaturated fatty acids, aromatic compounds and phenolic chemicals are just a few of the many potentially beneficial compounds found in bryophytes. However, there continues to be more research to be done before specific bryophyte species or compounds are related to specific medicinal uses (Ludwiczuk and Asakawa, 2020). The secondary metabolites of bryophytes viz. terpenoids, phenols, glycosides and fatty acids are particularly abundant in bryophytes the second-largest class of terrestrial plants. Bryophytes may have medical applications, but little is known regarding their chemistry and it is difficult to get enough of one species to do an examination (Sabovljevic *et al.,* 2009). Plants are clever to produce an expansively and wide-ranging group of secondary metabolites. They include a bulky number of bioactive compounds that serve as plant defense molecules. Plants are the most important source that are used for important ingredients that can be used for to treatment of aliments (Gonzalez *et al.,* 2019). The therapeutic potential and secondary metabolites of bryophytes have been discussed in this chapter.

SECONDARY METABOLITES OF BRYOPHYTES

Plants maximum source of secondary metabolites is 80%. In plants secondary metabolites are present in maximum economic importance of valuable products. They are highly used for insecticides, fragrances, dyes, fungicides, chemicals, etc. Plants are large in a wide variety of secondary metabolites like flavonoids, alkaloids, tannins, terpenoids, steroids and phenolic compounds which have been present *in vitro* antimicrobial activity (Thirumurugan *et al.,* 2018).

Marko *et al.* (2001), reported that the analysis of chemical compounds from bryophytes has been increased isolation since 1960. There are over 2200 highly chemical compounds present in bryophytes and they are abundant and largely growing (Horn *et al.,* 2021). The chemically investigated mosses are approximately 3.2% and 8.8% are liverworts. Some secondary metabolites are isolated from various species but they are widely unknown. Despite the potential medicinal value of many plants secondary metabolites, there has been a decrease in the introduction of new drugs to the market in recent years secondary metabolites are the intermediates and end products of metabolism (Mishra *et al.,* 2014).

In the dictionary of natural products, terpenoids make up around 33,000 of the total number of secondary metabolites, alkaloids make up approximately 16,000 and flavonoids make up roughly 8,182 and other compounds. Medicinal plants are known for being rich in secondary metabolites, a variety of compounds that have found wide use in the pharmaceutical and medicine industries. These substances, such as alkaloids, glycosides, amines, insecticides, steroids, flavonoids and other related metabolites, are categorized based on their metabolic processes. Flavonoids, steroids and alkaloids are the major chemical types of secondary metabolites in plants. Analysis of secondary metabolites is required for different phytocompound extraction processes, purification processes, separation, crystallization and identification (Daniel and Krishnasskumari, 2015).

CLASSIFICATION OF SECONDARY METABOLITES

Approximately 2,140,000 secondary metabolites have been identified and they are frequently categorized based on the wide range of their structure, function and biosynthesis (Thirumurugan *et al.,* 2018). Fatty acid-derived, polyketides, alkaloids, non-ribosomal polypeptides, steroids and terpenoids are the secondary metabolites.

GENERAL CLASSIFICATION OF SECONDARY METABOLITE IN PLANTS

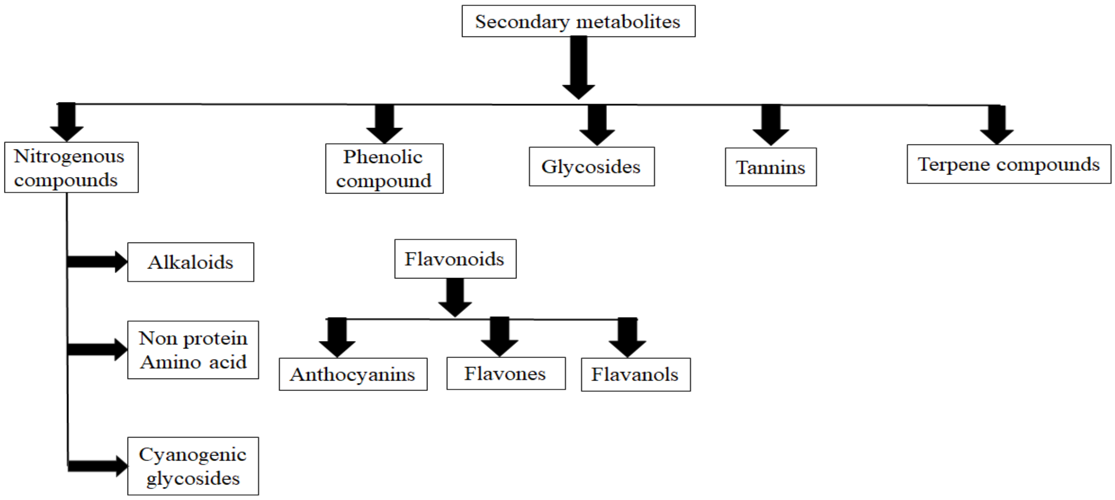

Fig 1: Secondary Metabolites

ALKALOIDS

Heterocyclic nitrogen compounds are called alkaloids. Alkaloids are the most important kind of secondary plant metabolites and they are extensively distributed and almost 5500 are known. They have been used in pharmaceutical effects and also used in medicine as well as entheogenic practices (Jain *et al.*, 2019). Alkaloids are also used in medicines commonly in the form of salts (Thirumurugan *et al.*, 2018).

TERPENOIDS AND STEROIDS

Asakawa *et al.* (2013) mentioned that more than 800 terpenoids without triterpenoids, tetraterpenoids, and aromatic compounds 300 and flavonoids have been isolated from Marchantiophyta. They constitute an important class of compounds produced biosynthetically from isopentenyl diphosphate. Approximately 35,000 terpenoid and steroid compounds have already been found. Terpenoids are usually used as flavor and fragrance agents (Thirumurugan *et al.*, 2018).

In bryophytes, terpenoids a major class of known natural compounds influence a variety of biochemical as well as ecological activities. The wide range of terpenoids produced by liverworts is greater than that of mosses and hornworts. Nearby 1,600 terpenoids from liverworts have been obtained and identified throughout the last 40 years (Horn *et al.*, 2021). There are nearly 300 species of hornworts, but only a small number have been biochemically tested and there is very little information available on the presence of terpenes in hornworts (Chen *et al.*, 2018).

FLAVONOIDS

Polyphenolic compounds are a group of flavonoids (Jain *et al.*, 2019). Asakawa *et al.* (2013) mentioned that identified the presence of flavonoids in mosses, with 300 species across 59 families. Flavonoids are found abundant in Liverworts, vascular plants and mosses. To our knowledge, hornworts have not reported been with any kind of flavonoids (Horn *et al.*, 2021). Flavones, flavanols, iso-flavonoids, aurones, 3-deoxyanthocyanins, anthocyanins and presently found auronidins specific to liverworts are the major types of flavonoids in bryophytes. In the bryophyte life cycle, flavonoids have several roles, particularly UV-B radiation protection (Li *et al.*, 2019).

PHENOL COMPOUND

Phenolics are the second largest group of metabolites in bryophytes, with reported compound diversity only slightly lower than that of terpenoids. The most important characteristic of bryophytes is polymeric phenolics, which include polymeric flavonoids in mosses (Kulshrestha *et al.*, 2022). Phenolic compounds are crucial for plants for multiple purposes, including growth, reproduction, pigmentation and disease resistance. One of the primary groups of secondary metabolites is made up of these substances (Kadam, 2015).

THE ECONOMIC POTENTIAL OF BRYOPHYTES

MEDICINAL VALUE:

Bryophytes play a significant role in herbal medicine. In China, some species are used to treat bites, wounds, burns, injuries, cuts, boils, and cardiovascular diseases. Similarly, in India and North America, different bryophytes are used as herbal medicines (Hallingback and Hodgetts, 2000). Bryophytes have been traditionally utilized for medicinal and ethno pharmacological purposes in India, China and Native America (Motti *et al.,* 2023). According to (Chandra *et al.,* 2017; Bandyopadhyay *et al.,* 2022) *Polytrichum commune* has been used to treat injuries, respiratory diseases, fever, blood cancer and uterus problems. *Plagiochasma appendiculata* has been traditionally used to treat skin disorders. Glime (2013) mentioned that in China, cardiovascular disorders to treated by *Rhodobryum giganteum*. In India, *Reboulia hemisphaerica*, *Plagiomnium cuspidatum*, *Polytrichum commune*, *Pogonatum cirratum*, *Taxiphyllum taxirameum* and *Funaria hygrometrica* species stop blooding. *Funaria hygrometrica* and *Marchantia polymorpha* are used to treat pulmonary tuberculosis in India. Many bryophytes like *Reboulia hemisphaerica*, *Funaria hygrometrica* and *Oreas martiana* are used to cure skin blotches, external wounds and bruises. *Targionia hypophylla* is a species used for treatment of skin diseases in India.

Mosses and liverworts have been used extensively in medicinal plants due to their active compounds, which have shown biological efficacy in treating different ailments. These include but are not limited to anticancer and antimicrobial activities, cardiovascular disorders, fever, infections, skin problems and wounds. They have also been found to possess anti-inflammatory and healing effects (Azuelo *et al.,* 2011). Different types of mosses, such as *Bryum, Mnium* and *Philonotis*, have been utilized for their medicinal properties in treating burns and pain (Flowers, 1957). In China, mosses are broadly therapeutically used to treat various disorders such as snake bites, cardiovascular diseases, external injuries, TB, pneumonia, skin burns, healing, bruises and other uses (Ozturk *et al.,* 2018).

DECORATIVE PURPOSE AND NURSERY GARDENING

In ancient times mosses were traditionally used for gardening and horticulture (Hallingback and Hodgetts, 2000). Bryophytes are widely used in horticulture. Mosses are also used for decoration, plugging and packing material (Marko *et al.,* 2001). Mosses are used for a feeling of serenity in Japanese gardens horticulture significant role in flower pots, covering flower containers, flower arrangements and marking baskets. Mosses play an important role in maintaining nutrition (Glime, 2007).

OTHER MUCILAGINOUS USES OF BRYOPHYTES

In many locations worldwide, the bryophytes are useful vegetation components. They are important goals in the maximum parts of wetlands, biodiversity in moist forests and ecosystems. *Sphagnum* is important for peat formation and plants in bogs (Hallingback and Hodgetts, 2000). *Sphagnum* has been extensively used for sanitary napkins, green roofs, diapers, horticulture uses, gardening uses, fuel and flower arrangements (Glime, 2012). *Fontinalis novaeangliae* has been recorded to survive wet mosses and high temperatures (Glime, 2013).

CONCLUSION

According to the above data, bryophytes are used in both biological and industrial contexts due to a wide range of secondary metabolites that are present in bryophyte plants. The use of herbal medicines should be based on comprehensive phytochemical research to determine the chemical components of the plants involved. The identification and comprehension of an increasing number of secondary metabolites in bryophytes will benefit ecological research through breakthroughs in bryophyte chemistry and bioassays.

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Chapter
15

ORGANIC FARMING AND ECONOMY OF INDIA

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ABSTRACT

India's growth is mainly based on agriculture. Nearly sixty percent of its population is reliant on agricultural activities for a living. So, any sudden change in agriculture will directly affect the people of this country. Demand of food is increasing because of rapid population growth. Cultivation of high yielding varieties of crops required excess fertilizers, irrigation which invites other weeds also which is a serious problem for our farmers. Sustainable and organic farming are the best option for ecosystem and human health.

KEYWORDS: Agriculture, High yielding varieties, Organic farming.

