



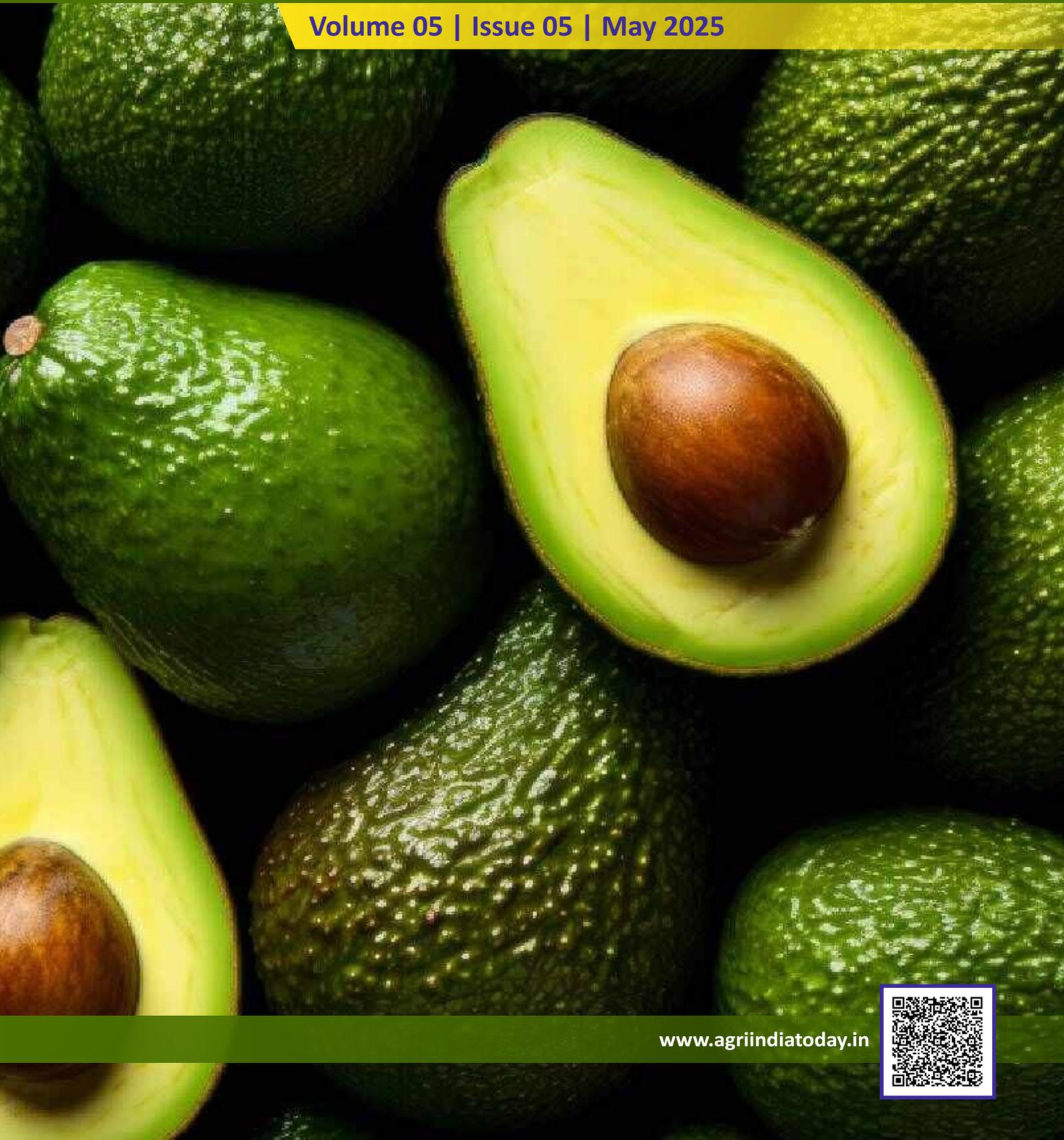
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TECHNOLOGICAL TRANSIENTS IN POSTHARVEST MANAGEMENT SYSTEM

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Abstract

Postharvest management is a critical aspect of food production and food security, with significant losses occurring due to inadequate handling, storage, and transportation. This article explores the role of technological transients in improving postharvest management systems. It examines the application of artificial intelligence, Internet of Things (IoT), big data analytics, and other technologies in reducing losses and enhancing food quality. This research article reveals that these technologies have the potential to transform postharvest management, improving efficiency, reducing loss across all actors of value chain, and enhancing food security for all.

Keywords : Technological, Postharvest, Management, transients, and Artificial-intelligence

Introduction

Postharvest management is a crucial stage in food production, involving handling, storage, and transportation of produce from the farm to the consumer. However, this stage is often characterized by significant losses if not properly handled, estimated to be up to 40-50% of total production in some cases (Kumar et al., 2020). These losses can be attributed to inadequate handling, storage, and transportation practices, resulting in reduced food quality and availability. Recent advancements in technology have created opportunities for improving postharvest management systems. This article examines the role of technological change in postharvest management, focusing on the initial indigenous method, technological change (improved technologies), and the emerging artificial intelligence and other relevant technologies.

A. Traditional Storage Methods and Their Limitations

From time immemorial, rural food crops handlers have been engaged in postharvest activities and have sought means to improve their techniques and method of handling on which they depended on at the time. The traditional or indigenous storage methods which they used vary depending on the crop and region but often include:

- **Ambient Storage:** Storing produce in open-air structures with minimal protection from the environment. Such as maize, millet and sorghum.
- **Earth Pits:** Burying produce underground to maintain a relatively constant temperature and humidity. Crops such as yam tubers, cassava etc.
- **Elevated Granaries:** Storing grains in raised structures to prevent rodent and insect infestation. Such as maize, millet and sorghum.



Elevated Granaries

- **Natural Ventilation:** Utilizing natural air currents to cool and dry produce. While these methods are often low-cost and readily available, they have significant limitations: Limited Temperature Control: Traditional storage provides minimal control over temperature, leading to accelerated respiration, spoilage, and moisture loss.
- **High Susceptibility to Pests and Diseases:** Open storage exposes produce to rodents, insects, and fungal pathogens, causing significant damage and contamination.
- **Inadequate Humidity Control:** Fluctuations in humidity can lead to shriveling, sprouting, and quality degradation.

Short Shelf Life: Traditional storage methods typically provide a short shelf life, limiting the availability of produce during off-season periods.

B. Storage Technological Change: A Range of Solutions

Improved storage technologies offer a range of solutions to overcome the limitations of traditional methods. These technologies can be broadly classified into the following categories:

1. Improved Structures and Ventilation

- **Improved Granaries and Bins:** These structures provide better protection against pests, rodents, and moisture, with features such as sealed floors, screened windows, and improved ventilation. Studies have shown that improved granaries can significantly reduce grain losses caused by insects and rodents (Tefera et al., 2011).
- **Evaporative Cooling Structures (ECS):** ECS, such as zero-energy cool chambers, utilize the principle of evaporative cooling to lower the temperature and increase humidity, extending the shelf life of fruits and vegetables. These structures are particularly effective in hot and arid climates.
- **Cold Storage:** Refrigerated storage is a highly effective method of preserving perishable produce by slowing down respiration, enzymatic activity, and microbial growth. Cold storage is widely used for fruits, vegetables, and dairy products.

2. Modified Atmosphere Packaging (MAP) and Controlled Atmosphere (CA) Storage

- **Modified Atmosphere Packaging (MAP):** MAP involves packaging produce in films with modified gas compositions, typically lower oxygen and higher carbon dioxide levels, to slow down respiration and spoilage. MAP is used for a wide variety of fresh produce, including fruits, vegetables, and meats (Sandhya, 2010).

- **Controlled Atmosphere (CA) Storage:** CA storage involves precisely controlling the levels of oxygen, carbon dioxide, and other gases in a sealed storage environment. CA storage is particularly effective for extending the shelf life crops. CA storage can significantly reduce respiration rates, ethylene production, and the incidence of physiological disorders.



Inert Atmosphere Silo

3. Chemical Treatments and Coatings:

- **Fungicides and Insecticides:** Postharvest application of fungicides and insecticides can control fungal diseases and insect infestations during storage. However, the use of these chemicals requires careful consideration of food safety and environmental concerns.
- **Edible Coatings:** Edible coatings, derived from natural sources such as polysaccharides, proteins, and lipids, can create a protective barrier on the surface of fruits and vegetables, reducing moisture loss, slowing down respiration, and preventing microbial growth.

4. Drying and Curing:

- **Solar Drying:** Drying agricultural produce using solar energy is a traditional method of preservation, particularly for grains, fruits, and vegetables. Improved solar dryers can accelerate the drying process and protect produce from contamination.
- **Curing:** Curing involves subjecting produce to controlled temperature and humidity conditions to promote wound healing and reduce the incidence of decay. Curing is commonly used for onions, garlic, and sweet potatoes.

C. Emerging Artificial technology

With the recently continuous emergence of artificial intelligence and machine learning, postharvest system keep evolving giving it an easier and seamless operationalized engagement in real time.

- **Artificial Intelligence (AI)**

AI-powered technologies are being increasingly applied in postharvest management to improve efficiency and reduce losses. For instance, AI-powered sorting and grading systems can detect defects and sort produce efficiently (Yang et al., 2022). Additionally, AI-powered predictive analytics can forecast crop yields, quality, and potential spoilage, enabling informed decision-making.



Automated processing of peaches
Source: Hayat *et al.*, (2024)

➤ Internet of Things (IoT)

IoT technologies are being used to monitor and track produce in real-time, enabling swift interventions to prevent losses. Smart sensors can monitor temperature, humidity, and other factors affecting produce quality (Lee et al., 2020). Automated tracking systems enable real-time location tracking and monitoring of produce.

➤ Big Data Analytics

Big data analytics is being applied in postharvest management to analyze large datasets and optimize processes. Data-driven insights can help optimize postharvest processes, reducing losses and improving efficiency (Kumar et al., 2020). Big data analytics can also streamline logistics and transportation, reducing costs and improving delivery times.

Conclusion

Technological transients have the potential to transform postharvest management systems, reducing losses and improving food quality. The application of artificial intelligence, Internet of Things, big data analytics, and other technologies can improve efficiency, reduce waste, and enhance food security. Further research and investment are needed to fully realize the benefits of these technologies and improve postharvest management practices.

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NEED & ROLE OF NANOTECHNOLOGY IN FERTILIZER, DEVELOPMENT OF NANO UREA IN INDIA & ITS SUPERIORITY OVER THE GRANULAR UREA

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Agriculture has evolved in parallel with human evolution. Conventional agriculture demands the regular use of fertilizers, along with traditional agricultural practices, which can tremendously boost the crop growth, the yield, the productivity, and the nutritional value. Hence, chemical fertilizers have played an indispensable role in the growth of modern agricultural practices since the era of the green revolution. In the early years of the previous century, rapid mechanisation occurred in the field of agriculture whereas new technologies, such as marker-assisted breeding and transgenic crop production, were developed in the later years. Use of fertilisers is indispensable for agricultural development in the world. India is no exception. It has played and will continue to play pivotal role in enhancing agricultural production. Food security has always been the national priority since independence to rapidly growing population. It has been documented that 50% increase in food grain production is on account of fertiliser use. Food grain production showed an increase of 4.48 times from 1966-67 to 2023-24 and outpaced the growth of population which went up by 3.2 times during the period. The consumption of total fertilizer products is about 65 million MT annually in India & share of urea consumption is more than 50%.