INTRODUCTION

Our population is increasing day by day and to fulfill the demand of food grains there is a huge pressure on our farmers and the government. To meet the demand of food grains, farmers are blindly using excess amount of chemical fertilizers, pesticides, etc in their land. Due to this, soil health is declining day by day and other environmental and health issue also. Since last decade, Organic farming has been encouraged continuously throughout the country. Organic farming has become a revolution of farming in the country. Farming lands are the life line and base of our farmers. Many farmers are doing organic farming with huge production and profit. Organic farming is natural, low invested, sustainable and totally chemical free farming. The main benefit of organic farming is that the farmer can maintain the fertility of the soil for longer period of time without use of any chemical fertilizers. In organic farming, use of insecticides, pesticides, herbicides and other synthetic materials are prohibited. In organic farming there is use of bio fertilizers, compost, vermi-compost and other botanicals products. If we talk about our country, before independence, our farmers used to do organic farming. Because of chemical fertilisers so many diseases are being faced by us. The young generation is facing diabetes in early age. Farmers are dependent on chemical fertilizers so their farming investment increases and this is a problem for marginal farmers. Farmers who are doing organic farming are preserving and enhancing the biological components of the soil. The government is also aware for organic farming and has taken so many steps. The government has opened national centre for organic farming in Ghaziabad and national program on organic production has been launched. The government is giving subsidy also for the farmers to encourage the organic farming. In 2016, Sikkim got to be the first Indian state to be organic totally. Like this, if other states will become aware then very soon our country will become fully organic.

WHAT IS ORGANIC FARMING

It is a system of farming in which chemical fertilizers, pesticides, etc are excluded and involves bio-fertilizers, manures and traditional systems mostly. It enhances ecosystem health, biodiversity cycles in a good way. It sustains the health of soils. In simple, organic farming makes healthy food, healthy soil, healthy crops and healthy environment along with crop production. The product of organic farming is very healthy for humans as well as environment. As in organic farming use of chemical products are avoided so it does not cause soil as well as water pollution. Punjab uses highest amount of chemical fertilizers so soil of this state is losing its fertility as well as the state is facing high cancerous diseases. Fruits, vegetables and animal products which have been grown organic have huge demand because people are becoming more health conscious these days. Organic fruits, vegetables and animal products are tastier and healthier. India has highest number of organic farmers and at ninth place in organic farming area. In North-East India, farming is mostly organic. States like Sikkim, Nagaland, Mizoram, Arunchal Pradesh, and Tripura mostly do organic farming. Chemical uses in farming are far lesser than the rest part of the India. Banana, pineapple, plum, mango, litchi etc are grown organic and are very tasty. Life of organic products is longer in comparison to chemical grown fruits and vegetables. India exports organic products to other nations like flax seeds, sesame, soybean, tea, medicinal plants, rice and pulses.

Organic cultivation in North-Eastern region

(In hectares)

State	Area	In conversion
Sikkim	74,094	1,982
Meghalaya	2,580	37,756
Assam	9,883	18,129
Nagaland	3,526	5,314
Arunachal	51	6,129
Manipur	158	5,240
Tripura	204	2,048
Mizoram	0	999
Total	**90,496**	**77,597**

Fig. 1: Organic cultivation in North-Eastern Region

Source: https://www.thehindubusinessline.com/specials/tapping-the-n-es-organic-farming-potential/article25050315.ece

PRINCIPLES OF ORGANIC FARMING

Organic farming is flourishing with some principles which are contributing for better ecosystem and health of the people.

Some Principles are as follows:

- Health of people and communities.
- Not to harm the ecosystem
- Chemical free farming
- Natural Products

The above principles are fully focused to do eco-friendly farming and to provide the chemical free product to the consumer.

ADVANTAGES OF ORGANIC FARMING

1. It helps to enhance environmental condition by decreasing pollutants.

2. Living beings health and life can be protected by risks by decreasing toxic residues...
3. Healthy and nutrition richer agricultural products.
4. Agricultural expenditures on fertilizers, pesticides can be reduced.
5. It is integrated farming system and assists in saving the resources for coming generation.
6. It saves extra efforts, energy which is done by humans, machines and also declines crop failure chance.
7. Soil physical and chemical status improves by good air pass, root penetration, organic matters.
8. Nutrient loss can be reduced and more organic matters can be added to the soil.
9. Demand of organic products is increasing day by day as people are becoming more health conscious. So, the farmers can sell their products at satisfactory rate and earn more profits.
10. The government can export organic farm products like fruits, vegetables dairy and meat products which have been grown organic.

MANAGEMENT OF ORGANIC FARMING

- Soil management
- Crop rotation
- Household wastage for compost making
- Green manures and cover crops
- Manuring and composting
- Tillage
- Mulching
- Biological pest control

MANAGEMENT OF SOIL NUTRITION

To do Organic farming, the farmer has to enrich the soil fertility by the use of decomposable wastes. Bio-fertilizers, green manure, decomposed household and farm wastes can be used to increase soil fertility. Organic nutrients also maintain appropriate condition for the growth of soil micro organisms for their better growth and development. Soil having more organic matter repels soil erosion, and requires lesser water for field to be irrigated. Some natural minerals that are needed by the plants to grow and to improve the soil's consistency can also be added. Lime improves the pH balance in the soil. Heavy metals into the water are not good for the soil health. Animal manures and domestic wastes are the good sources for organic manure. The collected organic matters are decomposed for three months in proper humidity and temperature of 120°-145°F to eradicate unwanted microbes and plant residues. Microbial action is also very beneficial in increasing the soil health. Many bacteria, fungi are helpful in sustaining the soil fertility.

Fig. 2: Organic Farming

Source: https://borgenproject.org/organic-farming-in-india/

Unwanted plants- Weeds

As uses of chemical are prohibited in organic farming so controlling weeds is a challenge in organic farming. There are few practices which can control weeds which are tillage, mulching, drip irrigation. These practices are very effective and helpful in controlling the nutrients loss also. Mulching, drip irrigation controls the distribution of soil nutrition and water to the weeds.

CONTROL OF INSECTS AND PESTS

Pest controlling is a big challenge in organic farming. The farmer can follow so many effective pest control practices like light trapping, herbal plants. The farmer can grow some plants around the crop field whose host insects feed main crop insects. When excessive attack of pest causes then other beneficial insects cannot help much then , the use of natural insecticides like Neem residues, turmeric, Aloe Vera are suggested. The reasons behind organic pesticides are lesser harmful to people and other animals and lesser harmful in the environment. These criteria are suggested by the National Organic Standards.

MANAGEMENT OF DISEASES

Diseases in crops are a major factor for declination in crop production in organic farming. Proper supply of micro and macro nutrients to the soil and crop rotation can help in resisting many diseases. This makes organic farming healthy with nutritious soil and essential microbes. Healthy microbes like fungi and bacteria check the growth of harmful microbes and help in proper growth and development of plants.

OTHER SIDES OF ORGANIC FARMING

Organic farming has some limitations which are like

1. Availability of organic manure is limited and can be produce with proper management. The cost of organic manure is costlier than chemical fertilizers.
2. Production in organic farming declines in starting, so the government should give support to these farmers.
3. India farmers have lack of knowledge about the instructions of organic farming, manufacturing, transport system, etc
4. Business for organic products is not well channeled. Many Indian farms are still chemically free but the pattern of farming is not satisfactory. Many farmers are growing organic products but they are sold at the same price in the market.
5. Government support is lesser. Government must provide subsidy and market channel so that they can get good price for their products.

6. Lack of training facilities for our farmers. Training program should be organized time to time so that interest can be generated among our farmers towards organic farming.

ROLE OF ORGANIC FARMING IN INDIAN ECONOMY

Organic farming is generally more profitable and environmental friendly as it uses no chemicals and its residues can be used for the production of organic manure. Day by day people are becoming more health conscious in the world. So, it is pressure on our farmers to supply organic products for people. India has second place in the production of fruits and vegetables and first place in the production of milk. Most of the production is organic in nature. Our country is getting foreign exchange by exporting organic fruits-vegetables and meat to the neighboring nations like Pakistan, Bangladesh, Sri Lanka, Myanmar, Gulf countries and some European countries also. Onion, banana, apple, spices, mango, etc are some organic products which are mostly exported. India has a boon and has the calibre to grow every kind of organic products because of its climatic zone which are divided into 15 zones. Organic farming is a gift from our ancestors which is sustainable and eco-friendly...

CONCLUSION

Chemical free food is safer to eat in comparison to chemically processed or grown food. We can get a kind of food which can rarely harm our environment and can positively nourish us. The cost of organic food is more than chemically grown food because the organic products have higher demand. Doing organic farming is beneficial because it is good for human health as well as the ecosystem. It can give more prices to the farmers which is good for their livelihood. Organic food products are costlier in the developed nations. India is a nation where availability of labors is in plenty amount and here scope of organic farm products are increasing gradually. People are mostly middle class so doing organic farming is helping them to reduce farm expenditures which they used to do in chemical based farming. The support of government for organic farming has helped and encouraged much to incline towards this farming system and is building a strong base food sectors.

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Chapter
16

ROLE OF TECHNOLOGY IN ECONOMIC DEVELOPENT OF RURAL INDIA

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ABSTRACT

About 60% Indian population lives in rural part. These people are directly or indirectly engaged in agriculture work for their livelihood. Their livelihood is mainly dependent on crop farming and animal rearing. Farming and animal products are used for family consumption and also for selling products. Introduction of modern ideas and technologies have uplift their life. Farmers are using advance farm machineries to increase the production. KVK (Krishi Vigyan Kendra) has guided them very well to adopt these technologies and ideas so that their production and effort can help in rural development of the India. Internet has brought revolution in rural development. Internet has helped our farmers in learning and transferring of advance knowledge related to agriculture, medical, weather, education, etc. GOI (Government of India) is trying hard to spread the web of optical fibre in rural areas also for better internet connectivity. Organizational links and networking capacities are working together to provide multiple opportunities to the rural communities for their development.

KEYWORDS: Livelihood, KVK, Internet, Farm machineries.

INTRODUCTION

India is considered as a land of agriculture where more than half of the population is directly or indirectly engaged in rural occupation. The Indian government has extreme pressure to facilitate health, education, employment to rural people. The present strategy of rural development in India is on poverty alleviation, huge livelihood opportunities and infrastructure facilities and self-employment. So, introduction of modern technologies to the rural people can help in their all round development. In India, about 352 million people are internet users which is 20% more than urban internet users (according to ministry of external affairs, Government of India, 2022). First time it has happened that rural population has overcome urban population in internet usage. Education can play a great role in rural development. Government should open enough number of schools in the rural areas having modern facilities. For health management, hospitals should be open with modern equipments so that people can be benefitted. For farming, tractors, threshing machine, etc should be used. Several schemes, loans have been provided by the government to the farmers so that they can purchase farm machines and tools. In broad line, we can say that for the rural development the government has to do all round development and that is possible only by the use of modern technologies.

EDUCATION

Education is the key of every kind of development because if people are educated than the society will definitely progress and that's why old age education was also started in India so that every age group can contribute in rural development. The government has launched so many schemes to attract rural people to send their children to the school. The government has even started mid-day meal for the children for their proper and healthy nourishment. Qualified teachers with knowledge of computer have been posted in rural areas so that rural children can be benefitted. Educated rural children, once they pass out their school education, move for higher education or they do start up business in their rural areas which help them to become economically strong.

HEALTH

The government has focused to open more and more hospitals and health centres in rural areas. The advance machines, computers have been installed in the hospitals which are helpful for disease test. The Modi government has launched a scheme "one city, one hospital" and by 2024 this scheme has to be completed. This has done a health development of the rural region.

FARMING

India is considered as the land of agriculture. 51% land is used for farming purpose. More than 60% people are directly or indirectly dependent upon the agricultural activities. Information and communication technology (ICT) acts a great role in highlighting rural challenges and uplift the life of the rural communities. The growing population has increased the pressure on our farmers to grow more and more food grains, fruits and vegetables. The advance farming tools and machines can help them in surplus production. Several farming techniques also come under technology as they are discovered and tested by the use of advance technologies. For development and sharing of new technologies computer, internet is very important. Development of hybrid seeds, GM (genetically modified) seeds, remote sensing, weather forecasting, etc are done by advance laboratories, internet, etc. These all efforts are made for rural development.

ANIMAL REARING

Animal rearing in rural areas are a good source of income. Cattle, sheep, goat, pig rearing is very profitable as the rearer can send milk, meat, fur, wool in the market. There are techniques for milking cattle and buffaloes if their number is more. The shearing machine helps the farmers to shear the sheep in shorter interval of time. Poultry rearing is also a very beneficial business in the rural areas. The rearer can use brooding machine, hatchery machine, incubators etc which can help in flourish their poultry business. For fumigation of poultry shed, formaldehyde (HCHO), potassium permanganate (KMno4) are used and it requires a big exhaust with proper channel and this technique has helped poultry shed free from many kinds of diseases.