Emerging soil health degradation threats pose serious concerns. Abysmally low soil organic carbon (<0.5%), emerging multi-nutrient deficiencies (N, P, K, S, Zn, B and Fe), low nutrient use efficiencies (30-50% Nitrogen, 15-25% Phosphorus, 50-60% Potash, 8-12% Sulphur and 2-5% micronutrients) and declining fertiliser responses (<5 kg /kg NPK) are major issues threatening growth in agriculture production on sustainable basis. Absolutely low nitrogen use efficiency in India is responsible for unutilized nitrogen contributing to accelerated greenhouse gas emissions (climate change), groundwater contamination with nitrates, eutrophication, soil acidification, etc.

Nanotechnology and its associated applications have gained tremendous importance in the present age, as this branch of technology has greatly revolutionised modern science; moreover, this field of science is growing at an exponential rate. Nanomaterials are particles and materials that are handled at a nanoscale range of 1–100 nm. The novel properties of nanomaterials, higher nutrient efficiency. Therefore, the development and application of smart agricultural practices using advanced, cutting-edge technologies are urgently needed for sustainable agriculture. This includes the need for the development of new and innovative fertilizers that have a very high efficiency and negligible disadvantage. Nanotechnology offers a promising pathway to sustainable and efficient agriculture by enhancing fertilizer performance, reducing environmental impact, and improving soil health, ultimately contributing to increased crop yields and food security. The efficiency of nutrient use can be improved by applying nanofertilizers that utilise the unique properties of nanoparticles. Nanofertilizers can be produced by adding nutrients individually or in combination to the

adsorbents with nano-dimensions. A new technology involves the encapsulation of fertilizers within nanoparticles, which can be accomplished as nanoscale particles or emulsions; it can be coated with a thin polymer layer; or it can be enclosed within nanoporous materials.

Development of Nano Urea in India

Nano urea research started in India from 2017 firstly by Indian Farmers Fertilisers Cooperative Ltd (IFFCO) at their NBRC, Kalol & Govt of India granted permission on 24th February, 2021 in FCO by Gazette Notification & commercial production started in June, 2021 with 4 % Nitrogen (w/v) nano urea which is known as first generation Nano Urea & later on 15th April, 2024 developed improved version of nano urea that is known as Second generation i.e Nano Urea plus & content 20% nitrogen (w/v) & commercial production started by 9th May, 2024 details are as under (Table 1 & Diagram .1)

Table 1: DETAILS JOURNY OF NANO UREA FERTILISERS IN INDIA

SN	YEAR	DETAILS JOURNY OF NANO UREA FERTILISERS IN INDIA FIRST BY IFFCO
1	2017	Research & Commercial Exploration of Nano Fertilisers
2	2018	Initiation of Lab Scale Trials
3	2019	Inauguration of NBRC, Kalol & Research & Field trials undertaken across 11,000 locations
4	Feb., 2021	24th February- Nano Urea - Liquid Notified under FCO & permission for commercial production granted (1 ST Generation)
5	June, 2021	Commercial Dispatches of Nano Urea (Liquid) initiated from Kalol, Gandhinagar Plant.
6	28th May 2022	Hon'ble Prime Minister of India inaugurated First IFFCO's Nano Urea (Liquid) plant at Kalol (Gujarat)
7	15th April 2024	FCO Notification for Nano Urea Liquid 16 (20 % Nitrogen w/v)
8	9th May 2024	Commercial Production & Dispatch of Nano Urea Liquid Plus (20 % Nitrogen w/v) (2 nd Generation)



Diagram 1. NANO UREA & NANO UREA PLUS 500ml BOTTLES OF IFFCO

Nano Urea is a nanotechnology-based fertiliser that is used to provide a sufficient amount of nitrogen to plants. This revolutionary fertiliser came across as a sustainable option for farmers and is helping them achieve better crop yields while taking a step towards smart agriculture. The main issue with traditional urea is that it leads to environmental pollution if used frequently and excessively. This form of urea fertiliser has high water solubility that can lead to issues like leaching, de-nitrification, and volatilization losses where as nano urea applied directly on leaves by foliar spray & due to the nano particles size is smaller than stomato of leaves so the more & easily absorptions taken by leaves (Diagram-2).

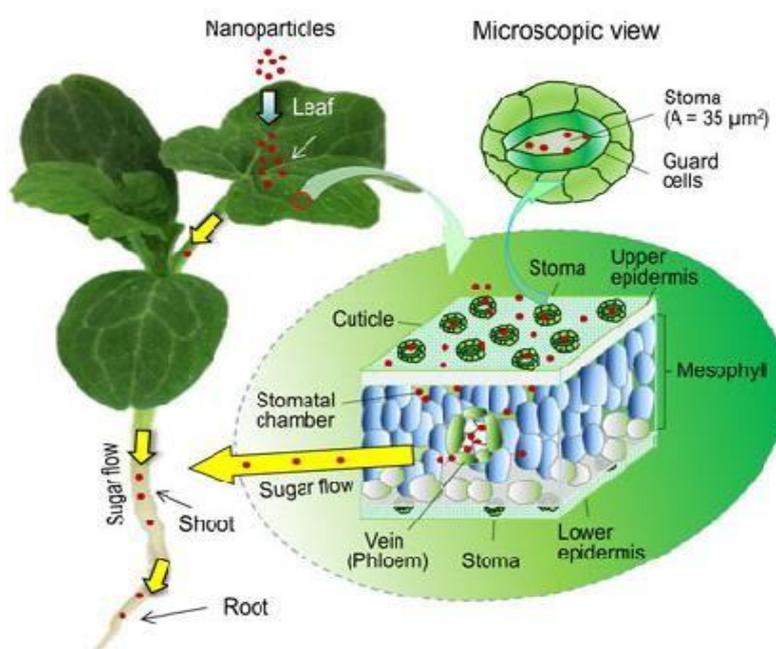


Diagram-2. Source: Wang et al. 2013

Liquid nano urea, on the other hand, is applied as a foliar spray. Here's a more detailed look at the benefits of nano urea fertilisers:

1. Enhanced Nutrient Uptake:

- Nanoparticles have a high surface area-to-volume ratio, allowing them to deliver a greater amount of nutrients to crops than traditional fertilizers.
- This improved nutrient availability, especially for micronutrients like zinc, can lead to significant gains in crop yields.

2. Controlled Nutrient Release:

- Nano Urea -fertilizer can be designed to release nutrients slowly and precisely, ensuring plants have access to them when needed, which reduces nutrient loss and waste.
- This controlled release minimizes the risk of nutrient leaching into water bodies, which can cause environmental pollution and harm aquatic ecosystems.

3. Increased Efficiency and Reduced Waste:

- Nano Urea utilised for nitrogen nutrient needs optimizing their growth and minimizing the amount of fertilizer required & that have the efficiency of more than 82 %.
- This reduces the environmental impact of fertilizer use, such as the release of greenhouse gases and water pollution from excess fertilizer runoff.

4. Sustainable and Eco-Friendly:

- This approach reduces the need for granular urea, which can have negative impacts on soil and water quality & acts as sustainable fertiliser.

5. Improved Soil Health:

- Nano Urea application given directly to plant by foliar spray so that there is residual effect on soil & in other words it improve soil structure, water retention, and microbial activity, leading to healthier and more productive soils.
- This can also increase the soil's ability to sequester carbon, further contributing to a more sustainable agricultural system.
- A liquid fertilizer containing nanoparticles like nano urea, which can be sprayed directly on to crops for faster absorption and reduced nutrient loss.

6. Improving the crop quality of products

- The nano urea nature in plant acts a slow release of nitrogen which imparts the proper growth & development of plant which ultimately improving the quality of products.

7. Reduce attack of Insects & pest on plant

- The application of nano urea is foliar spray so the nano urea utilised by plant as slow release & precisely , so the plant leaves are leathery and less infestation of insect & pests.

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AGROFORESTRY AND CARBON SEQUESTRATION: CASE STUDIES, INTERNATIONAL COMMITMENTS AND POLICY IMPLICATIONS

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Introduction

Nair (1979) defined Agroforestry as a “land use system that integrate trees, crops and animals in a way that is scientifically sound, ecologically desirable, practically feasible and socially acceptable to the farmers”. It provides numerous advantages such as improved soil fertility, conservation of biodiversity, and carbon sequestration. The potential of agroforestry systems as carbon sink varies depending upon the species composition, age, geographic location, local climatic factors, and management regimes. Carbon sequestration involves capturing and storing atmospheric carbon dioxide in plants and soils, which helps to alleviate the greenhouse effect and reduce global warming (Montagnini & Nair, 2004). Agroforestry systems play a crucial role in carbon sequestration by promoting the accumulation of carbon in both aboveground biomass and soil organic matter (Jose, 2009). Trees in agroforestry systems act as carbon sinks, absorbing CO₂ during photosynthesis and storing it in woody biomass and roots (Nair, 2012). Moreover, agroforestry enhances soil carbon sequestration through the deposition of organic matter from tree litter and root exudates, as well as the improvement of soil structure and microbial activity (Montagnini & Nair, 2004). The mechanisms underlying carbon sequestration in agroforestry systems are multifaceted and vary depending on factors such as tree species, management practices, and environmental conditions (Jose, 2009). Trees in agroforestry systems accumulate biomass through photosynthesis, resulting in the sequestration of carbon in woody tissues such as stems, branches, and leaves (Jose, 2009). The C sequestration potential of tropical agroforestry systems: 12 and 228 Mg/ha with a median value of 95 Mg/ha. In India, average sequestration potential in agroforestry: 25t C per ha over 96 million ha. In terms of potential, currently area under agroforestry worldwide is 1,023 M ha, and areas that could be brought under agroforestry have been estimated to be 630 M ha of unproductive croplands and grasslands that could be converted to agroforestry worldwide, with the potential to sequester 586 Gg C/yr by 2040.

Agroforestry enhances soil organic carbon storage by increasing inputs of organic matter from tree litter, root exudates, and decomposing residues, which are incorporated into the soil matrix through biological processes (Nair, 2012). The extensive root systems of trees in agroforestry systems contribute to carbon sequestration by stabilizing soil structure, increasing soil organic matter content, and facilitating nutrient cycling (Montagnini & Nair, 2004). Agroforestry offers several advantages for climate change mitigation beyond carbon sequestration. It promotes biodiversity by providing habitat and resources for a variety of plant and animal species, thereby enhancing ecosystem resilience to climate change impacts (Saha, 2020). The presence of trees in agroforestry systems reduces soil erosion, improves water infiltration, and enhances soil moisture retention, mitigating the adverse effects of climate-related phenomena such as droughts and floods (Jose, 2009). Agroforestry diversifies land use and provides multiple sources of income for farmers,

reducing reliance on monoculture crops and enhancing agricultural sustainability (Montagnini & Nair, 2004). Despite the numerous benefits of agroforestry for carbon sequestration and climate change mitigation, several challenges hinder its widespread adoption. Limited awareness and knowledge about agroforestry practices among farmers and policymakers pose a barrier to adoption, highlighting the need for capacity building and extension services (Nair, 2012). Inadequate policy incentives and institutional support systems hinder the scaling up of agroforestry initiatives, underscoring the importance of supportive policy frameworks and investment incentives (Saha, 2020). Issues related to land tenure and ownership rights often impede the establishment of agroforestry systems, necessitating reforms in land tenure policies and community engagement mechanisms (Jose, 2009).