MARKETING

Rural development can be enhanced by the availability of proper marketing channel where our farmers can sell their products. Commodities rate are updated through internet, television, radio which helped our farmers in fixing their products price in the market.

TRAINING

Several training programs are run by the government like health training, educational training, and farming training. Women are trained for making pickles, sewing and other eatables which they can make. The trainer show them documentary videos and demonstration to teach them and to encourage them. The farmers are taught the modern techniques of farming like sowing, harvesting, using fertilizers, insecticides, harvesting etc by the use of projectors, computers. KVK (Krishi Vigyan Kendra) helped our farmers in dealing with all these electronic gadgets and technologies. Farmers are also taught how to deal with drought, flood and other disease outbreak.

OTHER INFRASTRUCTURE

Other infrastructure includes the all round development of the rural areas which include better road connectivity, transport facilities, canal system for the irrigation are helping in building the rural infrastructure stronger.

GOVERNMENT ROLE IN RURAL DEVELOPMENT

Government is playing a great role in the rural development because it understands that if rural areas will develop then obviously the nation will develop. The government is launching so many schemes related to farming, health, education, etc.

1. Government is encouraging the rural people to follow the modern technologies.
2. Several NGOs and other volunteer organizations are also helping in rural development by several means.
3. Subsidies and funding by the government to overcome the loss by any natural disasters.
4. KVK, ATMA, NABARD etc are running training program to train the rural people by modern techniques.

Fig. 1: Modern Technology

CONCLUSION

Majority of the Indian population lives in rural areas. Most of them are engaged in farming and animal rearing. Their traditional ways of farming do not give much yield. So, there is a need of modernization of our farmers which can be done only by introducing them with modern technologies like computers, internet, android mobile, projectors, drone, etc. Several projects, schemes by the government and NGOs have been helped rural people to uplift their life. Government is equally helping the infrastructure in by building roads, health centres, schools, market, etc. So that rural people couldn't migrate to other places. The efforts are changing the face of rural life. Now, rural people have more comforts than previous decades and this has become possible by the modernization and following the modern technologies.

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Chapter
17

BIOLOGICAL ACTIVITIES OF *OCIMUM SCANTUM* L. – AN OVERVIEW

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ABSTRACT

The therapeutic uses of plant are considered as safe, inexpensive and efficient as their ease of availability. Tulsi is recognized as the "Queen of herbs “and "Nature's Mother Medicine." Tulsi, also known as *Ocimum sanctum*, is an herb with powerful anti-disease qualities. In the Indian subcontinent, it is revered as a divinity. *Ocimum sanctum* Linn. (Labiateae or Lamiaceae) include 30 species that grow in tropical and subtropical climates. This plant belongs to lamiaceace family and characterized by square stem and specific smell Essential oil is extracted from the leaves and blooming tops. The oil of *Ocimum sanctum* contains five fatty acids (stearic, palmitic, oleic, linoleic, and linolenic acids). Tulsi is a medicinal plant present in India recognized and valued for its medicinal and therapeutic use. Several medicinal properties of Tulsi are present in the roots, leaves and seeds. It has a wide range of action on the human body. It heals many diseases chronically due to its chemical constituent and believes that it has Anti-ageing, Immunomodulatory property along with antimicrobial and anticancer property. Tulsi is famous for its vital role in the conventional ayurvedic and unani systems of body fitness health and herbal medicine of the East. The biological functions of holy basil are fully summarized in this chapter.

KEYWORDS: *Ocimum sanctum*, eugenol, Anti-cancer, Anti-oxidant effect.

INTRODUCTION

The Lamiaceae plant family has a wide variety of medicinally significant plants that are used to treat and prevent a wide range of illnesses. Basically, There are more than 6000 species in 236 genera belong to lamiaceace family. The Lamiaceae family's major genera include Plectranthus, Scutelleria, Stachys, and Salvia Vitex, Thymus, Nepeta, Hyptis, Teucrium, the medicinal potential of these herbs Genus is due to the existence of a diverse array of phytochemicals such as flavonoids, alkaloids, and saponins content of polyphenols. Many academics have described a number of bioactive potentials of Various Lamiaceae genera display biological diversity. Actions such as cardio protective, antibacterial, anti-inflammatory, anti-inflammatory, anti-diabetic, and antioxidant effects.

There are more than 150 species in the genus Ocimum, including *Ocimum tenuiflorum* L. (holy basil), *Ocimum gratissimum* (African basil), *Ocimum basillicum* (sweet basil), and *Ocimum ammericanum*. It has been established that this genus of plants has a number of key bioactivities for medicine, including antifungal, antinociceptive, anticonvulsant, antioxidant, germicidal, and antimalarial activities. These Ocimum genus members have outstanding therapeutic potential and medicinal qualities. Holy basil or tulsi are common names for *Ocimum tenuiflorum*.

Tulsi has been described as of two types- vanya (wild) and gramya (grown in homes). Since ancient times, Tulsi has been used for therapeutic purposes. Tulsi is utilized in a variety of ways, including as an herbal tea, dried powder, or fresh leaf. The dried tulsi leaves are sometimes sprinkled with stored grains to keep insects away. Prevention of illnesses since the Ancient times. By altering several biological systems, *Ocimum sanctum* has shown to have positive benefits on health. The medical value of *Ocimum sanctum* is evidenced by its anti-oxidant, anti-inflammatory, anti-microbial, anti-diabetic, hepatoprotective, and wound-healing characteristics. Furthermore, as it slows the spread of disease, the *Ocimum sanctum* component works in synergy with anti-cancer medications. To use its potential for illness management and therapy, molecular mechanism and human clinical studies should be conducted.

TAXANOMICAL CLASSIFICATION

Kingdom: Plantae

Order: Lamiales

Family: Lamiaceae

Genus: *Ocimum*

Species: *tenuiflorum*

TRADITIONAL USES:

Tulsi, also known as holy basil, has been widely used in traditional medicine systems like Ayurveda and Siddha for its various health benefits. Its different parts, especially the leaves, have been utilized to prevent and treat a wide array of illnesses and everyday ailments. Some of the traditional uses of Tulsi include:

1. **Common Cold, Cough, and Flu:** Tulsi is known for its effectiveness in managing symptoms associated with the common cold, cough, flu, and sore throat. Its properties are believed to boost the immune system and help alleviate these symptoms.
2. **Headaches and Migraines:** Tulsi is used traditionally to relieve headaches and migraines due to its analgesic properties.
3. **Respiratory Disorders:** Conditions like bronchitis, asthma, and coughs can benefit from Tulsi due to its expectorant properties, which help in relieving respiratory issues.
4. **Digestive Disorders:** It's believed that Tulsi aids digestion and can help with issues like flatulence, colic pain, diarrhea, and digestive disorders.
5. **Antimicrobial and Antiseptic Properties:** Tulsi possesses antibacterial, antiviral, and antifungal properties, which may help in treating infections, wounds, and ulcers.
6. **Liver Health:** It has been used traditionally to support hepatic health and manage hepatic diseases.
7. **Fever Management:** Tulsi is believed to help in managing fevers, including malaria fever.
8. **Snake Bite and Scorpion Sting:** It's considered an antidote for snake bites and scorpion stings in traditional medicine.
9. **Skin Conditions:** The application of Tulsi leaves or its extracts may assist in managing various skin conditions.
10. **Stress, Insomnia, and Fatigue:** Tulsi is known for its adaptogenic properties, helping the body adapt to stress. It's also believed to aid in managing fatigue and promoting better sleep.
11. **Memory Enhancement:** Chewing Tulsi leaves is believed to help sharpen memory and benefit the nervous system.
12. **Eye Health:** Traditional medicine mentions Tulsi's role in managing night blindness.

It's important to note that while Tulsi has been used traditionally for these purposes, scientific research is ongoing to better understand its medicinal properties and validate these claims. Always consult with a healthcare professional before using Tulsi or any other herbal remedy, especially if you have underlying health conditions or are taking medications.

MORPHOLOGY

Holy basil is a branching subshrub that grows 30-60 cm (12-24 in) tall and has hairy stems. The leaves are green or purple, simple and petioled, with an oval, up to 5 cm long blade with a slightly curved border; they are deeply scented and have a decussate phyllotaxy. The violet blossoms are arranged in compact whorls on lengthy recemes (Hemalatha R babu *et al.,* 2011). The three primary morphotypes grown in India and Ram tulsi (the most common form, with large brilliant green leaves that are mildly pleasant) and the less common Nepal tulsi Common wild vana tulsi and common purplish green-leaved (Krishna tulsi).

Fig. 1: The plant - *Ocimum scantum*

CHEMICAL COMPOSITION

The chemical constituents of *Ocimum sanctum* are oleanolic acid, ursolic acid, rosmarinic acid, eugenol, carvacrol and linaloolo, carvacol and caryophyllene (Saravanan *et al.,* 2012). The chemical structure of the active molecule is shown in Figure 2.

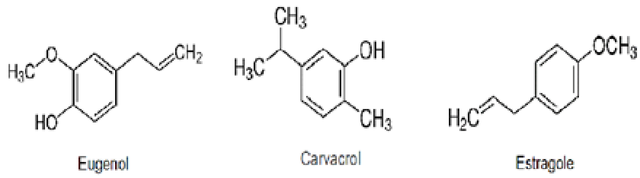

Fig. 2: Chemical structure of active compound of holy basil.

Tulsi has been used to make a variety of essential oils. Tulsi essential oils have been shown to suppress the development of microorganisms. Several chemicals have been found in Tulsi leaves, flower spikes, or essential oil, and three of them are expected to be responsible for such activity: camphor, eucalyptol, and eugenol. Tulsi's significance in cancer suppression was demonstrated when aqueous and ethanolic extracts of *Ocimum sanctum*.

MECHANISM

Tulsi has a variety of chemicals in various plant sections, including a number of substances, including saponins, triterpenoids, flavonoids, and tannins are present in the stem and leaves, (De witt *et al.,* 2000) and volatile oil from leaves includes eugenol. These components have a crucial role in the treatment of diseases and illness control by adjusting numerous biological processes. The increased concentrations of reactive oxygen species cause oxidative stress. Pathogenesis is caused by stress and damage to macromolecules. Medicinal herbs antioxidant function neutralizes free radicals, potential and operate as a free radical scavenger. Plant that has medicinal properties by neutralizing oxidative stress, it suppresses pathogenesis through antioxidant property. One of the most important is free radical scavenging activity.

Through its function, holy basil plays a crucial role as an anti-tumor, fight or prevents the growth of cancer cells. Additionally, holy basil's anti-tumor effects were seen through altering cell signaling. Holy basil leaf extracts prevent cellular growth; Apoptosis is induced by migration, invasion, and other factors of cells from pancreatic cancer. The activity of genes that support the down regulated in pancreatic after O. sanctum therapy, cancer cells (shimizu T *et al.*, 2013).