CARBON STOCKS OF SOME PROMINENT LAND USE SYSTEMS IN THE TROPICS			
S. No.	Land Use Practice	Duration (Years)	Carbon Stock (Mg C ha⁻¹)
1	Pastures	4-12	27 to 31
2	Cropping after slash and burn	2	39 to 52
3	Sun – Coffee monoculture	-	52
4	Javanese homegarden	-	63
5	Simple agroforests	15	65 to 92
6	Shade – coffee mixture	-	82
7	Secondary forests, Sumatra	30	86
8	Panama teak plantation	20	120.2
9	Sumatran homegarden	13.4	55.8 to 162.7
10	Natural Forests, Indonesia	120	500

Agroforestry holds significant promise as a sustainable approach to climate change mitigation through carbon sequestration and ecosystem restoration. By harnessing the synergies between agriculture and forestry, agroforestry systems offer a multifaceted solution to address the challenges of climate change while promoting environmental sustainability and rural livelihoods. To unlock the full potential of agroforestry for climate change mitigation, concerted efforts are needed to overcome barriers, enhance knowledge dissemination, and create enabling policy environments that prioritize agroforestry as a key strategy for sustainable development.

Case Study 1: Traditional Agroforestry Practices in Kerala, India

In Kerala, traditional agroforestry practices namely “Homegardens” have been integral to rural livelihoods and ecosystem sustainability for centuries. In Kerala, these home gardens are called as “Puriyada Krishi”. These home gardens serve as microcosms of agroforestry, embodying principles of biodiversity conservation, carbon sequestration, and sustainable land use (Sundaram, 2016).

A study conducted in the Palakkad district of Kerala by Veena *et al.*, (2020) assessed the carbon sequestration potential of home gardens compared to conventional agricultural systems. The findings revealed that gardens sequester significantly higher amounts of carbon in both aboveground biomass and soil organic matter, attributed to the diverse tree species and organic farming practices employed. Moreover, the presence of trees in these gardens enhanced soil fertility, water retention, and microclimate regulation, leading to increased agricultural productivity and resilience to climate variability. The success of traditional agroforestry practices in Kerala underscores the importance of indigenous knowledge systems and community-led approaches to sustainable land management. By recognizing and supporting traditional agroforestry systems,

policymakers can harness local expertise and promote environmentally sound practices that contribute to climate change mitigation and rural development.

Carbon sequestration potential of agroforestry systems in different regions of India

- Strip plantations in Haryana – 15.5 t/ha during first rotation of 5 years and 4 months
- About 69 % of soil carbon equivalent to 8.5 to 12.5 t C/ha has been locked in the soils of agroforestry systems in the Indo-Gangetic plains
- Poplar based AF systems in Saharanpur and Yamuna Nagar store 27 – 32 t/ha C in boundary plantation and 66 – 83 t/ha C in Agri silviculture system at a rotation period of 7 years
- Studies from Punjab suggest that a rotation of 7 years, Poplar timber carbon content could be 23.57 t/ha
- A bamboo-based AF system in the Barak Valley of Assam sequesters C at a mean rate of 1.32 Mg/ha/yr
- In tropical homegardens of Kerala, average above ground standing stocks of C ranged from 16 to 36 Mg/ha
- Carbon stock of Eucalyptus clones on the boundary plantation of Khammam district of Telangana is estimated to be 45.3 t C/ha

Case Study 2: Teak-Based Agroforestry Systems in Madhya Pradesh, India

In the central Indian state of Madhya Pradesh, teak (*Tectona grandis*) based agroforestry systems have emerged as a viable strategy for carbon sequestration and rural livelihood enhancement. Teak, a fast-growing hardwood species valued for its timber, is intercropped with agricultural crops such as pulses, oilseeds, and vegetables in smallholder farms across the state (Bundela *et al.*, 2019).

A study conducted by Bundela *et al.* (2019) assessed the carbon sequestration potential of teak-based agroforestry systems in Madhya Pradesh using field measurements and remote sensing techniques. The results indicated that these systems sequester substantial amounts of carbon in both aboveground biomass and soil organic matter, with carbon stocks comparable to natural forests. Moreover, the integration of teak with agricultural crops provided additional income opportunities for farmers and reduced pressure on natural forests for timber extraction. The success of teak-based agroforestry systems in Madhya Pradesh highlights the potential of tree-crop integration as a climate-smart agriculture approach. By promoting agroforestry with economically valuable tree species like teak, policymakers can incentivize carbon sequestration, biodiversity conservation, and rural development, contributing to India's climate change mitigation efforts and sustainable development goals.

International Commitments & Policy Implications

1. Paris Agreement and India's Nationally Determined Contributions (NDCs)

India is a signatory to the Paris Agreement and has ratified the accord, demonstrating its commitment to global climate action. In its Nationally Determined Contributions (NDCs), India has outlined ambitious targets for mitigating greenhouse gas emissions and enhancing carbon sinks. Agroforestry is recognized as a key strategy in India's NDCs, with the government pledging to increase forest and tree cover to sequester additional carbon and enhance ecosystem resilience (Government of India, 2020).

2. Bonn Challenge and AFR100

India has endorsed the Bonn Challenge, a global initiative to restore degraded and deforested land, committing to restore 13 million hectares of land by 2020 and an additional 8 million hectares by 2030. Agroforestry plays a significant role in India's efforts to achieve the Bonn Challenge targets, with the government implementing large-scale afforestation and reforestation programs that

integrate trees with agricultural crops. Moreover, India's participation in the African Forest Landscape Restoration Initiative (AFR100) underscores its commitment to sharing expertise and best practices in agroforestry and landscape restoration with other countries (Government of India, 2020).

Policy Implications

1. National Agroforestry Policy

India has formulated a National Agroforestry Policy to promote the adoption of agroforestry practices across agricultural landscapes. The policy aims to incentivize farmers to establish agroforestry systems by providing financial support, technical assistance, and access to markets for agroforestry products. Moreover, the policy emphasizes the integration of agroforestry into national development agendas, recognizing its potential to enhance carbon sequestration, improve rural livelihoods, and mitigate climate change impacts (Government of India, 2014).

2. Forest Rights Act and Community Participation

India's Forest Rights Act (2006) recognizes the rights of forest-dwelling communities, including indigenous peoples and other traditional forest dwellers, to access and manage forest resources. The act empowers communities to engage in agroforestry and sustainable forest management practices, thereby promoting community-based conservation and livelihood enhancement. By ensuring the participation of local communities in agroforestry initiatives, policymakers can foster stewardship of forest resources and enhance the sustainability of agroforestry interventions (Ministry of Tribal Affairs, 2006).

3. Climate-Smart Agriculture Initiatives

India has launched various climate-smart agriculture initiatives that promote agroforestry as a climate change adaptation and mitigation strategy. Programs such as the National Mission for Sustainable Agriculture (NMSA) and the Pradhan Mantri Krishi Sinchayee Yojana (PMKSY) emphasize the adoption of agroforestry practices to enhance soil health, water conservation, and resilience to climate variability. By mainstreaming agroforestry into climate-smart agriculture initiatives, policymakers can leverage synergies between agriculture, forestry, and climate change mitigation to achieve multiple development objectives (Government of India, 2020).

Conclusion

Agroforestry stands as a promising solution for carbon sequestration and climate change mitigation in India. Aligned with international commitments such as the Paris Agreement and the Bonn Challenge, India has taken significant policy strides, including the formulation of the National Agroforestry Policy and the recognition of community rights through the Forest Rights Act. By integrating agroforestry into climate-smart agriculture initiatives and leveraging local expertise, India can harness the potential of agroforestry to enhance carbon sinks, improve rural livelihoods, and build resilience to climate change, thus contributing to sustainable development goals and global climate action.

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ANT: AN ECOLOGICAL WONDER

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Abstract

The branch of science which deals with the study of ants is called as "Myrmecology". Ant species hold desirable characters unshared by other beneficials. Ants comprise one-third of all insect biomass and equals biomass of humans. They have wide range of abundance, stability of populations, their feeding habits influence to stay in many habitats. Ants (Hymenoptera; Formicidae) are found between 110 to 130 million years, and are eusocial insects and are widely regarded as "ecosystem engineers" because of their nest construction and contributions to changes in the biological, chemical and physical properties of the soil around their nests. Ants are important in bio-control, pollination, bioturbation, seed dispersal, soil improvement, nutrient cycling, bioindication. Ants directly impact the dead wood environment primarily through nesting in standing dead trees, etc., contributing to the physical breakdown of woody materials and called saproxylic insects. Foraging and nesting by ants below ground in soils and in live tree canopies has been thoroughly documented and these are often considered primary domains of ants.

Keywords: *Ant, ecology, beneficial, ecosystem*

Introduction

Ants (Hymenoptera: Formicidae) are eusocial insects and widely regarded as 'Ecosystem engineers' because of their nest construction and contributions to changes in the biological, chemical and physical properties of the soil around their nests. An ant colony is the basic unit around which ants organize their life cycle. The typical colony consists of one or more egg-laying queens, numerous sterile females (workers and soldiers). Seasonally many winged sexual males and females in the colony. Ants are one of the most diverse groups of social insects with an estimated 25,000 species which is a dominant taxon of the terrestrial fauna accounting for large percentage of the total animal biomass and occupy almost every continent. Moreover, ants are the world's strongest creatures in relation to their size as individual ants can carry 50 times of their own body weight (Griffiths *et al.*, 2017). Ants are important in bio-control, pollination, bioturbation, seed dispersal, soil improvement, nutrient cycling and bio-indication.

Ants are the dominant arthropod in most terrestrial environments. Ants can excavate a significant amount of soil from deeper layers and deposit it on the soil surface. Microbial activity may be substantially higher in the nest than in the surrounding soil because of a surplus of available nutrients, suitable moisture and temperature. Ants are important part of the food web because they eat plants, animals, fruits, grains, seeds, dead and decaying materials and also provide food for many different organisms. Many ant species are very sensitive to the habitat structure and microclimate fluctuations and strongly react to environmental alterations (Saha and Das, 2020).

Ants are the most successful and intelligent arthropod due to their social life form. Ants are successful due to their ability to live symbiotically with other organisms. It maintains ecological balance by increasing the soil fertility and maintaining soil properties. The real contribution of ants

to nutrient recycling, decomposition of organic matter, soil structuring, bioturbation, pollination, pest suppression and limiting disease development on plants, is an additional asset supporting their use as biological control agents in agro-ecosystems. Beside their importance in nature, they are nuisance for the farmers while carrying agricultural operations.

Ant as Ecological Engineer

1. In Food web: Ants are important part of the food web. As they eat plants, animals, fruits, grains, seeds dead and decaying material. Ants are near the bottom of the food chain and near the outside of the food web, so there are lots of animals that like to eat them. Ants are very effective predators which thrive in huge numbers. They're also very territorial and very aggressive, defending their resources and territory against other predators. Despite being predators, their presence can also lead to an increase in density and diversity of other animal groups. Thus, play important role in transferring energy from one trophic level to another.

2. As Pollinators: Ants are the most abundant animals consuming the sugar-rich nectar from extra floral nectaries, which are commonly located in leaves and occur mainly in tropical plants. They have recently been recognized as effective yeast vectors between flowers. Different ant species carry both ascomycetous and basidiomycetous yeasts that could metabolize nectar sugars (de Vega and Herrera, 2013). So, it is possible that with their continuous visits to flowers, they further alter nectar chemical composition consistent with their role as yeast transporters. Quantity of yeast deposited flowers have more fructose, glucose and less sucrose which attracts many more pollinators, thus, ants indirectly helps in plant-pollinator mutualism. In case of dwarf owl's clover - *Triphysaria pusilla* (Orobanchaceae) flowers hardly qualify as an attractive display, which largely depends on ants for pollination and the number and weight of coffee berries are same between trees pollinated by insects (bees, wasps, butterflies) or by ants.

3. Bioturbation agents/ecosystem engineers: Bioturbation which involves the mixing and accumulation of soils from different sources and horizon and the galleries mined by ants when building nests. It excavates large amount of soil from different horizons thus causes aeration in soil. Ants considered as a better component of the soil fauna that displaces most soil after earthworms. It plays substantial role in organic matter decomposition by transporting organic material from surroundings into the nests as food or organic material. The ant environment may also support species with fast root growth or long rhizomes (Dostal *et al.*, 2005).

4. On soil physical properties: Building of tunnels and chambers both above and below ground increases soil macro porosity and reduces bulk density. For example, bulk density in nests of *Pogonomyrmex occidentalis* was 1.47g/cm³ compared with 1.54g/cm³ in the surrounding soil (Frouz and Jilkova, 2008). Reduced bulk density may increase soil aeration and permeability of soil for water, speeding up mineralization takes place. Nests increase not only soil macro porosity but also organic matter content, which may increase water repellency at low soil moisture. The macro porosity in nests of imported fire ants can increase drainage, quickly bringing water to deeper soil layers and ensuring higher moisture in soil below the nest while reducing moisture in the nest compared with that in the surrounding soil.

5. On soil chemical properties: Many studies have reported significant differences in chemical soil properties between ant nests and the surrounding soil. In general, ants shift nest pH toward a neutral value (Frouz *et al.*, 2003) i.e., ants increase pH in acidic soils and decrease it in basic soils. Nutrient accumulation in a particular species is affected by properties of the surrounding soil and

the material used for building the nest. The effect of ants on soil pH and other chemical properties can increase as the nest ages, and the effect is greater near the nest periphery. Changes in N and P content in ant nests have often been reported. There are interspecific differences in the accumulation of macronutrients in the nests as seen from measurements of several species in one locality. On the other hand, nutrient accumulation in a particular species is affected by properties of the surrounding soil and the material used for building the nest. Besides affecting the total content of nutrients in nests, ants also affect the availability of nutrients. In addition to accumulating easily decomposable substances in the nest, they can also increase total P content in the nest was accompanied by a substantial increase in the available forms of P.

6. As Predators: Predatory ants can be two types *viz.*, Generalist predators and Specialist predators. Generalist ants (scavenger ant) those ant species prey on small organisms including eggs and pupae. Specialist ants are those ants which prey certain insects only. The majority of ants are broadly omnivorous and highly opportunistic in their diet, taking prey or plant-derived food resources according to colony needs (e.g., high demand for protein during reproductive phases) or simply because of availability. Ants may be an especially important limiting factor for termite populations as they are a specific predator on termite kings and queens in dead wood, preying upon alates (winged reproductives) during mating flights and during the founding stage when termite colonies are especially vulnerable, due to small colony size. For example, species from the genus *Aphaenogaster* often are among the most common dead wood nesting species in eastern US forests and termites from the genus *Reticulitermes* are an important part of their diet (King *et al.* 2013). The entire Ponerinae genus *Centromyrmex* (15 species) is termitophagous and has morphological adaptations, including short, stout legs apparently adapted to moving through narrow, tubular termite galleries, making this a conspicuous, if not especially common, group of termite predators from the New and Old-World tropics.

7. In seed dispersal: The seed dispersal by ants called 'Myrmecochory'. Ants seed dissemination ability helps to reduce competition between plants for space. *Rhytidoponera metallica* and *Melophorus bruneus* were important seed dispersers in non-disturbed and disturbed zones, respectively. In general, large bodied ants tended to move more seeds to longer distances in disturbed zones and whereas, smaller bodied ant species carried out a greater percentage of short distance dispersals (<1m of seed) (Palfi *et al.*, 2017).

8. As bioindicators: Ants plays a key role in ecosystem assessment e.g. - *Monomorium salomonis* – closely associated with high irrigation and fertilizer used soil (Yeo *et al.*, 2011). The ant species richness and abundance declined with increasing SO₂ except the *Camponotus* sp.

9. Role of ants in suppressing pathogens and pests: Some ants produce natural antibiotic chemicals to defend themselves against fungi and bacteria. out of 30 plant species that were commonly inhabited by some kind of ant, 18 showed a decrease in the effects of pathogens. These included reduced bacterial load and increased germination rates enjoyed by plants inhabited by ants compared with plants of the same species that did not host ants. Ants secrete antibiotics from glands in the body and also host colonies of bacteria on their legs and body that secrete antibiotic properties which helps in curing of plant diseases due to pheromones (Offenberg *et al.*, 2019).

Conclusion

Ants are small organisms, intelligent and advanced social system in their lives. They play the role of predator which decreases other organisms in their niche and also act as prey for larger organisms

which contribute in the food web. They maintain ecological balance by increasing the soil fertility and maintaining soil properties and also play a major role in nutrient cycling, decomposition of organic matter, bioturbation and suppression of pathogens and pests.

Thus, by understanding more about ants, it can be utilised in various ways in agriculture and allied sectors by characterization of pheromones and antibiotics secreted by the ants at molecular level. It can also act as biological buffers. Further research can be carried out to utilise ants as biocontrol agents to fight against multiple resistant pathogens. Moreover, indirect chemical effects of ants on arthropod pests and disease can also be studied for sustainable management.

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THE VIRUS PROBLEM IN APPLES: WHAT EVERY GROWER SHOULD KNOW

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Abstract

Apple is one of the most widely cultivated fruit crops in temperate regions, valued for its appealing flavor, nutritional content, and numerous health benefits. Viral diseases pose a significant threat to apple production and fruit quality, prompting urgent efforts to find effective solutions. One of the most critical strategies is the cultivation of virus-free propagules, which supports the healthy propagation of high-quality apple cultivars and helps reduce the spread and impact of viral infections in orchards.

Keywords: Apple, Viral diseases, Detection, Management.

Introduction

Apple (*Malus × domestica* Borkh.), a member of the *Rosaceae* family which includes over 300 species, is a highly profitable crop cultivated widely across temperate regions of the world. Often referred to as the “King of temperate fruits,” it is highly valued for its exceptional flavor and strong global demand, making it a key export commodity in many countries. Viral infections in apple trees represent a significant obstacle to the sustainable and robust growth of apple orchards. The most common and widely distributed viruses include *Apple chlorotic leaf spot virus* (ACLSV), *Apple stem grooving virus* (ASGV), *Apple stem pitting virus* (ASPV) and *Apple mosaic virus* (ApMV). These viruses often cause latent infections, with ACLSV being the most frequent in old apple cultivars. Viroids, such as *Apple scar skin viroid* (ASSVd) also infects apple trees.

Apple Chlorotic Leaf Spot Virus

ACLSV causes economic losses in orchards by affecting fruit quality, yield and tree health. Infection is generally latent in apple crop but sometimes symptoms include, bark splitting or severe fruit deformations, chlorotic rings, russet rings on fruits, graft incompatibility, bud necrosis, chlorotic leaf spots and leaf curling. In extreme situations, it causes early fruit drop (Manzoor *et al.*, 2025).

Apple stem grooving virus

The virus affects the tree’s vascular system and impairs the movement of nutrients and water, negatively impacting fruit development and size. ASGV infections often remain latent in many cultivars and induce various symptoms like stem grooving, deformation at graft unions, interveinal mottling, leaf deformation, and chlorosis). ASGV is transmitted through seeds and mechanical means, and to date, no natural vectors have been identified.

Apple stem pitting virus

ASPV produce symptoms like xylem pits, epinasty, decline, vein yellowing, leaf red mottling, pear necrotic mark, or fruit stony pits. The virus is transmitted by grafting and infected propagative material. No vector has been reported to transmit this virus.

Apple mosaic virus

ApMV is characterized by the appearance of bright pale-yellow chlorotic spots and mosaic patterns on the leaves of infected apple trees. Chlorosis typically develops along the leaf veins, creating a reticulated pattern, or manifests as large, irregular chlorotic areas between the veins. The disease does not produce visible symptoms on branches or fruits. Sometimes, mosaic symptoms remain masked, particularly at temperatures rise above 27°C, and can be mistaken for nutrient deficiencies or herbicide damage. ApMV affects tree growth and overall quality with yield losses 30% -50%. Also, Apple necrotic mosaic virus (ApNMV) has been reported in association with Apple mosaic virus (ApMV), producing symptoms resembling those caused by ApMV. The mode of transmission of virus is infected root stocks or grafting and pruning tools.

Diagnosis

Early detection of plant viral diseases is crucial to prevent economic losses. Common methods include visual inspection for symptoms, use of indicator plants, and serological techniques like ELISA for detecting viral proteins. While molecular tools include PCR, RT-PCR, and LAMP to identify viral nucleic acids with high accuracy. Modern advancements include next-generation sequencing (NGS) for detecting multiple viruses simultaneously and CRISPR/Cas technology for precise diagnosis (Nabi *et al.*, 2022).

Management

Apple virus management relies on the isolation, sanitation, quarantine, and certification of planting material. Additional strategies include meristem tissue culture, cross-protection, and chemical therapies. To improve the management of viral diseases new technologies like genome editing and RNA interference (RNAi) can be used. Plant viruses are challenging to control using curative approaches due to their obligate intracellular nature. Therefore, effective management of virus-induced plant diseases requires strategies that prioritize prevention and risk reduction. National authorities implement quarantine laws in accordance with international phytosanitary standards, which are crucial in avoiding the spread of novel infections into unaffected areas (Kanapiya *et al.*, 2024).

Conclusion

Viral diseases pose a critical challenge across global agriculture, substantially impacting both the productivity and quality of major crop productions. Understanding the nature of these viruses, their modes of transmission, and their effects on apple trees is crucial for developing effective management strategies and ensuring the sustainability of apple production. Furthermore, having access to sensitive and high-throughput virus detection methods is essential for developing effective, risk-reducing approaches for managing plant viruses.

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BEES AND BEYOND: UNLOCKING THE POWER OF DIVERSE POLLINATORS IN FRUIT CROPS

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Abstract

Pollinators are essential for sustaining global fruit production, contributing to the food security, biodiversity and economic resilience. While honeybees are the most well-known pollinators, a diverse range of species, including native bees, butterflies, birds, bats and beetles also play critical roles in pollinating the fruit crops. These pollinators influence fruit set, yield, genetic diversity and the quality of fruits. Honeybees contribute to pollinating approximately 66% of the world's 1,500 crop species, but other pollinators, such as bumblebees, butterflies and hummingbirds, can be even more effective for specific crops. Despite their importance, pollinator populations are increasingly threatened by habitat loss, pesticide use and climate change. Addressing these challenges through habitat restoration, reduced pesticide uses and supporting native pollinator species is crucial for maintaining a sustainable and resilient agricultural ecosystem. By safeguarding pollinators, we can enhance fruit production and protect global food security.

Keywords: Pollinators, Fruit Crops, Honeybees, Agricultural Sustainability

Introduction

Pollination is a crucial process that sustains agriculture, particularly in fruit crop production. From the sweet apples in our orchards to the vibrant strawberries in our gardens, pollinators ensure that we have the diverse fruits we enjoy. While the honeybee is the most famous pollinator, the true story of pollination is far more complex. The diversity of pollinators, from bees to birds, bats and beetles and explores their essential roles in fruit production.