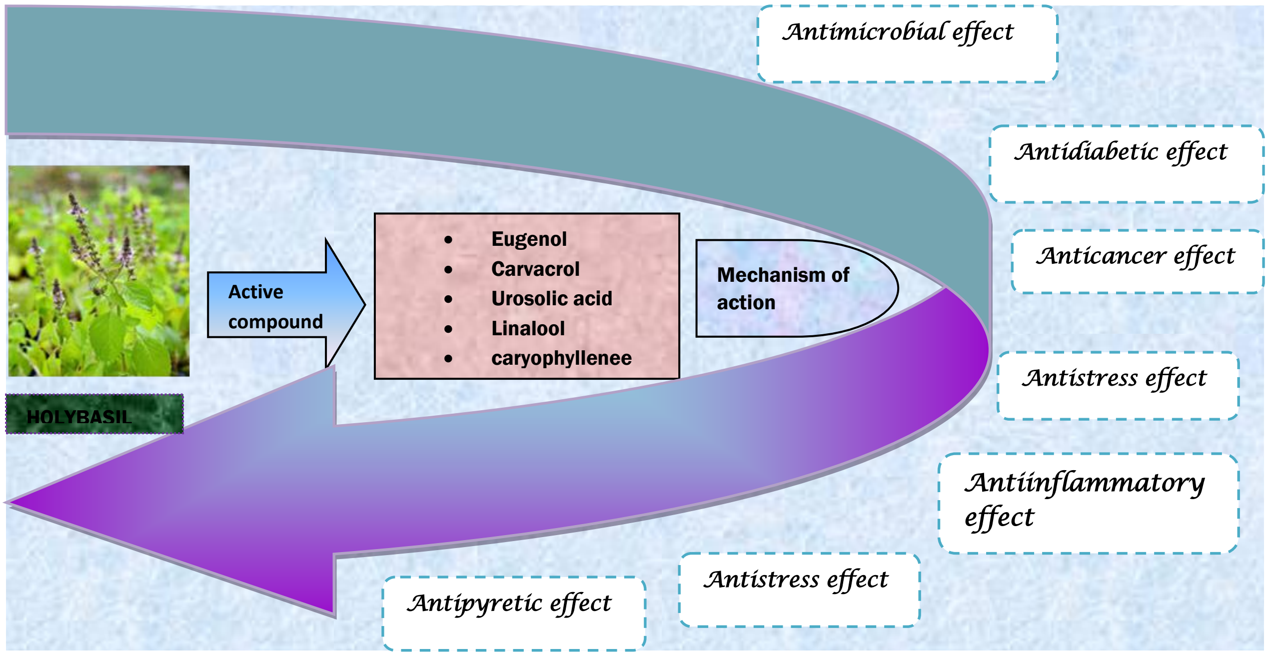

Fig. 3: Mechanism of action of holy basil

Table 1: Biological activities of the plant

S.no	Therapeutic activity	Extract used	Parts used in the plant
1.	Anti-stress	Ethanolic	Whole plant (dried)
2.	Anti-inflammatory	Methanolic/aqueous	Leaves
3.	Anti-fungal	Methanolic/ethanolic	Leaves
4.	Anti-fertility	Benzene	Leaves
5.	Anti-diabetic	Ethanolic/aqueous	Leaves
6.	Anti-ulcer	Ethanolic /aqueous	Leaves
7.	Anti-microbial	Ethanolic	Leaves
8.	Anti-cancer	Ethanolic	Root
9.	Anti-oxidant	Methanolic	leaves
10.	Anti-pyretic	Ethanolic	Root

ANTIBACTERIAL ACTIVITY

The essential oil found in the majority of Ocimum species is responsible for their antifungal, antibacterial, and antiviral activities. Microorganisms acquire resistance to many antibiotics, causing a massive clinical challenge in the treatment of infectious illnesses. This issue can be solved by using medicinal herbs. Tulsi leaves have been shown to have potent antifungal properties against Aspergillus species. When oil from *O. gratissimum* was utilized, in vitro antifungal activity against Candida species was also reported (kelm

MA, Nair MG, 2000). Ocimum has potent antibacterial action against Klebisella (a bacterium that causes pneumonia and urinary tract infections), *E. coli*, Proteus and *Staphylococcus aureus*, and *Vibrio cholerae*. *O. basilicum* has been demonstrated in studies to be a powerful antiviral agent against DNA viruses (herpes viruses (HSV), adenoviruses (ADV), and hepatitis B). Coxsackievirus B1 (CVB1) and enterovirus 71 (EV71) RNA viruses (Chiang L C, Ng L T, Cheng P W *et al.,* 2005). It has also been shown that O. tenuiflorum exhibits antiviral action against Bovine herpes virus -1. Essential oils derived from Ocimum sp., which contain eugenol, carvacrol, methyl eugenol, and caryophyllene, are thought to be primarily responsible for diverse antibacterial effects.

ANTI INFLAMMATORY

Due to a combined suppression of arachidonate metabolism and the addition of antihistaminic action, the oil found in OS seeds has anti-inflammatory properties. The prostaglandin inhibition and analgesic effects of the seed oil also provide it antipyretic properties. Additionally, it has hypotensive, anticoagulant, and immunomodulation effects. The oil's antiulcer action is aided by its lipoxygenase inhibitory, histamine antagonistic, and ant secretory properties (Singh S *et al.,* 2007).

When isoproterenol (ISP) was used to induce MI in rats, a methanolic extract of OS (Tulsi) leaves demonstrated an anti-inflammatory activity (Kavitha S *et al.,* 2015). Consuming tulsi leaf (OS Linn.) on an empty stomach strengthens the immune system (Mondal S *et al.,* 2011). [45]. Its alcoholic leaf extract has an immune modulatory effect (Mondal S *et al.,* 2011). The majority of immune-based therapies use tulsi. To increase fertility reduces echo- and endoparasites, manage poor mothering, and set bones. Additionally, it has immune-modulating qualities alterations in histamine release, cytokine secretion, Class switching, cellular co-receptor expression, lymphocyte expression, phagocytosis, and immunoglobulin secretion (Mahima *et al.,* 2007).

ANTI DIABETIC

Ocimum tenuiflorium indicates antidiabetic, (Eshraghian *et al.,* 2013) Blood glucose levels in induced hyperglycemic tilapia (*Oreochromis niloticus*) are reduced by OT aqueous extract. (Arenal A *et al.,* 2012) extracts or fragments of Significant inhibition was discovered between AM and MC (P0.05), glucosidase activity, having an IC50 that is similar to the medication1-deoxynojirimycin, same therapy was administered in vivoon mice with a high glycogen load revealed significant (P 0.05) depressing impact on the increase in post-meal blood sugar level after consuming AM and MC extracts. Two floral and green components might be utilized in alternative nutritional treatment, mostly for diabetes control since they block enzymes that hydrolyze carbohydrates. (Subratty AH *et al.,* 2012) OS is used to treat metabolic abnormalities associated with diabetes and has both hypoglycemic and hyperglycemic effects, restoring glucose levels (Grover JK *et al.,* 2002). *Ocimum tenuiflorum* showed the capacity to inhibit glucosidase and -amylase. When compared to ascarbose, a well-known glucosidase inhibitor, the three OT extracts effectively inhibited murine pancreatic and intestine glucosidases. (Bhat M *et al.,* 2011). Plant extracts also have antioxidant qualities and normalize the harm caused by free radicals.

ANTICANCER AGENTS

Due to its chemo preventive and radio protective qualities, the tulsi herb has been shown to be extremely helpful in the treatment and prevention of cancer (Baliga MS *et al.,* 2013). According to (Nanghia-Makker P *et al.,* 2013). *Ocimum sanctum* is a nutritious plant well known for its several favorable pharmacologic properties, including its ability to fight cancer. Plants have cancer-fighting abilities and can be used to treat and prevent cancer in humans. *Ocimum sanctum* includes plant compounds such as apigenin, rosmarinic acid, and eugenol. To mediate these effects, retinal, luteolin, sitosterol, and carnosicacid increases antioxidant activity and changes gene, triggering apoptosis, and preventing angiogenesis in chemically caused skin, liver, oral, and metastasis (Baliga MS *et al.*, 2013). Lung tumours.Tulsi's aqueous extract and its bio-organic constituents were shown to be effective. Flavonoids, orintin, and vicenin protect mice against radiation sickness and decreased mortality. It protects the healthy tissues benefit from radiation's tumour improving effects. It has also been established that a number of keyphyto chemicals such as eugenol, rosmarinic acid, and apigenin and canonic acid, protect DNA from radiation damage and deterioration.

A test was performed to see if holy basil had any positive effects on rat models of pulmonary hypertension. The results showed that *Ocimum sanctum* therapy at a dosage of 200 mg per kg decreased right ventricular hypertrophy and enhanced lung weight to body weight ratio. The impact of a methanolic extract of Tulsi leaves on rat myocardial infarctions caused by isoproterenol was investigated. Myocardial infarction was brought on by isoproterenol, which also increased the levels of cardiac markers and phospholipid content. But after being treated previously with holy basil leaf extract, the same were diminished.

ANTIFERTILITY EFFECT

The anti-fertility impact of holy basil was studied, and it was shown that giving rats a leaves extract at a concentration of 250 mg/kg body weight reduced total sperm count and sperm motility. Furthermore, the percentage of aberrant sperm rose in caudal epididymal fluid, whereas fructose content dropped in caudal epididymal plasma. According to the findings, these effects are produced by androgen deficiency, which is induced by the anti-androgenic characteristic of holy basil leaves (Jyoti S *et al.*, 2007).

ANTI-ULCER EFFECT

The antiulcer effects observed against different inducers such as aspirin, indomethacin, alcohol (ethanol 50%), histamine, reserpine, serotonin, and stress-induced ulcers point to the broad spectrum of action of Tulsi fixed oil against diverse causes of ulcers.

Several mechanisms may contribute to this observed antiulcer activity:

1. **Lipoxygenase Inhibition:** Lipoxygenases are enzymes involved in the biosynthesis of inflammatory mediators known as leukotrienes. By inhibiting lipoxygenase, Tulsi fixed oil may help reduce the formation of these pro-inflammatory compounds, subsequently mitigating ulcer formation or progression caused by inflammatory pathways.
2. **Histamine Antagonism:** Histamine is a compound involved in various physiological processes, including the regulation of gastric acid secretion. Antagonizing histamine's effects might help in decreasing excessive gastric acid secretion, which can contribute to ulcer formation.
3. **Antisecretory Effects:** The fixed oil from Tulsi may possess properties that reduce the secretion of gastric acid or other harmful substances in the stomach, thus protecting against ulcer formation.

The multi-pronged approach of Tulsi fixed oil in inhibiting lipoxygenase, antagonizing histamine, and exerting Antisecretory effects collectively contributes to its significant antiulcer activity across various ulcer-inducing conditions. These findings suggest that Tulsi fixed oil could be a potential candidate for the management or prevention of ulcers. However, further research, including clinical studies, is needed to validate these effects in humans and ascertain the optimal dosage and safety profile for therapeutic use. Always consult with healthcare professionals before using herbal remedies or supplements for medicinal purposes (singh S *et al.*, 2007).

ANTIOXIDANT EFFECT

Tulsi (*Ocimum sanctum*) contains various compounds, including polyphenols like rosmarinic acid, which possess antioxidant properties. Antioxidants are molecules that help neutralize or counteract the damaging effects of free radicals in the body. Free radicals are highly reactive molecules produced during normal metabolic processes or introduced from external sources like UV radiation, pollution, and certain foods. These molecules can cause oxidative stress, leading to cell damage and potentially contributing to various health issues and aging.

Rosmarinic acid, found abundantly in Tulsi leaves, acts as an antioxidant by scavenging these free radicals. By neutralizing these reactive molecules, rosmarinic acid helps protect cells from oxidative damage, thereby reducing the risk of cell rupture or disruption caused by excessive oxidation. The presence of antioxidants like rosmarinic acid in Tulsi may aid in maintaining cellular health by limiting the harmful effects of oxidative stress. By reducing oxidative damage, these antioxidants contribute to overall health and potentially help lower the risk of various diseases associated with oxidative stress, such as cardiovascular diseases, certain cancers, and neurodegenerative disorders. Consuming Tulsi or incorporating it into one's diet may provide antioxidant benefits due to compounds like rosmarinic acid, thereby assisting in reducing the detrimental effects of excessive oxidation within the body. However, it's important to maintain a balanced diet rich in various antioxidants from different sources for optimal health benefits. (Kaur *et al.,* 2018).

ANTIPYRETIC EFFECTS

The antipyretic effect of the fixed oil derived from Tulsi (*Ocimum sanctum*) was assessed in rats that had fever induced by the typhoid-paratyphoid A/B vaccine. The study aimed to evaluate whether the oil could reduce the fever caused by the vaccine-induced pyrexia, indicating potential antipyretic properties. Upon intraperitoneal (IP) administration of the Tulsi oil at a dosage of 3 ml/kg, a significant decrease in the febrile reaction was observed. This reduction in fever suggests that the Tulsi oil has antipyretic effects similar to those seen with aspirin administration at the same dosage.