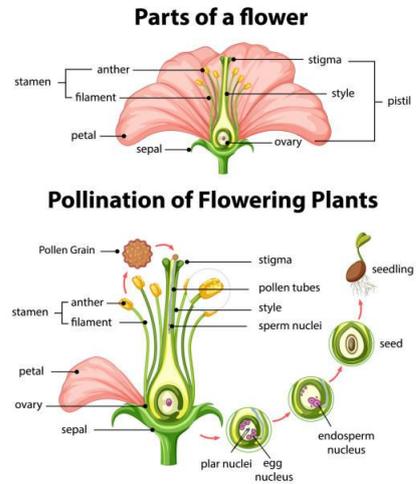
The Unseen Heroes of Fruit Crops

Many people are familiar with honeybees and their importance to agriculture. However, a vast number of other creatures contribute to the pollination of fruit crops. By expanding our understanding of these diverse pollinators, we unlock new opportunities to enhance productivity, biodiversity, and sustainability in our agricultural systems. As global challenges like climate change and pesticide use put increasing pressure on the pollinator populations, it is more crucial than ever to appreciate and protect this ecological network. Roles of bees often go unnoticed, yet these unsung pollinators also including butterflies, beetles, flies, birds, and bats play vital roles in

maintaining healthy ecosystems. Fostering habitats for these species can significantly boost pollination efficiency and crop resilience

The science of pollination and its role in fruit crops

Pollination is the process by which pollen is transferred from anther of a flower to the stigma, resulting in fertilization and formation of the fruit. While some plants are self-pollinating, the vast majority depend on external pollinators to carry out pollination. The characteristics of flowers such as their type, shape, colour, odour, nectar amount and structure are crucial in determining which pollinators visit them. These traits, known as pollination syndromes, can help predict which pollinator species will ensure successful pollination. These pollinators include not just bees, but a variety of insects, birds and even mammals. Pollination directly influences fruit yield, quality and genetic diversity. Without pollination, our global food systems would face severe challenges. Insects alone contribute 15–30% of global food production, with honeybees serving as the primary pollinators for nearly 66% of the world's 1,500 crop species.



Pollination's Role in Fruit Production

- **Enhanced Fruit Set and Yield:** Pollinators significantly increase the quantity and quality of fruit by enabling cross-pollination, which leads to better fertilization.
- **Genetic Diversity:** Cross-pollination allows for greater genetic variation in fruit crops, leading to healthier, more resilient plants.
- **Fruit Characteristics:** The shape, size and flavour of fruits can all be impacted by the pollinators involved in their fertilization.



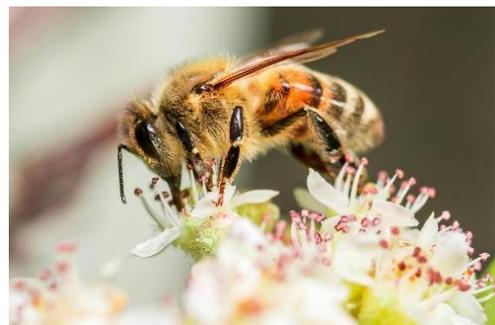
Bees: The primary pollinators in fruit agriculture

The Power of Honeybees (*Apis mellifera*)

Honeybees are perhaps the most iconic pollinators. Managed hives are used commercially to pollinate crops such as apples, almonds, blueberries and berries. Their ability to travel distances and their large colony size make them invaluable for large-scale fruit production. As pollinators, they improve not just the quantity but also the uniformity and quality of fruit.

Native bees: a vital alternative

While honeybees are widely used, native bees, such as bumblebees and stingless bees, play an equally crucial role in pollination. In many cases, native bees are more efficient than honeybees due to their specific adaptations to certain plants. Bumblebees, for instance, are more effective in pollinating blueberries, leading to higher fruit set. These native species are also more resilient to environmental stress, making them essential in areas where honeybee populations are declining. As in Florida, native bumblebees have been found to be 60%



more effective than honeybees in pollinating blueberries, leading to improved fruit set and higher quality yields.

Beyond bees: Exploring the diversity of pollinators in fruit crops

Pollination is a multi-faceted process that involves a range of creatures beyond bees. A comparative study found that bumblebees pollinate twice as many flowers per minute as honeybees, leading to a 20-30% higher fruit set in crops like blueberries. Understanding this diversity can lead to more sustainable, resilient and productive agricultural systems.



Butterflies and Moths (Lepidoptera): Butterflies and moths are highly effective at pollinating crops like guava, citrus and mango. Their long proboscis allows them to access nectar deep within tubular flowers. Moths, which are typically nocturnal, are especially important for pollinating night-blooming fruits like some varieties of mango.

Birds (Ornithophily): Birds, particularly hummingbirds and sunbirds, play a crucial role in pollinating crops with tubular flowers. They are vital for the pollination of crops like papaya, passion fruit and bananas. Hummingbirds, for instance, are excellent pollinators because of their constant movement from flower to flower, transferring pollen along the way. Birds also improve cross-pollination for certain tropical fruits that may not attract insects due to their specific flower structure.

Bats (Chiropterophily): Bats are key pollinators in tropical regions, where they pollinate fruit crops such as durian, bananas, and figs. Their nocturnal activity makes them particularly useful for flowers that bloom in the evening or at night. Bats are large size and efficient foraging behaviour enable them to pollinate a variety of crops over large distances, making them a critical component of the pollination network in many regions.

Beetles (Cantharophily): Beetles are among the oldest known pollinators, especially for ancient flowering plants such as magnolia and custard apples (*Annona spp.*). These insects are often attracted to fruits that have strong scents and large flowers. While beetles may not be as efficient as bees, they are important contributors to the pollination of certain fruit species, especially in tropical and sub-tropical environments.



Flies (Myophily and Sapromyophily): Flies, including houseflies and hoverflies, are often underappreciated pollinators but are crucial for crops like cacao, avocado and mango. These insects are attracted to the scent of fermenting fruit or decaying matter, making them effective pollinators for certain species that bees may overlook. They are particularly important in environments where bees are less abundant or absent.

Wasps and Other Insects: Wasps, particularly fig wasps, engage in mutualistic relationships with fig trees, where the wasp pollinates the tree in exchange for a place to lay its eggs. Other insects, including ants and small mammals, also contribute to pollination, especially in more specialized



ecosystems. Their interactions with plants highlight the complexity of the pollination process and the importance of maintaining diverse pollinator species in agricultural landscapes.

The economic and ecological impact of pollinators in fruit crops

Pollination services are inevitable to fruit production globally, with studies estimating that pollinators contribute billions of dollars to the global agricultural economy. Without them, many crops would experience reduced yields, lower quality and diminished genetic diversity.

Economic Contributions

Pollinators are responsible for enhancing the productivity of major fruit crops, from apples and blueberries to avocados and citrus. The global economy benefits not only from direct pollination services but also from improved fruit quality, which increases market demand and profitability. Pollination is not just an ecological necessity; it is an economic powerhouse. Studies estimate that insect pollination contributes approximately \$14.6 billion annually to the U.S. economy and £440 million per year in the UK. Although managed honeybees play a role, research suggests that wild pollinators, including bumblebees and solitary bees, perform most of the pollination in many crops.

Ecological Benefits

Pollinators help sustain biodiversity within agricultural ecosystems. By facilitating the reproduction of a wide variety of plants, they contribute to ecosystem services such as soil health, pest control and water regulation. Their presence ensures that agricultural landscapes remain resilient and adaptable to climate change.

Threats to pollinators and their impact on fruit production

Despite their importance, pollinators are facing numerous threats that are undermining their populations and by extension, the crops they help pollinate.

Declining Bee Populations

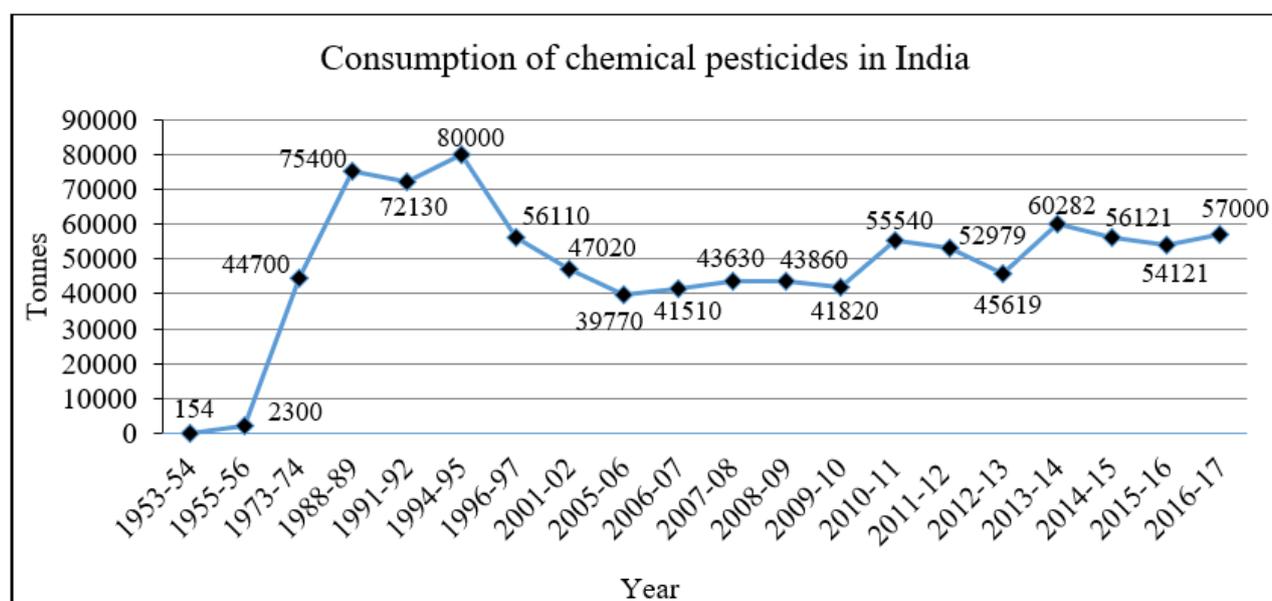
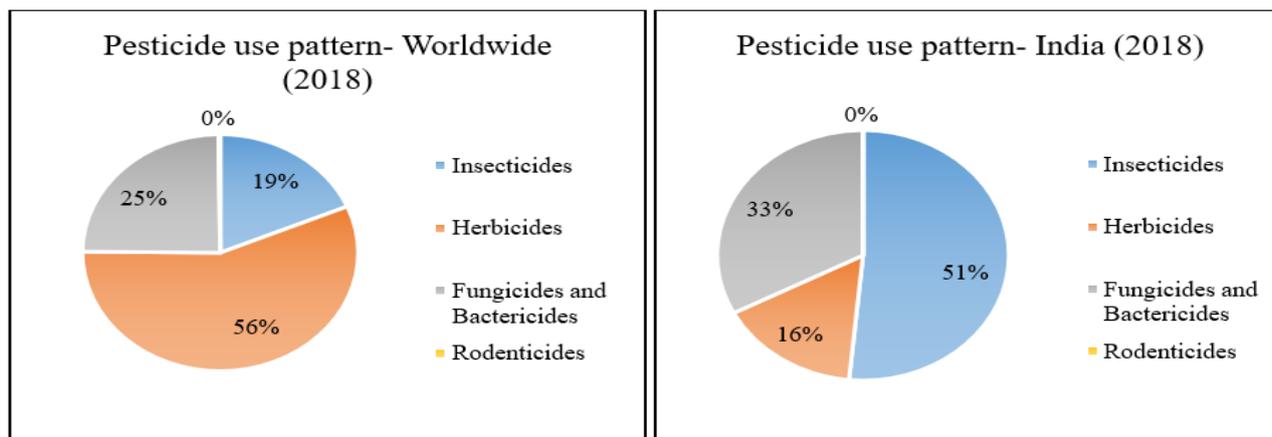
The decline in honeybee populations, largely due to colony collapse disorder (CCD), pesticides, and disease, has become a significant concern for fruit farmers. This decline affects crop yields and threatens food security, particularly for crops heavily depend on bee pollination. In the UK, apple yields declined by 40% in regions experiencing significant pollinator losses, illustrating the direct impact of declining bee populations on fruit production.