One mechanism by which antipyretics like aspirin exert their effects is through the inhibition of prostaglandin synthesis. Prostaglandins are lipid compounds that play a role in various physiological processes, including the regulation of body temperature. During fever, the body produces prostaglandins, particularly PGE2 (Prostaglandin E2), which act on the hypothalamus to increase the body's set-point temperature, leading to fever. The fixed oil from Tulsi is believed to possess prostaglandin inhibitory activity. By inhibiting the synthesis or action of prostaglandins, especially PGE2, Tulsi oil can potentially modulate the body's thermoregulatory mechanism, thus reducing fever.

The specific components within Tulsi oil that contribute to this inhibitory action on prostaglandins may include bioactive compounds such as eugenol, rosmarinic acid, and other phytochemicals. These components could interfere with the enzymes involved in prostaglandin synthesis or directly affect the receptors that prostaglandins bind to, thereby mitigating the fever response. However, it's important to note that while the study suggests antipyretic effects of Tulsi oil and its prostaglandin inhibitory activity, further research is needed to elucidate the exact mechanisms by which Tulsi exerts its antipyretic properties and to validate its efficacy and safety for human use. Consulting healthcare professionals before using Tulsi oil or any herbal remedy for medicinal purposes is advisable (Singh S, TanejaM et.,al 2007).

ANTICOAGULANT ACTIVITY

The information you provided suggests that the fixed oil derived from Tulsi (*Ocimum sanctum*) exhibited an effect on blood clotting time when administered intraperitoneally (ip) in a dose of 3 ml/kg. This dosage prolonged the blood clotting time, and this effect was similar to the impact seen with aspirin administration at a dose of 100 mg/kg.The observed effect on blood clotting time is likely due to the anti aggregator action of the Tulsi oil on platelets. This means that the oil may have properties that inhibit or reduce the aggregation or clumping of platelets, which are cells in the blood that are involved in clotting. The comparison to aspirin, a well-known antiplatelet medication, suggests that Tulsi oil may have similar effects in terms of inhibiting platelet aggregation. Aspirin is widely used to reduce the risk of blood clots, heart attacks, and strokes by interfering with platelet function. This finding could indicate a potential use or relevance of Tulsi oil in the context of blood clotting disorders, cardiovascular health, or in preventing conditions related to excessive clotting. However, further scientific research is necessary to validate these effects and understand the precise mechanisms involved in the action of Tulsi oil on platelets and blood clotting.

FUTURE PERSPECTIVE OF TULSI

According to study, tulsi may be an effective therapy for conditions such as ulcers, high cholesterol, Type 2 diabetes, obesity, and impaired / suppressed immune systems, modern medicine (from cancers and other diseases, AIDS). Plant Cultures describes the typical applications of Tulsi's use in Ayurveda might be attributed to some intrinsic essential oils are found in several kinds of Tulsi, contains eugenol, an anti-inflammatory chemical different antioxidant and anti-inflammatory acids qualities that might back up Tulsi's claims of becoming a Ayurvedic medicine treats a wide range of ailments.

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Chapter 18

TRENDING POSSIBLE GENE TECHNOLOGIES FOR CROP IMPROVEMENT: FROM ADVERSE TO ADVANCE

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ABSTRACT

The increased human invasion in nature has led to negative impact for kingdom of life. Plants tolerate to survive against these macabre consequences. Environmental stresses such as biotic and abiotic affect the plants growth and agricultural productivity. The rapidly growing human population may lead to the problem for food security and serious health issue. Traditional techniques of improving quality of grains through plant breeding were time-consuming, labor-intensive, opaque and unpredictable. To salve the problems of food security and environmental challenges, it is compulsory to adapt advance and sustainable technology. Gene technology is an effective method that enables gene editing in plants. This process helps plants to withstand and reduce both biotic and abiotic stress, increase productivity and enhance their nutrient qualities. The discovery of the DNA double helix by Watson and Crick initiated the gene revolution, which initiated a new era in the life sciences. Later, ongoing research on epigenetics and utilization cutting edge technologies such as recombinant DNA technology, gene transferring, gene cloning, and polymerase chain reaction have stablished a transparent research platform. Recent discoveries of gene editing tools such as ZFN, TALLEN, RNAi technology, artificial gene synthesis, molecular marker technology, and CRISPR-Cas allow for a more predictable and direct approach to gene modification. Genomic sequences data from EMBL and DDBJ have made major contributions to comparative genomics. This has been useful in identifying new species, discovering novel genes, enhancing medication research, disease diagnosis as well as improving plant and animal quality and quantity attributes.

KEYWORDS: Genetic Tools, Molecular Breeding, Eco-TILLING, TALEN, ZFN, CRISPR/Cas, RNAi, NGS.

INTRODUCTION

Trending gene technology such aszinc finger nuclease (ZFN), transcription activator-like effector nuclease (TALEN) and clustered regularly inter spaced shortpalindromic repeats (CRISPR)-CAS systems have been successfully implemented in various plant species to accomplish desired genome editing (Jinek *et al.*, 2012). In recent years, plethora of peer-reviewed and research papers have been reported CRISPR technology in plants. However, still now this is more challenging for new users to select a CRISPR system to target a specific genetic engineering outcome in an interested plant. Introducing specific genomic changes, i.e., "genome editing", has been along-sought-after goal in molecular biology. In the mid of 2010 to 2012 a new genetic engineering tool was included with a third nuclease class generally known as transcription activator-like effector nucleases (TALENs). The DNA binding property of the TALE (transcription activator-like effector) protein is exploited in the construction of TALEN. TALENs are similar to ZFNs, employ DNA binding motifs to instruct the same non-specific nuclease (Fok1) to cleave the genome at a specific site. Recently discovered CRISPR/Cas9 technology quickly surpassed the previous ZFNs and TALENs. The CRISPR/Cas9-based GE platform exhibits as an unparalleled technology in plant science research due to its simplicity, high efficiency, cheap cost, and ability to target several genes at once. CRISPR/Cas9system tools was first applied in human cell later utilized for plants cell (Muntazir Mushtaq and Kutubuddin A. Molla, 2021).As a result, there is an urgent need to improve cereals in order to increase production and deal with less arable land, less water resources, and changing climate. Crop breeding technology innovations are required to address present issues. Traditional cross breeding, genetic engineering and mutation breeding are the major procedures employed for this goal. Major study on omics have revealed that several genes activated under abiotic stress are similarly induced under abiotic stress, suggesting that plants share comparable stress response mechanisms. (RamegowdaYamunarani *et al.*, 2022). In this book chapter, recent trends in biotechnology through omics and its major contribution major in crop improvement have been discussed.

GENOMICS

MARKER ASSISTED BREEDING

The genome-wide selection (GWS) or genomic selection (GS) method is a quick selection method that is based on genomic estimated breeding values (GEBVs) computed from genome-wide marker data. QTL-oriented breeding techniques include all the major and minor loci for target trait variation (MG Mallikarjuna *et al.*, 2022). Marker-assisted selection (MAS) in plant breeding uses markers such as cleaved amplified polymorphic sequences (CAPS), restriction fragment length polymorphism (RFLP), amplified fragment length polymorphism (AFLP) and single sequence repeat (SSR) to monitor features of interest. Single nucleotide polymorphism (SNP) markers are highly informative for distinguishing between two distinct alleles and are simple to generate after the polymorphic region has been found. (Fernie and Schauer, 2008). The GWAS addresses some of the limitations of traditional QTL/gene mapping by allowing for the detection of single nucleotide polymorphisms (SNPs) within genes that are responsible for phenotypic variation.(Brachi *et al.*, 2011). GWAS mapping was developed for various abiotic and biotic stress tolerance and related functional adaptation characteristics, such as drought, heat, cold, submergence tolerance, salinity, diseases, and pests. (G Mallikarjuna *et al.*, 2022). In recent years, functionally characterized genes, EST and genome sequencing studies have facilitated in identification of molecular markers from the genome's transcribed regions. Single-nucleotide polymorphisms (SNPs) are significant and widely used molecular markers which are developed from ESTs (Varshney *et al.*, 2005).

TARGETED GENE EDITING TECHNOLOGY

One of the most recent addition to next-generation plant breeding technologies in cereals is genome editing. Genome editing manipulates gene expression and function related with various abiotic and biotic responses in crops (Ansari *et al.*, 2020). The three most significant genome editing tools, zinc finger nuclease (ZFN), transcription activator-like effector nuclease (TALEN), and clustered regularly interspaced short palindromic repeat (CRISPR)/CRISPR-associated protein9 nucleases are trending in plant science (Matres *et al.*, 2021; Mishra *et al.*, 2021). TALENs technology was applied for editing gene associated with specific disease (Li *et al.*, 2012). CRISPR-Cas9 tool has been applied to knockout f lowering-related genes SP5G and FT to later the flowering time and induce early yield in soybean (Cai *et* *al.,* 2018). While CRISPR Cas9 has had a significant impact on yield enhancement, a few additional phenotypic changes with potential applications in breeding and the production of novel varieties have been developed in Brassica napus, Brassica oleraceae and barley (Lawrenson *et al.,* 2015). Recently, multiplexed genome editing in wheat was carried out by utilizing CRISPR-Cas9 to knockout TaLpx-1, TaGW2 and TaMLO genes at the same time (Wang *et al.,* 2018a). Recently, multiplexed genome editing in wheat was carried out by utilizing CRISPR-Cas9 to knockout TaLpx-1, Among these, TaLpx-1 and TaMLO gene silencing resulted in resistance to Fusarium graminearum and powdery mildew, respectively (Wang *et al.,* 2018a). Badh2 was disrupted and rice aroma was increased by using TALEN and CRIPSR-based genome editing (Shao *et al.,* 2017). One of the best examples of genome editing is targeting SBEIIb-gene responsible for enhancement quality and increasement of amylose content in rice (Sun *et al.,* 2017). Similarly, the genes of this pathway were applied in tomato (Nonaka *et al.,* 2017) and potato (Li *et al.,* 2018a) using CRIPR-Cas9 to facilitate GABA accumulation VIGS (Virus-Induced Gene Silencing) has been applied successfully in gene functional analysis without the many drawbacks associated with standard reverse genetic techniques (RamegowdaYamunarani *et al.,* 2022). Traditional genome editing entails repairing DSBs (DNA double- Strand Break) at targeted loci. SSN reagents identify and cleave target DNA in plant cells, resulting in DSBs that are repaired by endogenous DNA repair mechanisms like as homology-directed repair (HDR) and non-homologous end joining (NHEJ). NHEJ is the most common method for DSB repair, and when DSBs are repaired by NHEJ, indels may be introduced at the rejoined chromosomal junctions (Chen *et al.,* 2019). 1000 wheat RILs population was prepared by the combination of fast breeding and quick phenotyping led in the establishment of a Nested Association Mapping (NAM) population of around 1000 wheat RILs (F5) in 18 months to identify QTL for stay-green and root adaptation characteristics (Christopher *et al.,* 2021).Eco-TILLING enables the identification of natural alleles at a locus across various germplasms, allowing for SNP discovery as well as haplotyping. (Varshney *et al.,* 2005).

NEXT GENERATION SEQUENCING TECHNOLOGY

Major genomics-based technologies for discovering and manipulating trait associated genomic areas include Quantitative trait loci, miRNAs, and genome-editing systems such as CRISPR/Cas system. The advancement of Computational and Statistical Genetics/genomics tools accomplish the study of gene function with statistical association analysis simultaneous. A number of emerging technologies of next-generation sequencing (NGS) are able to generate thousands or tens of millions of short DNA sequence reads at a reasonable cost. Recent time, a new generation of sequencers based on "next-next" or third-generation sequencing (TGS) technologies, such as Heliscope Single-Molecule Sequencer, the Ion Personal Genome Machine (IPGM) and Single-Molecule Real-Time (SMRT) Sequencer are available which can generate longer sequence reads in less time and in low cost (Bennur *et al.,* 2020). NGS data might potentially be used to monitor accessions' regeneration in order to verify their genetic integrity, such as, by comparing sequence information from samples before and after regeneration of data (Van Hintum *et al.,* 2007). NGS technologies provide massively parallel analysis with high throughput from several samples at a significantly lower cost (Mardis. 2011). The release of draft genome sequences for rice kicked off the cereal genomic revolution, which was quickly followed by sorghum, maize, pearl millet, barley, and wheat. As a result, the availability of genome sequences and diverse genetic resources helped to improve mapping population's development and enhanced genomics-assisted breeding in cereals (Sharm*et al.,* 2022).