Habitat Loss and Fragmentation

The destruction of natural habitats through urbanization and agricultural expansion is driving pollinators away. Many pollinators depend on diverse landscapes with a mix of wildflowers, trees and water sources for nurturing and nesting.

Pesticide Use and Chemical Exposure

Pesticides, particularly neonicotinoids are harmful to pollinators, affecting their ability to forage, navigate, and reproduce. Reducing pesticide use is essential to preserving pollinator populations and ensuring the long-term viability of fruit crops. According to a study by the European Food Safety Authority (EFSA), neonicotinoid pesticides have been shown to cause a 50% decline in honeybee populations in regions where these chemicals are heavily used and One of the most dramatic cases of pollinator decline comes from southwest China, where excessive pesticide use and habitat destruction have led to the eradication of wild bees. Farmers in these regions are now forced to hand-pollinate their apple and pear orchards using paintbrushes and pots of pollen, with children climbing trees to reach the highest blossoms. This labour-intensive method is economically unfeasible on a large scale and highlights the devastating consequences of pollinator decline.



Source: Pragati Nayak & Hitesh Solanki, 2021

Climate Change

Climate change disrupts the synchronicity between plants and pollinators. As temperatures rise and rainfall patterns change, flowers may bloom at times when their pollinators are not active, leading to reduced pollination efficiency & climate change is altering the timing of flowering in many fruit crops, which disrupts the synchronization between flowering plants and their pollinators, leading to reduced pollination efficiency. And as per a meta-analysis of 88 studies found that a 2°C rise in temperature could lead to a 40% decline in key pollinators' activity, threatening crops such as mangoes, coffee, and cherries (IPCC, 2023).

Strategies to enhance and conserve pollinators in fruit agriculture

To ensure a sustainable future for fruit crops and the ecosystems that support them, it is critical to implement conservation strategies that protect and promote pollinators.

Habitat Restoration and Agroforestry

Creating pollinator-friendly habitats within and around orchards is essential. Planting wildflower strips, maintain hedgerows, and restoring natural habitats can provide critical resources for pollinators and also Studies in Europe and North America have shown that simple interventions,

such as planting strips of wildflowers and preserving patches of forest, can significantly enhance pollinator populations. These natural habitats provide essential nesting sites and food resources, supporting a diverse pollinator community while simultaneously reducing the need for chemical pesticides.

Reducing Pesticide Use

Farmers can adopt Integrated Pest Management (IPM) strategies to minimize pesticide use. When pesticides are necessary, using them in ways that limit harm to pollinators can protect these vital species.

Supporting Native Pollinators

In Australia, the introduction of 'bee hotels' and native flowering plants in orchards has increased pollination efficiency by 30%, leading to higher fruit yields that means encouraging the conservation of native pollinator species, such as bumblebees and solitary bees, is essential (Providing nesting sites and promoting diversity in agricultural landscapes helps create a more resilient pollination network).

Policy and Global Initiatives

Governments and international organizations must invest in pollinator conservation through legislation, funding for research, and the promotion of sustainable agricultural practices that benefit both farmers and pollinators.

Conclusion

Pollinators are indispensable to fruit crop production, contributing significantly to global food security, biodiversity, and economic sustainability. While honeybees are the most recognized pollinators, the role of native bees, butterflies, birds, bats, and beetles cannot be overlooked. However, pollinator populations are under severe threat due to habitat loss, pesticide exposure, and climate change, posing serious risks to fruit agriculture. Addressing these challenges requires a multi-pronged approach, including pollinator-friendly farming practices, reduced pesticide use, habitat restoration, and policy interventions. By prioritizing pollinator conservation, we can safeguard food production, enhance fruit quality, and ensure long-term agricultural sustainability. Protecting pollinators is not just an ecological necessity but also an economic imperative for the future of global fruit production.

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SMART FARMING FOR A BETTER HARVEST: HOW IOT AND CLOUD TECHNOLOGIES ARE TRANSFORMING AGRICULTURE IN INDIA

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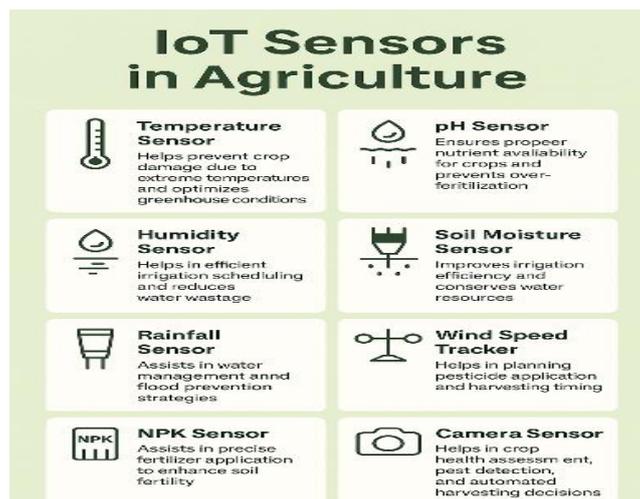
Abstract

As climate volatility and resource scarcity intensify, Indian farmers are embracing a technological revolution: precision agriculture. By integrating IoT (Internet of Things) devices and cloud computing, farmers can now monitor crops in real time, automate irrigation, and make data-driven decisions to boost yields and sustainability. This article delves into how tools like soil sensors, drones, and AI-powered analytics empower farmers to tackle water shortages, reduce input costs, and improve crop health. We also address challenges like rural connectivity and affordability while spotlighting government initiatives bridging the digital divide. Practical examples, infographics, and visual guides simplify complex concepts, making this a must-read for farmers eager to adopt smart farming.

Keywords: Real time, IoT, soil sensors, crop health.

Introduction: The Digital Shift in Indian Agriculture

Agriculture sustains over 50% of India's population, yet farmers grapple with unpredictable monsoons, depleting groundwater, and rising fertilizer prices. Traditional methods, reliant on guesswork and manual labor, are increasingly unsustainable. Enter precision agriculture—a tech-driven approach using IoT and cloud platforms to collect field data, analyze trends, and automate tasks. For instance, soil moisture sensors can prevent over-irrigation, while AI models predict pest outbreaks days in advance. This shift isn't just for large farms; scalable solutions are helping smallholders in states like Punjab and Maharashtra thrive.



IoT in Action: The Farmer's Digital Toolkit

IoT devices act as the "eyes, ears, and hands" of modern farms, enabling 24/7 monitoring and automated responses. Key technologies include:

- 1) **Soil Moisture Sensors:** Buried in fields, these devices send real-time alerts to farmers' phones via SMS or apps. For example, a farmer can reduce water use by 25% after installing sensors linked to a drip irrigation system.
- 2) **Drones and Satellites:** Equipped with multispectral cameras, drones capture detailed crop health maps. Early detection of yellowing leaves or pest infestations allows targeted interventions, saving crops before damage spreads.
- 3) **Automated Irrigation Systems:** These systems adjust water flow based on soil data, weather forecasts, and crop type. Studies by the FAO show such systems can cut water waste by 30%.
- 4) **Livestock Wearables:** GPS collars and health monitors track cattle location, body temperature, and feeding patterns, reducing losses from disease or theft.

Cloud Computing: Turning Data into Decisions

Cloud platforms serve as the "brain" of smart farming, storing vast datasets and generating actionable insights. For example:

- 1) **Weather Analytics:** Hyper-local forecasts help farmers time sowing and harvesting, avoiding unseasonal rains.
- 2) **Crop Health Dashboards:** Simple color-coded charts show nutrient deficiencies or disease risks, even for non-tech-savvy users.
- 3) **Resource Optimization:** Machine learning algorithms analyze soil reports to recommend fertilizer quantities per acre, reducing overuse.

A cooperative in Maharashtra adopted a cloud-based app to share soil health reports with 500 smallholders. By switching to organic manure based on these insights, farmers cut fertilizer costs by 20% and improved soil pH levels within two seasons.

Tangible Benefits for Indian Farmers

- 1) **Higher Yields:** Data-driven practices increase output by 15–20%.
- 2) **Cost Savings:** Precision application of inputs reduces waste—e.g., laser-guided tractor and implements save 10% on seeds and fuel.
- 3) **Sustainability:** Aligns with India's National Mission for Sustainable Agriculture by minimizing chemical runoff and water use.
- 4) **Time Efficiency:** Remote monitoring via apps saves labor, allowing farmers to focus on secondary income sources like dairy or poultry.

Overcoming Challenges: Connectivity, Costs, and Security

While promising, smart farming faces hurdles:

- 1) **Spotty Internet:** Rural areas often lack 4G or broadband. **Solution:** Government schemes like BharatNet are expanding fiber-optic networks to 250,000 villages.
- 2) **High Initial Costs:** IoT devices may seem unaffordable. **Solution:** Subsidies under the Digital Agriculture Mission offer sensors and drones at 50% subsidies.
- 3) **Data Security:** Weak passwords or unencrypted apps risk cyberattacks. **Solution:** Training programs by Krishi Vigyan Kendras teach farmers to secure devices.

The Future: 5G, AI, and Blockchain

Emerging technologies promise further transformation:

- 1) 5G Networks: Enable real-time drone monitoring and faster data uploads from remote fields.
- 2) AI Advisories: Apps like Kisan Suvidha offer voice-based advice in regional languages, helping farmers choose drought-resistant crops.
- 3) Blockchain: Transparent supply chains let farmers bypass middlemen, selling directly to buyers at premium prices.

Conclusion: Embracing the Smart Farming Revolution

IoT and cloud technologies are no longer luxuries—they are essential tools for India’s agrarian future. By adopting precision agriculture, farmers can mitigate climate risks, reduce costs, and secure higher profits. With government subsidies, training programs, and affordable devices, even smallholders can join this digital wave. As the proverb goes, where the sun cannot reach, the farmer’s innovation will. The time to act is now.

ORGANIC AND NATURAL FARMING FOR A GREENER & SUSTAINABLE TOMORROW SUSTAINABLE FARMING PRACTICES : BALANCING PROFITABILITY AND ENVIRONMENTAL HEALTH

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Introduction

Soil health is pivotal for sustainable and regenerative agriculture. It emerges as a holistic approach that encourages diverse plant communities and microorganisms that enhance soil structure, nutrient cycling, water retention, etc, through the application of various soil health-based inputs. It boosts farmer's income while restoring soil fertility. Soil health management through natural farming emerges as a unifying solution.

Concepts of Organic and Natural Farming

According to the definition by the United States Department of Agriculture (USDA), the term organic farming refers to "a system which avoids and largely excludes the use of artificial inputs" (e.g., fertilizers, pesticides, hormones, feed additives, etc.). Natural farming is an ecological farming approach where the farming system works with the natural biodiversity, encouraging the soil's biological activity and managing the complexity of living organisms, both plant and animal, to thrive along with the food production system. Natural Farming improves soil fertility and environmental health as well as helps in the reduction of greenhouse gas emissions, and also promises the enhancement of farmer's income.

Modern Agriculture to Organic and Natural Farming

The environment and people are impacted differently by modern agriculture compared to organic and natural farming methods. Increased greenhouse gas emissions, land erosion, water pollution, and human health are significant consequences of traditional agriculture. Organic farming reduces carbon emissions, improves soil health, and restores natural ecosystems for cleaner water and air, all while avoiding hazardous pesticide residues. At the same time, organic farming produces healthy, abundant food by solely relying on natural principles such as biodiversity and composting.

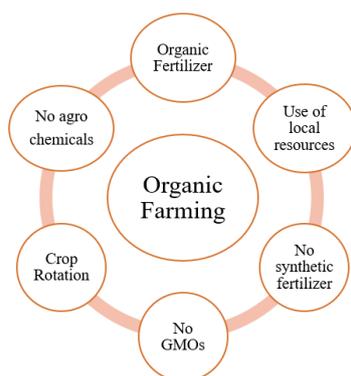


Fig1: The main practices of Organic farming

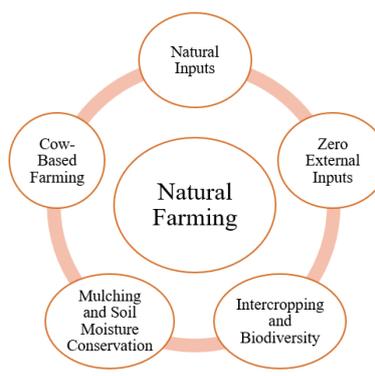


Fig2: The main practices of Natural farming

Present need: Natural Farming

A report from NITI Aayog says that natural farming is the need of the hour as the cost of production of food grains has escalated drastically due to increased cost of agricultural inputs, viz., chemical fertilizers, pesticides, fungicides, and herbicides. Besides, it is the best way to restore degraded lands, enhance soil health, conserve water, and reduce the usage of chemical inputs while improving the nutritional quality of crops and supporting the local food systems.

Importance of Natural Farming

After the COVID pandemic, health matters a lot, and consumers are going back to old remedies and natural methods, and are more aware of what they eat. Hence, today's focus is on providing comprehensive, sustainable solutions to humankind through complementary farming practices, namely natural farming.

Natural farming seeks to address food hunger, farmer distress, health issues brought on by pesticide and fertilizer residue in food and water, global warming, climate change, and natural disasters. Additionally, it may provide jobs, which would stop young people from rural areas from moving. As the name implies, natural farming is the art, practice, and science of working with nature to accomplish much more with less.

Natural Farming and its scope

Natural farming, with its emphasis on sustainable and eco-friendly practices, holds significant promise for the future of agriculture.

1. Environmental scope

- **Soil health:** Natural farming techniques improve the soil health through enhancing the organic matter in soil, promoting microbial activity and improving soil structure.
- **Biodiversity:** By avoiding monocultures and chemicals, natural farming supports a diverse range of flora and fauna, thus maintaining a diversified agro-ecosystem.
- **Water conservation:** With practices like mulching and no-till farming, there's a significant reduction in water evaporation, promoting efficient water use.
- **Reduced pollution:** Non-addition of synthetic chemicals in natural farming helps in maintaining the purity of water bodies including groundwater without pollution

2. Economic scope

- **Cost efficiency:** Natural farming often requires very fewer external inputs, thus reducing the production costs towards fertilizers, pesticides, other chemicals and machinery.
- **Premium pricing:** Produce cultivated through natural farming can often fetch higher prices in niche markets and among health-conscious consumers.

3. Health scope

- **Nutrient-rich produce:** Crops grown in naturally nourished soil often possess a richer nutrient profile.
- **Reduced chemical residues:** The avoidance of synthetic chemicals means lesser residues on food, approaching safer consumption.

4. Social Scope

- **Empowered communities:** As natural farming leans on traditional knowledge, it empowers local communities and encourages collaborative efforts.
- **Connection with nature:** Natural farming promotes a deepened connection between farmers, consumers, and the earth, fostering respect for the environment.

Conclusion:

In agriculture, sustainable agriculture balances three considerations, namely, environmental, social, and economic. Organic agriculture has been proven to be beneficial in the long run, in view of a steady increase in yield and profitability. Natural farming is an agricultural revolution that will not only improve crop yields at minimum costs but will also help to increase farmer's incomes. To save the world from a food crisis in the future, natural farming is considered to be an ideal solution. It is the right time to bring about this transition from chemical farming to natural farming by creating vast awareness among the farming community through several schemes and capacity-building programmes.

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SEWAGE SILVICULTURE: A SUSTAINABLE APPROACH FOR WASTEWATER MANAGEMENT AND BIOMASS PRODUCTION

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Abstract

Sewage silviculture represents an emerging interdisciplinary approach combining wastewater treatment and forest management. Sewage silviculture is the practice of utilizing treated sewage sludge as a fertilizer in forest plantations and offers a sustainable approach to wastewater management while enhancing biomass production. By utilizing treated sewage effluent and biosolids in forest plantations, this method offers a sustainable solution to environmental challenges such as water scarcity, soil degradation and deforestation. This article explores the scientific principles, ecological benefits, practical applications and potential risks associated with sewage silviculture, emphasizing its role in circular economy and sustainable development. However, considerations regarding heavy metal accumulation and biodiversity changes are essential to ensure environmental safety.

Keywords: Sewage silviculture, wastewater, irrigation, biosolids, sustainable forestry

Introduction

The disposal of sewage sludge is a growing environmental concern. Traditional methods like landfilling and incineration pose environmental risks and are often economically unfeasible. Sewage silviculture presents an alternative by applying treated sewage sludge to forest plantations, thereby recycling nutrients and improving soil fertility. This practice not only addresses waste management challenges but also contributes to afforestation efforts and biomass production. Municipal wastewater treatment facilities (WWTPs) have grown significantly globally, particularly in developed nations where they are subject to particular regulations. One significant organic residue produced in large quantities in WWTPs is sewage sludge (SS). Compared to the nitrogen and phosphorus found in mineral fertilizer, the sludge's delayed release into the soil solution allows crops to better utilize the nitrogen and phosphorus, which are mostly in organic form. Nevertheless, sewage sludge has varying N and P contents. The optimal fertility management of sludge-treated soils is therefore a complex topic for farmers and wastewater treatment plant managers particularly in tropical regions where soils are highly weathered and infertile (Junior *et al.*, 2017). The biological processes in soil, including the number, activity, and variety of the soil microbial population as well as the activity of enzymes involved in biotransformation, are adversely affected by heavy metals.

Regulating the use of sewage sludge in agriculture has therefore been done through legal compliances. The detrimental effects, rate, and timing of the application of sewage sludge remain unknown to farmers. Because sewage sludge is made from municipal garbage, the type of waste it contains will determine how much heavy metal it contains. The size, activity and variety of the soil microbial community as well as the activity of enzymes involved in biotransformation are among the biological processes in soil that are adversely affected by heavy metals.

Effect of sewage sludge:

- **Effect of sewage sludge on Tree Growth and Biomass Production:**

Application of sewage sludge resulted in significant increases in tree growth and biomass production. For instance, *Eucalyptus* plantations treated with sewage sludge on infertile tropical soils showed enhanced wood volume compared to those receiving only mineral fertilizers. Similarly, *Larix decidua* plantations exhibited improved radial and height growth following sludge application. According to De Lira *et al.*, the application of sewage sludge significantly increased the production of eucalypt biomass, and there was a substantial correlation between tree growth and the improvement of the top soil layer's nitrogen, phosphorus, and base cation concentrations. When sludge is applied to rapidly expanding plantation woods, the nutrients that are exported during harvest are returned to the ecosystem. It is feasible to replenish soil nutrient stocks during the forest plants development cycle thanks to the sludge's gradual release of nutrients.

- **Effect of sewage sludge and inorganic fertilizers on soil nutrients build up in soil:**

Sewage sludge significantly increased the mobility of nitrogen to plants. Sludge-treated soil's other plant component N was influenced by the enhanced availability of soil N and free-living microorganisms brought about by N₂ fixation. Inorganic nitrogen, which comes from sewage sludge and soil organic carbon, increased the amount of nitrogen that plants could access. According to the findings, applying sewage sludge to rice fields can significantly reduce the amount of nitrogen fertilizer needed (Azam *et al.*, 2003).

- **Effect of sewage sludge Soil Fertility Enhancement:**

Sewage sludge application improved soil fertility by increasing organic matter and essential nutrients. Studies reported elevated levels of nitrogen and phosphorus in the soil, contributing to better tree nutrition and growth. The strong nutrient content of sewage sludge, a byproduct of wastewater treatment, makes it a promising fertilizer. Its capacity to improve soil fertility by supplying vital macronutrients like potassium (K), phosphorus (P) and nitrogen (N) makes it especially prized. Phosphorus promotes root development and energy transmission, potassium supports a number of physiological processes vital to plant health, and nitrogen is essential for vegetative growth (Kumar *et al.*, 2017). Sludge promotes soil aeration by boosting worm and microorganism populations and root growth. Thus, increased biomass yields and better soil quality are the ultimate results (Mohamed *et al.*, 2018).

Effect of sewage sludge on Heavy Metal Accumulation:

While sewage sludge contains trace amounts of heavy metals, studies indicated that, with controlled application rates, heavy metal concentrations in soil and plant tissues remained within safe limits. For example, research on *Larix decidua* plantations found no significant increase in heavy metal content in needles and sporocarps following sludge application. Nonetheless, continuous monitoring is essential to prevent potential bioaccumulation over time. There are two methods to control the pollution of heavy metals in sewage sludge: namely, heavy metals removal, and heavy metals immobilization (Zhang *et al.*, 2020).

Biodiversity Impacts:

Increased understory vegetation diversity was observed in areas treated with sewage sludge. The number of species in amended plots increased by 80% compared to control plots, suggesting that sludge application can enhance habitat heterogeneity. However, the relative abundance of new species was low, indicating minimal shifts in ecosystem composition.

Environmental Considerations:

Proper treatment of sewage sludge before application is crucial to mitigate risks associated with pathogens and organic pollutants. Techniques such as thermal drying and phytoremediation using aquatic plants like *Lemna* and *Eichhornia* have been employed to improve sludge quality. Additionally, adherence to recommended application rates and regulatory guidelines ensures environmental safety.

Future Prospects and Recommendations

- Development of strict treatment protocols and monitoring systems.
- Public education to improve acceptance of sewage reuse.
- Policy integration and support from environmental and forestry departments.
- Research on long-term ecological impacts and tree species selection.

Conclusion

Sewage silviculture offers a viable solution for integrating wastewater management with forest biomass production. The application of treated sewage sludge enhances tree growth and soil fertility while contributing to sustainable waste recycling. However, careful management is necessary to address potential risks related to heavy metal accumulation and biodiversity changes. Ongoing research and monitoring are essential to optimize practices and ensure long-term environmental sustainability. Even though sewage sludge has many benefits for soil chemical properties, agro morphological traits, and crop yields in a variety of species, proper heavy metal screening is required for all kinds of SS, soil and food products. The majority of the data in this study were below legal limits, however agricultural goods showed concerning values for human food intake in developing nations, which could have serious health consequences (in the case of soil and SS). The use of SS and biosolids in these situations necessitates strict regulations and regulatory control in order to prevent contamination of agricultural soils. Additionally, there must be tight regulations on the use of this bioresource as a soil amendment and in food production. Because so much of this residue is produced globally, adding value to waste products is essential, and biosolids are among the most important.