TRANSCRIPTOMICS

Transcription factors (TFs) govern the expression of gene induced under stress condition by binding to their cognate cis-acting elements in the promoter region. Tran's membrane motifs on transcription factors (TFs) allow them to translocate from the cytoplasm to the nucleus. Another distinguishing trait is the presence of a DNA-binding motif/domain, which allows them to bind with a DNA signature sequence (cis-acting site). Some transcription factor families such as WRKY, ERF/DREB, NAC, bZIP and MYB have been reported in model plants involved disease resistance (FM Watto *et al.,* 2022). Study on transcription Factors reveal that WRKY TFs bind to W-box (motif TTGACC/T) of downstream target gene promoters to control their transcription activities in various physiological and developmental processes in abiotic and biotic stress condition. Activation of ethylene-responsive element-binding factor-TF (ERF) which is subfamily of AP2/EFR gene regulates the biotic stress. PAMP-control the triggered immunity, hormon signaling and effector-triggered immunity which is governed by bZIP-TF effector-triggered immunity. Zhang *et al.,* 2007, reported that TaERF3 gene is responsible for the early effective against Blumeriagraminis through SA signaling and late defense response against Fusarium graminearum and Rhizoctoniacerealis through jasmonic acid/ethylene signaling pathways in wheat (Zhang *et al.,* 2007). WRKY is one of the most majorly reported transcription factors in plants during biotic stress. Member of WRKY-TFs have been reported as repressors or co-repressors and activators of key pathways such as alkaloid, terpenes and other metabolite production and activation of a various immune response pathways (Schluttenhofer and Yuan. 2015). Mechanism of Rice fungus Magnaporthe resistance in rice is regulated by NAC gene subsets - OsNAC6, OsNAC60, OsNAC58, OsNAC111, ONAC122, ONAC066and ONAC131 and tolerance against virus RDV is negatively regulated by RIM1 (Yoshii *et al.,* 2009). Xanthomonas oryzaepv. oryzae (Xoo) cause bacterial blight consequence 50% loss in rice grain production. Xoo possesses effector binding elements (EBE) in the promoter region of OsSWEET gene family (OsSWEET13, OsSWEET11 and OsSWEET14) which can be manipulated by genome editing tools to develop blight resistance rice varieties Boch and Bonas.2010; (Makino *et al.,* 2006; Chen *et al.,* 2012; Doyle *et al.,* 2013). According to report on TF-research about 2000 genes in plant genomes encode different transcription factors (Hong *et al.,* 2016).

PROTEOMICS

Protein research introduces structure of proteins and post-translational modifications (PTMs) which provides information about protein function to understanding the role in biological processes. Proteomic investigation identifies the functional role involved in specific cellular processes. Proteome has statically dynamic possibilities in nature like genome. (Kav etal., 2007). The advent of different sophisticated computational science tools and bioinformatics is integrating proteomics to other "omics," and physiological data have opened up a new method for crop improvement research through cell signaling, regulatory, and metabolic networks underpinning plant phenotypes (Eldakak *et al.,* 2013).Global proteome profiling programs are effective methods for enhancing knowledge base of plant breeders. Several studies on proteome have suggest that leaf senescence have focused on nitrogen mobilization from leaves during leaf senescence (Avice and Etienne. 2014). Proteomic study on plant microbe interaction have suggested that bacteroid responses to drought stress. Similar investigations revealed that protein expression in root nodules for nitrogen fixing in white sweet clover and soybean respectively (Reid *et al.,* 2012). Organ-specific proteome investigations are being conducted to discover proteins that often accumulate in organs under a wide range of biotic stresses. Proteomic analysis of rice leaf, seed exerts and root shows the presence of several allergenic proteins in the seeds which indicates the use of proteomic analysis of foods for allergen detection (Beyene *et al.,* 2016).A thorough proteome investigation of Arabidopsis organs sparked the notion of using plant proteomics to discover proteins as biomarkers. This method was then used to map the structural and metabolic changes that occur throughout the growth and differentiation of maize leaves (Vanderschuren *et al.,* 2013). According to a study that investigated several wheat varieties with various heat resistance capacities showed that low molecular weight (16-17 kDa) heat shock proteins (HSPs) and other proteins are essential for the heat resistance trait (Majoul etal., 2004). Protein-protein interaction investigation suggested that HSP90 interacts with the calmodulin-binding protein (CBP), suppressing calmodulin resulted in a reduction in heat tolerance (Zhang *et al.,* 2009). Additionally, almost 3500 proteins in plantains were discovered using plantain RNA-Seq data (Yang *et al.,* 2012). NGS will also give information on crop accessions' sequence diversity. The proteome information from new accessions is currently being added to the Arabidopsis and rice protein databases.

METABOLOMICS

Metabolomics deal with full examination, quantification and identification of an organism's metabolites at a particular moment. Plant metabolites are divided into two types: primary metabolites, which are created during primary metabolism and contribute to plant growth and development, and secondary metabolites, which are produced during secondary metabolism and help in pathogen and disease defense. Traditionally, researchers have focused on a single metabolic feature or a combination of traits of nutritional significance, such as tomato carotenoid content, maize protein content, and potato and rice starch content which is significant for industries also(Fernie *et al.,* 2006; Moose *et al.,* 2004).Metabolic profiling's identification of metabolic quantitative trait loci (mQTLs) and the similar metabolome-based genome-wide association studies (mGWAS) of plant genotypes have reinforced the role of metabolomics as metabolic marker-assisted breeding which helps in selecting elite breeding lines. mQTLs have been found in a variety of commercially important crops, including wheat, maize, mustard, rice and tomato (Agarrwal and Nair, 2020). Schauer *et al.,* 2006, found that mQTLs are predominantly inherited. Unintended side effects that occur when creating a genetically modified (GM) plant can be examined at the metabolic level through non-targeted metabolic profiling, which offers a metabolic overview of genetically modified plants. The use of comparative metabolomics is beneficial in determining the substantial equivalence of genetically modified (GM) crops (Agarrwal and Nair, 2020). Metabolomics analysis is based on two main technical approaches: nuclear magnetic resonance (NMR) spectroscopy-based techniques and mass spectrometry (MS) (Fuhrer and Zamboni, 2015). Metabolism approach have resulted in a detailed dissection and increased understanding seed oil synthesis, glucosinolate biosynthesis and oligosaccharine metabolism in Arabidopsis. Furthermore, these approaches have aided in the study of flavonoid production in Arabidopsis, zopulus and tomato (Fernie and Schauer, 2008).

CONCLUSION

The need for agricultural production rises year after year, necessitating the creation and enhancement of plant crops with both qualitative and quantitative qualities. Researchers employ genome editing technologies in conjunction with molecular breeding to precisely target and change desirable genes, resulting in varieties with high production, nutritional value, and resistance to abiotic and biotic stress challenges. VIGS and RNAi are still frequently employed in laboratories for plant species with standardized transformation techniques, despite the growing popularity of gene-editing technologies such as CRISPR-Cas. CRISPR/Cas9 technology is being utilized to accelerate breeding in order to protect global food security and agricultural productivity. More knowledge about gene function is being disclosed as sequencing tools progress. High-throughput-omics technologies, in particular, have the benefit of finding potential candidate genes, proteins and pathways.

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Chapter

19

LIQUID BIOFERTILIZERS AS A SUSTAINABLE SOLUTION FOR AGRICULTURE

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ABSTRACT

The world population has recently risen to 7.8 billion people, placing an increased demand on agricultural crops and creating significant hurdles for feeding such a big population.By 2030, the Food and Agriculture Organization of the United Nations predicts a 60% rise in global demand for agricultural commodities. Chemical fertilizers have been extensively utilized by nations to boost crop yields in order to achieve self-sufficiency. However, these chemical fertilizers are seriously polluting the environment because they decrease the soil's ability to hold water, which reduces its fertility. They also make the soil more acidic and reduce the quantity of microorganisms, which leads to nutritional imbalances in the soil. Furthermore, instead of being absorbed by plants, these dangerous compounds build up in groundwater, adversely damaging the soil. Therefore, it is vital to shift the focus to the production of safe and environmentally friendly methods for sustainable crop production.

KEYWORDS: Liquid Biofertilizer, Agriculture, Microorganisms.

INTRODUCTION

The world population has recently raised to 7.8 billion people, placing an increased demand on agricultural crops and creating significant hurdles for feeding such a big population. By 2030, the Food and Agriculture Organization of the United Nations predicts a 60% rise in global demand for agricultural commodities. Chemical fertilizers have been extensively utilized by nations to boost crop yields in order to achieve self-sufficiency. However, these chemical fertilizers are seriously polluting the environment because they decrease the soil's ability to hold water, which reduces its fertility. They also make the soil more acidic and reduce the quantity of microorganisms, which leads to nutritional imbalances in the soil. Furthermore, instead of being absorbed by plants, these dangerous compounds build up in groundwater, adversely damaging the soil. Therefore, it is vital to shift the focus to the production of safe and environmentally friendly methods for sustainable crop production.

Consumer awareness of government regulations, soil degradation, nitrate emissions, and the dangers of chemical fertilizers is growing with time. Consequently, it is anticipated that the market for biofertilizers would grow from USD 2.3 billion in 2020 to USD 3.9 billion in 2025. In addition to helping to promote plant growth, biofertilizers are well known for their capacity to supply plants with minerals like nitrogen, phosphate, zinc, and phosphorus. Liquid biofertilizers with a high cell count of more than 109 were created to address the shortcomings of carrier-based biofertilizers, which include their short shelf life, low cell count, and difficulty in storing and handling.

The process of making inexpensive, efficient biofertilizers comprises numerous steps, starting with selecting the best carrier, isolating and screening bacteria to discover the most potent one, and then going through several tests before scaling it up from the flask-stage to the commercial level. Finding less expensive raw materials that are rich in nutrients, carbon, and nitrogen is also crucial. These materials can be used as a substrate or a liquid media to cultivate microorganisms. Some industries must pay to dispose of their garbage or struggle to properly handle their waste. These wastes and byproducts can therefore be utilized as potential substrates to create a Biofertilizer that is sustainable and environmentally beneficial. Additionally, biofertilizers can be modified to provide plants certain amounts of nitrogen, phosphate, zinc, or other nutrients depending on the type of soil.

In light of these characteristics, this evaluation compares chemical and organic fertilizers with biofertilizers first, then assesses the production procedures and evaluates the liquid inoculants and their effects on plant growth. It is detailed how liquid biofertilizers are created from various substrates, or by-products and wastes of various businesses. Finally, the difficulties and suggestions for additional research are highlighted in order to enhance the creation and advancement of liquid Biofertilizer, hence promoting its growth and commercialization for the agricultural industries.

BIOFERTILIZERS

Biofertilizers in general Biofertilizers are one of the most promising ways to increase crop production while staying environmentally friendly.

Unlike organic fertilizers which consist of animal manure, compost, slurry waste, peat, bones, and blood meal, biofertilizers contain one or more living microorganisms (i.e., bacteria, fungi, algae) alone or in combination that settle down in the rhizosphere and enhance soil productivity by fixing down atmospheric nitrogen and solubilizing different nutrients, thereby exerting direct or indirect beneficial effects on crop growth and yield through different mechanisms.

In organic fertilizers, some organisms like earthworms need to convert the fertilizer into useful material which plants can absorb easily. Plant-growth promoting rhizobacteria is the most used bacteria in producing biofertilizers since it enhances plant growth by releasing potassium (K), fixing nitrogen (N), solving phosphorus (P), and producing hormones. Biofertilizers come in solid, liquid, polymer entrapped formulations, and fluidized bed dry formulations. Shows the differences between biofertilizers, chemical, and organic fertilizers with the pros and cons analyzed.

Plants need 14 essential mineral elements to grow and develop, which are macronutrients – N, P, K, Ca, Mg and S, and micronutrients – Fe, B, Cl, Mn, Zn, Cu, Mo, and Ni Although most of the elements are found in soil, they cannot be taken up by the plants because they are in forms that plants cannot assimilate. Some of these elements are absorbed by plants only in certain forms like nitrogen that is absorbed as either nitrate or ammonia. As shown in Figure 1, using microorganisms will promote plant growth and provide plants with nutrients Biofertilizers are classified based on the groups of microorganisms they contain and the functional features they have developed during the interactions with plants in the rhizosphere.

LIQUID BIOFERTILIZERS

Liquid biofertilizers are used as an alternative to carrier-based formulations. They are also called flowable or aqueous suspension. They are based on broth culture, mineral and organic oil, oil in water, and polymer based suspension Liquid biofertilizers typically consist of 10–40% microbes, 1–3% suspender ingredient, 1–5% dispersant, 3–8% surfactant, and 35–65% carrier liquid (water or oil) . Liquid biofertilizers should contain special cell protectants that contribute to the development of cysts and dormant spores.

Liquid biofertilizers are more attractive than solid inoculants because they have a long shelf life of 1.5–2 years, have no contamination, do not need sticky materials, can be used with modern machinery, can withstand high temperatures up to 45 C, are easy to handle and use, are easy for adding ingredients that enhance the growth of microbial strains, and are easy to apply on both seeds and soil. Also, liquid inoculants have higher microbial densities that allow for lower dosages compared to solid-inoculants yet obtain the same effect.

The carrier material for liquid biofertilizers should be cheap, abundantly available, non-toxic, and easy to use. The carrier also must have a suitable pH, high water holding capacity, and physical and chemical homogeneity to enhance microbial growth. Although liquid biofertilizers can be stored for a long time, microorganisms may face nutrient depletion, hypoxia, and environmental stresses which cause the microbial population to dramatically decrease. Therefore, special storing conditions are needed such as cool temperatures.

Liquid biofertilizers can reduce the use of chemical fertilizers by 15–40%. In addition, their dosages are less than solid Biofertilizer by 10%, thus less amount is needed, allowing for smaller storage spaces.

There are four types of liquid biofertilizers: suspension concentrates ultralow volume suspension, oil-miscible flowable concentrate, and oil dispersion. Suspension concentrates are favored by farmers more than wet table powders because they are not dusty, easier to measure, and can be poured in spray tanks. Suspension concentrates are made by combining solid active ingredients with low water solubility and acceptable hydrolysis stability. Before using, suspension concentrates must be diluted in water. Using surfactants and other chemicals can increase their storage and solubility. Ultralow volume suspension is a ready-to-use formulation that can be dispersed by ultralow volume aerial or ground spray machinery in a very fine spray. Oil miscible flow concentrate is a dispersion of active ingredients in an organic liquid. It must be diluted before use. Oil dispersion contains active ingredients in oil or in water immiscible solvent.

Oil is known to evaporate much less than water, so it stays in contact with plants for a longer time. It can be applied as an emulsion or an inverted emulsion (water in oil). Shows some of the companies that produce liquid biofertilizers in Jordan, India, Sri Lanka, and the United States.

MECHANISM OF BIOFERTILIZERS

Plant growth-promoting rhizobacteria stimulate plant growth through a variety of methods. They are frequently divided into direct and indirect methods. The bacteria may either directly increase plant growth by altering hormone levels or resource acquisition, or indirectly increase plant growth by reducing the impact of numerous pathogenic agents on plant growth and development

Direct mechanism

Nitrogen becomes available to plants by the energy intensive process of biological nitrogen fixation (BNF) due to the fact that most of it is available in the atmosphere. Diazotrophs which consist of bacteria and archaea use the large stock of N2 from the soil to biologically fix nitrogen. Atmospheric N2 is catalyzed and reduced into ammonium (NHþ4) by the nifH gene that encodes the highly conserved iron-protein subunit of the nitrogenase enzyme which consists of dinitrogenase reductase that has Fe as its co factor and dinitrogenase with Fe and Mo as its co factor as well as it being controlled by diazotrophs.

These microorganisms are divided into two groups symbiotic, and non-symbiotic. The symbiotic family consists of Rhizobiaceae and Cyanobacterium anabaena with azolla fern water where it has been used for more than 1000 years as a Biofertilizer (Azolla-Anabaena symbiosis). The non-symbiotic family consists of Azospirillum sp. And Cyanobacteria sp. Phosphate is the second most important element for plant growth and development after nitrogen, except that it is not available to plants since it is in an insoluble form and only 0.1% is available to plants. Microorganisms help solubilize insoluble P like dicalcium phosphate, tricalcium phosphate, hydroxyapatite, and rock phosphate by acids and other mechanisms that reduce the soil's pH into soluble forms of monobasic and dibasic which increase plants yield. Sometimes these bacteria mobilize the phosphorus.

Microorganisms and indole-3-acetic acid (IAA) primarily controls plant cell differentiation, cell division, and root length.

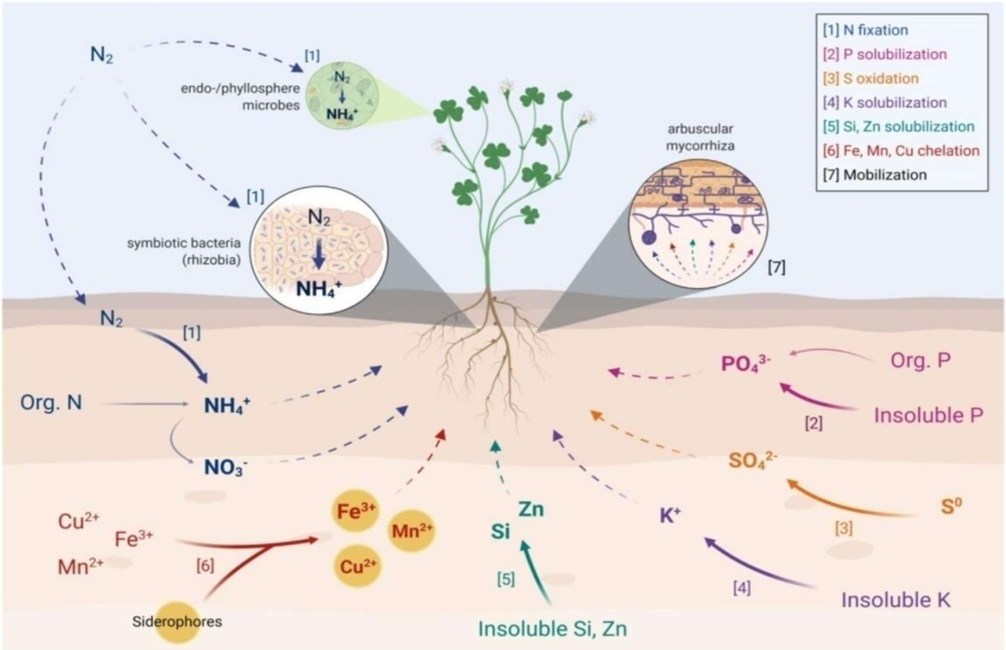

Fig. 1: Key microbially-mediated nutrient transformation/acquisition pathways associated with biofertilizers. Full arrows represent microbial transformations whereas dashed arrows represent mobilization/movement of nutrients (Mitter *et al.*, 2021).

Indirect mechanism

Indirect plant growth stimulants include the production of hydrogen cynide (HCN) and ammonia. The generation of ammonia can help the host plant fulfill its needs for nitrogen while simultaneously lessening pathogen invasion. Because of its great toxicity against phytopathogens, HCN is extensively used as a biocontrol agent in agricultural settings. However, HCN is also used to chelate metal ions, and therefore indirectly contributes to phosphate availability. Another method for controlling plant infections has been thought to involve microbial production of chitinase. Chitinase causes the disintegration of the cell wall, which impairs the stability of the structure and prevents the growth of pathogens. An integral part of the fungal cell wall known as chitin (1,4-Nacetylglucosamine) is attacked by the enzyme chitinase. A defense mechanism employed by the host plant against a variety of plant diseases, induced systemic resistance (ISR) is brought on by jasmonate and ethylene signaling. ISR is recognized to lessen the severity of disease in a variety of plant species. Through the interaction of specific rhizobacteria with plant roots, it is possible to establish plant resistance against pathogenic bacteria, fungi, and viruses.

BIOFERTILIZER PRODUCTION

Biofertilizer was registered in the United Kingdom in 1896 and first produced by Nobbe and Hiltner as a product named "Nitragin". It was also produced on a commercial scale in the United States, Malaysia and India in the 1930's, 1940's and 1960's, respectively.

Biofertilizer production consists of six steps – screening for inoculant strains, deciding on biofertilizer functional traits, product formulation, strain cultivation, testing product type and efficiency, and commercial production. Each of these steps is crucial to achieving a high-quality biofertilizer and must be carried out under strict conditions

As shown in Figure 2, in the first step, the microbial strains are isolated from soil, rhizosphere, and plant tissues such as stems, leaves, seeds, and roots. These strains must withstand the different cultivation methods. Then the microbes that can help enhance the plant growth are identified, isolated, and the functional traits are decided. Culturing improvements broaden the range of recovered microorganisms, increase the chances of discovering useful characteristics.

In the third step, the carrier material, which is an inert material that transform microorganisms from the biofertilizer to the soil, is selected, either carrier-based or liquid (broth, broth þ polyvinylpyrrolidone). Choosing the suitable carrier is very important to keep the microbes alive and in the right amount must be non-toxic, biodegradable, environmentally friendly, stable at room temperature, and cheap. Compared to solid carriers, liquid inoculants do not need sticky materials, need a fewer number of cells, and can be put in a bottle in larger amounts.

In the second step, a pure culture is selected based on the desired functional traits like nitrogen fixation, nutrient mobilization and solubilization, and phytohormone production. The suitability and applicability of the selected strains are tested using different lab testing methods, for example, growth on selective media and quantitative testing to determine efficacy degree. Also, before producing biofertilizers on a commercial scale, biofertilizer must undergo greenhouse tests to determine their efficiency before application on fields to make sure that it does not have any eco-toxicological effects and has beneficial impacts in promoting plant growth. Moreover, the strains are analyzed to see how they promote plant growth. This knowledge can help in formulating the best formula for Biofertilizer that can work in different ecosystems, since it is not profitable to produce a biofertilizer for each soil type.

In the fourth step, the microbial strains are cultivated and multiplied using fermenters in laboratories under optimal conditions, as well as the appropriate reproduction method. Solid state and liquid fermentation methods are used for producing biofertilizers. In the fifth step, different types of the product (microbial type, product type, and product properties) are tested to select the one with the best performance. In the sixth step, large-scale field testing of biofertilizers is done to determine their efficiency and shortcomings in a variety of ecological regions and environments before finalizing a standardized method for production and processing. Finally, the produced biofertilizers must be packed and the package must contain the following information: product name, date of production in addition to expiry date, the microbial strains in it, target crops, name and address of manufacturer, and instructions and recommendations for application.

LIQUID INOCULANTS

For liquid biofertilizers, peat is the most used carrier for biofertilizers due to its properties in supporting the microorganism's growth and survival. Still, due to its high sterilization cost, difficulty of application in large fields, and difficulty in processing, liquid inoculants were invented to be used as an alternative to solid inoculants. Liquid inoculants can be made from single mixed cultures that improve the cell survival in application and storage conditions. The selected carrier should provide the microorganisms with a protective and suitable medium to survive, as well as staying effective over a long period of release. They also must be at neutral or near neutral pH in addition to being environmentally friendly.

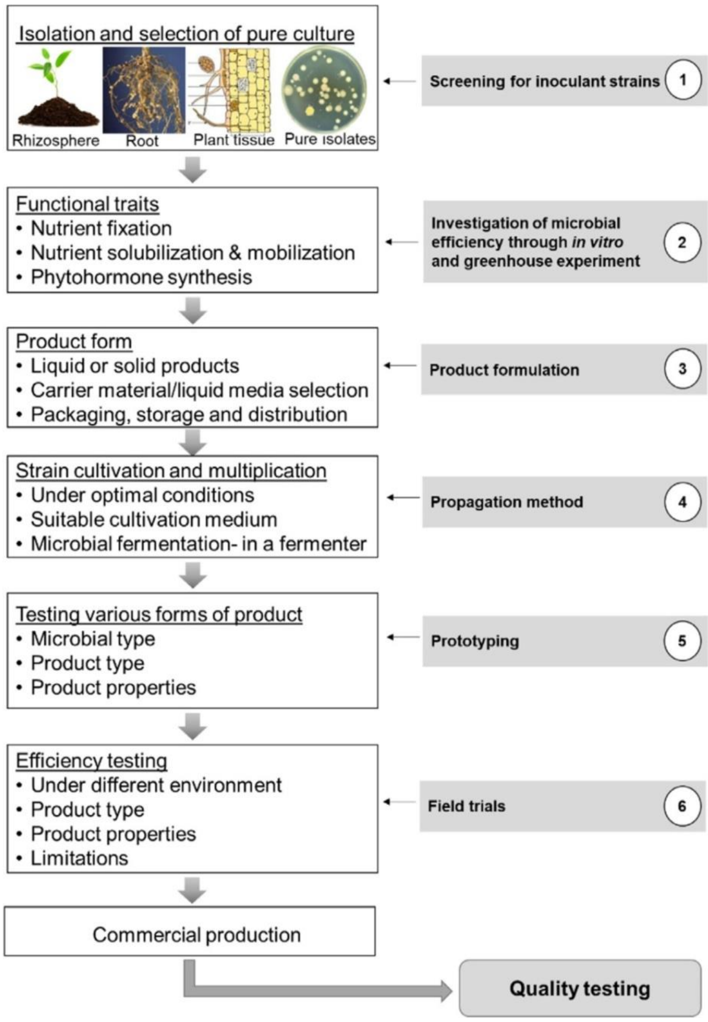

Fig. 2: Liquid Biofertilizers Quality testing

Tested the survivability, nitrogenase activity, indole acetic acid production, ammonia, and siderophore production of 43 isolates obtained on Jensen's medium of Triticumaestivum (wheat), Zea mays (Maize), Solanumtuberosum (potato), Aloe baradensis (Aloe vera), and Bacopamonnieri (Brahmi) soil samples. Four different liquid carriers of compost tea, biogas slurry, vermiwash, and minimal growth medium (peptone water) were used to develop the liquid biofertilizer. The viable cell count was counted over six months with samples drawn at monthly intervals. All the 43 bacterial strains were compared to a reference strain of A. chroococcum. It was found that only 18 isolates produced more than 150 nmol C2H4 h1mg1 of protein nitrogenase activity. In addition, out of these 18 isolates, only six showed higher nitrogenase activity compared to the reference bacterial strain of A. chroococcum, 13 produced IAA, nine produces siderophores, and 11 produced ammonia. Out of these isolates, the isolate from wheat rhizosphere was the most efficient. Based on the 16S rRNA gene sequencing, it was identified as S. rhizophila (WT-A2). As for the survivability test, only strain. After compost tea, biogas slurry was the second-best carrier folthe most efficient isolate of WT-A2 was tested. The compost tea carrier lowed by vermiwash and minimal growth medium. Glycerol can also be showed a mean value of cell count higher than that of the reference added to liquid carriers to increase biofertilizer's shelf life.

EFFECTS OF LIQUID BIOFERTILIZERS ON PLANT GROWTH

Summarizes some selected studies conducted on different crops with different liquid inoculants and bacteria strains. Did an experiment on alfalfa seed, which is a leguminous plant of the pea family

(Fabaceae) used to fix nitrogen to other plants, because it houses rhizobia bacteria. Alfalfa is planted as a cover crop to enhance the soil properties and increase its nutrient levels. It can also tolerate drought, heat, and cold weather. The Sinorhizobiummeliloti L3Si strain was grown in yeast mannitol broth (YMB). As for the liquid inoculant, ten different media were prepared. They were added in combination or separately. For the survival of L3Si during a storage time of 150 days, the most suitable liquid inoculant was found to be a glycerol medium formulated with agar or sodium-alginate. Sinorhizobiummeliloti L3Si's effectiveness on alfalfa seeds were studied on nodulation, plant height, shoot dry weight, and nitrogen content in the shoot dry weight. After one-month storage, alfalfa seeds pre-inoculated with YMB, YMB with agar, and YMB with sodium-alginate for up to three months produced successful alfalfa plants with nitrogen content ranging from 3.72 to4.19%.

Microalgae-based biofertilizers have also been evaluated. In liquid biofertilizers extracted from Chlorella vulgaris and *Spirulina platensis* were applied on green gram Vignaradiata (L.). Among all the treatment concentrations, the two treatments at 100% showed the highest yield of green gram yielding 29 and 30 pods plant1 for Chlorella vulgaris and *Spirulina platensis*, respectively. Also, the plant height, root and shoot dry weight, nutrient compositions were increased significantly. Amino acids were found to be higher in plants treated with Chlorella vulgaris, whereas N, P, and K were found to be higher in plants treated with *Spirulina platensis*

Enhanced plant growth, grain yield, and benefit-cost ratio. Statistically, BF1 and BF2 with 75% of the recommended dose of inorganic fertilizer can be used, yielding very close results to BF2 þ 100%, so it could save about 25% of inorganic chemical fertilizer. In a similar manner, experimented with a combination of bacterial consortia with an inorganic chemical fertilizer. They reached the same conclusion that a combination of both chemical and biofertilizer could save up to 25% of chemical fertilizer, enhancing the plant height, bulb yield, and number of leaves of onions.

CHALLENGES AND FUTURE PERSPECTIVES

Most of the biofertilizers produced are effective on certain crops, soil types, and climates. Plant growth and development is affected by several biotic and abiotic stresses in the soil environment Moisture is needed for nutrient uptake and absorption by plants. Yet, due to climate change, drought stress is considered one of the most serious abiotic environmental stresses affecting the hemostasis of soil, and the morphological, physiological, and nutritional traits of plants. The results of applying liquid biofertilizers are sometimes unpredictable like what happened in Belgium in the 1999–2000 seasons when a biofertilizer had positive effects at the start of the winter season, but as weather conditions worsened, the final yield did not reach its full potential. The same happened in Uruguay, where at first plant growth was observed, but decreased with time with no significant difference between inoculated and non-inoculated plants. When the experiment was done outside of the growth season, the results were negligible. Therefore, biofertilizers must be developed to resist drought stress and other environmental stresses due to seasonal changes, as well as to search for microbial strains that can withstand stressful conditions. By doing so, farmers in harsh environments or developing countries will benefit from such biofertilizers.

When transforming liquid Biofertilizer from laboratory scale to large scale, it may act poorly due to other variables not being studied on the lab scale. These variables must be taken into consideration to produce liquid biofertilizers suitable for various weather conditions and soil types. Another challenge is that for liquid biofertilizers, different or more advanced machinery might be required for large-scale application, thus making it energy intensive. Therefore, liquid biofertilizers must be produced in a way that can be used on the current or low-cost machinery.

To evaluate their viability, a cost-benefit analysis must be done to deduce the profitability of Biofertilizer. After discounting the gross cost and benefit, an organization will be profitable if the benefit-to-cost ratio surpasses 1. For example, the benefit-cost ratio was found to be 17 for soybean by fixing 100 kg N ha1, and 416 for clover by fixing 200 kg kg N ha1 based on n-fixation since they are legume crops. Also, the biofertilizer energy requirement is fully paid by nature when compared to chemical fertilizers that require 80 MJ for N, 12 MJ for P, and 8 MJ for K leaving many small-holder farmers unable to afford the expensive energy bill. In legume plants, 48–300 kg N ha1 is fixed in a season. The amount of biofertilizers required to supply plants with the same amount of nutrients is much less than chemical fertilizers. Additionally, this low-cost method of supplying nutrients to soil makes it attractive to small-holder farmers. Therefore, more studies are required to conduct cost-benefit analyses of biofertilizers based on plant yields.

Some biological molecules such as flavonoids, strigolactones, and polysaccharides can promote a symbiotic relationship between arbuscular mycorrhiza fungi and the host plant, as well as rhizobium during nodule formation. For improved product formulation, these compounds should be explored. The existing bacterial strains help in improving one trait of the plant, but scientists may need to develop genetically engineered strains that are more efficient while ensuring that these developed strains do not cause any hazards or risk.

Some studies have shown that biofertilizers can affect the surrounding environment by introducing microorganisms that can affect the structure of native microflora and some non-target effects like changes in biogeochemical cycles, soil texture, and soil properties. However, it is still unknown how these microorganisms react with the presented microflora. In addition, the severity of the changes on the ecological systems has yet to be revealed. No recent studies have explored the safety of bioinoculants for commercial use.

In addition, there is a need to improve education about biofertilizers and their long-term benefits compared with chemical fertilizers, and to correct the misconception about microorganisms being a source of disease. Biofertilizers will require new and innovative techniques for the growth, transportation, formulation, storage, and application of microorganisms as they go from small scale (laboratory and greenhouse tests) to large scale production. More investment is needed in the existing and future technologies via research to produce cost-effective and environmentally friendly biofertilizers. However, there is a lack of communication between farmers, industry, researchers, and governmental sectors. Multi-stakeholder partnerships are definitely crucial in order to develop biofertilizers that do the best job possible.

LIQUID BIOFERTLIZER APPLICATION

SEED TREATMENT

Seed treatment is the most common method adopted for all types of inoculants. The seed treatment is effective and economic. For small quantities of seeds (up to 5 kg), the coating can done in a plastic bag. For this purpose, a plastic bag sized 21” x 10” or larger can be used. The bag should be filled with 2 kg or more of seeds. The bag should be closed in such a way so as to trap the air as much as possible. The bag should be squeezed for 2 minutes or more until all the seeds are uniformly wetted. Then the bag is opened, inflated again and shaken gently. The shaking can stop after each seed gets a uniform layer of culture coating. The bag is opened and the seeds are dried in the shade for 20–30 minutes. For large amounts of seeds, the coating can be done in a bucket and the inoculant can be mixed directly by hand. Seed treatment with Rhizobium, Azotobacter, Azospirillum, along with PSM can be done.

The seed treatment can be done with any of two or more bacteria. There is no side (antagonistic) effect. The important things that have to be kept in mind are that the seeds must be first coated with Rhizobium, Azotobacter or Azospirillum. When each seed gets a layer of these bacteria, then the PSM inoculant has to be coated as an outer layer. This method will provide a maximum number of all bacteria required for better results. Treatments of seeds with any two bacteria will not provide a maximum number of bacteria on individual seeds.

ROOT DIPPING

This method is used for application of Azospirillum/ /PSM on paddy transplanting/ vegetable crops. The required quantity of Azospirillum/ /PSM has to be mixed with 5–10 liters of water at one corner of the field and the roots of seedlings have to be dipped for a minimum of half-an-hour before transplantation.

SOIL APPLICATION

Use 200ml of PSM per acre. Mix PSM with 400 to 600 kgs of cow dung FYM along with ½ bag of rock phosphate if available. The mixture of PSM, cow dung and rock phosphate has to be kept under any tree or in the shade overnight and 50% moisture should be maintained. The mixture is used for soil application in rows or during leveling of soil.

CONCLUSION

Liquid biofertilizers consist of living microorganisms that enhance soil properties and increase plant growth and yield. Liquid biofertilizers have been applied to different crops and yielded the best results when compared to other types of chemical or carrier-based fertilizers. In some cases, plant growth increased two-fold. Biofertilizers can be produced by using a single or a mix of microorganisms based on the role the biofertilizer is produced for. Also, liquid biofertilizers can be made from wastes and by-products of some industries as they could be a suitable and low-cost option for the growth of the bacterial cells instead of using specially made media. Finally, in order to develop effective liquid biofertilizers, more research is needed to overcome their limitations in the aspects of better climate adaptation, longer shelf life, better liquid inoculant, and use of low-cost or existing machinery for large-scale application. Cost-benefit analyses, field trials, long-term safety and effectiveness evaluations, and multi-stakeholder partnerships are the essential elements to evaluate the feasibility of the liquid biofertilizer on a case-by-case basis, taking into consideration the location, crop type, soil type, and climate.

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