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LIFE IN A COAL MINING VILLAGES: STRUGGLES AND VULNERABILITY IN THE SHADOW OF MINING

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Abstract

The mining sector plays a vital role in both national and local economic development. It creates employment opportunities, boosts income levels, supports infrastructure growth, and earns valuable foreign exchange for the country. However, while mining brings prosperity on one hand, it also casts a shadow especially at the local level. If not properly managed, mining activities can lead to serious environmental degradation and social disruptions, which may ultimately outweigh the economic benefits. This article sheds light on how mining impacts various components of the Asset Pentagon *i.e.*, human, natural, financial, social, and physical capital which together form the foundation of rural well-being. Further, this paper suggests the need to strengthen and reform government programmes in mining regions to specifically reduce the vulnerability of affected communities.

Key words: Mining sector, Impact and vulnerability

Introduction

Rising populations boost demand for goods, prompting governments to promote industries. Minerals support industrial growth and jobs, especially in developing countries like India (Mishra, 2009). Coal remains the main global fuel, with industries relying on it for growth. Coal will likely dominate energy use through 2050 (IPCC, 2007). Coal mining significantly boosts India's economy through royalties, taxes, and export earnings of around US\$184.4 million. It provides crucial jobs in rural areas and supports livelihoods. The sector also promotes regional development in mineral-rich states like Jharkhand, Chhattisgarh, Odisha, Telangana, and West Bengal, where employment options are limited. Telangana, India's youngest state, is rich in natural resources, especially coal, which has long powered industries and homes across the nation. Deep beneath its red soil lies the heart of India's energy supply mines operated by the Singareni Collieries Company Limited (SCCL), a public-sector coal mining giant with a legacy over a century old. One such prominent coal belt lies in the Bhupalapally district, a region that has come to symbolize both the economic promise and the human cost of coal mining. In the shadows of these vast coalfields lies few villages, which are found in the vicinity of 5 km from Core Zone of Singareni coal mining project, Kakatiya Khani, Open Cast II. Although mining companies provide certain benefits, large-scale mining operations often cause significant environmental destruction, which adversely affects the livelihoods of local communities (Githiria and Onifade, 2020). These communities are frequently displaced from their land, resulting in the loss of homes, agricultural fields, and forest-based sources of income. The

surrounding environment deteriorates daily due to air and water pollution. Moreover, the benefits from mining are sometimes unevenly distributed and may fail to adequately compensate for the loss of traditional livelihoods, environmental damage, and cultural disruption (Githiria and Onifade, 2020; Boldy et al., 2021). These impacts contribute to the degradation of ecosystem services that local populations depend on for their survival and well-being (Adetayo, 2012). Building on these challenges, this paper attempts to explore how various livelihood capitals natural, human, social, financial, and physical are being affected in coal mining-impacted villages. From degraded land and polluted water to disrupted education, weakened community bonds, and inadequate infrastructure, these pressures deepen vulnerability and threaten long-term rural sustainability and well-being.

The Crumbling Pillars: How Livelihood Capitals Are Affected in mining villages

1. Natural Capital – The Decline of Nature's Gift

Once rich with fertile soils and sufficient groundwater, the land in mining villages were its lifeline. But with expanding mine pits and dust emissions:

- Groundwater levels have dropped drastically due to heavy mining.
- Air and water pollution have made the environment unfit for cultivation or even safe living.
- The productivity of soils has been affected leads to the decrease in the yield of the crops particularly Paddy, Cotton and Chilli.

"The red soil that once bore golden harvests is now layered in coal dust and despair."

2. Human Capital – Erosion of Skills and Health

The people of villages who lives with in the vicinity of 5 km were skilled farmers, with generational knowledge of crop cycles, seed treatment, and soil care. But:

- Their traditional farming knowledge is now unused and devalued.
- Lack of proper healthcare has led to rising respiratory illnesses and fatigue, especially among children and elders.
- Educational attainment is low, and many youths remain unemployed due to lack of technical skills or access to new opportunities.

"Displaced from their lands, their knowledge too was uprooted—forgotten like the old wells they once dug."

3. Social Capital – Broken Bonds, Disrupted Networks

The village's strong social fabric – families helping each other during harvest, sharing water, celebrating festivals – is fraying:

- Migration and economic stress have led to social fragmentation.
- Trust in institutions like SCCL is low, due to unmet promises.
- Traditional village panchayats are losing influence, making it harder for collective action.

"The bonds that held this village together now feel thinner than the air they breathe."

4. Financial Capital – Compensation Without Continuity

Though villagers received compensation under the LARR Act, 2013, many say:

- The money was quickly exhausted due to inflation, medical expenses, and lack of financial literacy.
- No alternative income sources were provided; no proper livelihood rehabilitation plan.

- Daily wage work is seasonal, irregular, and insecure and migration of labour was quite common in mine effected villages

"Money came, but it came with silence—no training, no plan, and no future."

5. Physical Capital – Uneven Development

While mining brought roads and electricity, it also:

- Destroyed traditional irrigation canals, storage tanks, and village ponds.
- Housing is poorly maintained, and public infrastructure remains underdeveloped.
- Health facilities and schools are far, especially for elderly and women.

"Infrastructure arrived—but only as far as the coal trucks needed to go."

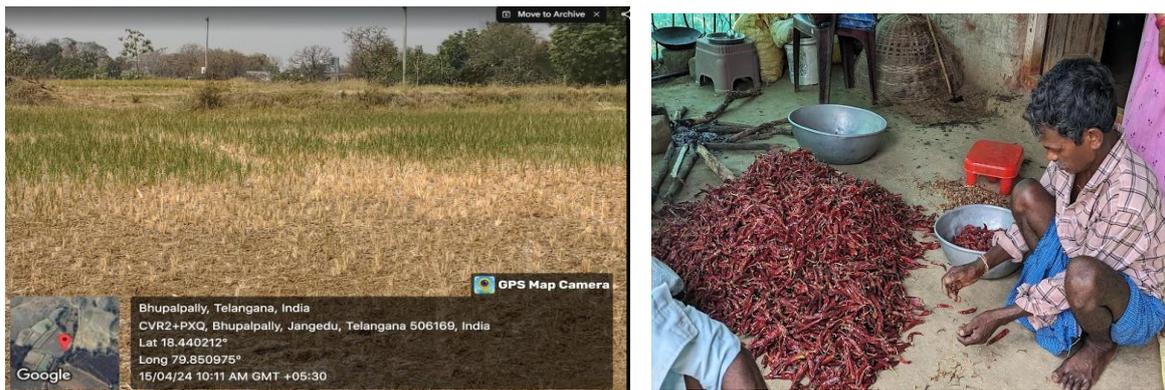


Fig.01: The crop failure of paddy and lack of yield in chilli crop



Fig.02: Enumerator with project effected people and Coal dust causing pollution

Suggestions to Improve Livelihoods in Coal Mining-Affected Villages

1. Natural Capital

- **Soil Rejuvenation Programs:** Promote bio-remediation and reforestation on degraded lands,
- **Water Resource Management:** Construct check dams and recharge pits to improve groundwater levels.
- **Promote Climate-resilient Crops:** Encourage cultivation of low-water crops like millets, pulses.
- The **Haritha Haram** programme, launched in 2015, should be reinforced and continued to restore green cover. Similarly, **Mission Bhagiratha** must function effectively to ensure the consistent supply of safe drinking water to all communities.

2. Human Capital

- **Skill Development Programs:** Offer training in tailoring, plumbing, electrical work, or digital literacy.
- **Health Camps & Clinics:** Regular health check-ups and mobile clinics to treat respiratory and skin illnesses.
- **Education Support:** Scholarships or study centers for mining-affected children.

3. Social Capital

- **Strengthening SHGs & Farmer Clubs:** Empower local women and farmers to negotiate better prices and gain market access.
- **Village Grievance Redressal Forums:** So, people can voice their problems directly to SCCL or district authorities.

4. Physical Capital

- **Infrastructure Development:** Build better roads, solar-powered street lights, and community halls.

5. Financial Capital

- **Access to Credit & Insurance:** Link farmers and labourers with rural banks for crop insurance and low-interest loans.
- **Compensation Monitoring:** Ensure timely and fair compensation distribution under LARR Act and that it includes land-for-land options.

Conclusion

Coal mining in affected villages leads to environmental degradation, loss of livelihoods, health issues, and inadequate infrastructure. To address these, it is essential to promote soil rejuvenation, water resource management, and climate-resilient crops. Additionally, skill development, health camps, and education support should be prioritized. Strengthening social capital through SHGs and grievance redressal forums, along with infrastructure development, such as roads and community halls, will help empower communities and improve their overall well-being, ensuring sustainable livelihoods.

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CORDYCEPS: THE SUPERMUSHROOM THAT BOOSTS ENERGY, ENDURANCE, AND IMMUNITY

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Abstract

Cordyceps is an entomopathogenic mushroom, also known as insect mushroom, caterpillar fungus and Himalayan gold. Cordycepin, cordycepic acid and other chemical compounds of *Cordyceps* exhibits antibacterial, antioxidant, anti-inflammatory, and anticancer activities, and has shown potential in treating various diseases, including cancer, diabetes, and cardiovascular disorders which makes it a most valuable medicinal mushroom for helping in maintaining good health.

Keywords: *Cordyceps*, Medicinal mushroom, Cordycepin

Introduction

Cordyceps, a caterpillar fungus which parasitizes moth caterpillar of species *Hepialis aromoricanis* by its mycelia and forms stroma or fruiting body. Club shape mycelia is the head of *Cordyceps sinensis* and the caterpillar moth forms its body. It is known as Yartsa Gunbu in Tibeto-Bhutanese, words originating from Tibetan language, meaning Yartsa: grass in summer and Gunbu: worm in winter, it is called “Dong chong Xia cao” in China and “Tockukaso” in Japan, words meaning the same. *Cordyceps* sp. have a variety of traits, including pharmacological qualities, which have drawn interest from traditional Chinese medicine (TMC) since the 1990s. Of them, *C. sinensis* is the most researched and used. *Cordyceps* thrive in high mountains that are 3,600–4,000 meters above sea level and therefore found throughout North America, Europe, and Asia, primarily in China, Japan, Nepal, Bhutan, Vietnam, Korea, and Thailand. It is mostly found in subalpine areas of India, including the higher-altitude Garhwal and Kumaun Himalayas.

Bioactive compounds

As this mushroom is only found in cohabitation with the larvae of an insect, and it is this unique growth parameter that has made it challenging to produce *Cordyceps* spp. in artificial cultivation. Further, *Cordyceps* naturally grows in rarefied atmosphere, mineral-rich soil, and low temperature resulting in a unique profile of secondary metabolites possessing interesting biological potential for medical exploitation. *Cordyceps* contains significant amounts of bioactive substances, including proteins, fats, essential amino acids, volatile oils, carotenoids, phenolic compounds, flavonoids, minerals (Fe, Ca, Mg, Ni, Sr, Na, Ti, Pi, Se, Mn, Zn, Al, Si, K, Cr, Ga, V, and Zr), vitamins (B1, B2, B12, E, and K), and different kinds of carbohydrates, including monosaccharides, oligosaccharides, polysaccharides, sterols, nucleosides, and so forth. Various bioactive substances, including proteins, lipids, carbohydrates, phenolic compounds, polysaccharides, cordycepin, exopolysaccharides, adenosine, proteoglycans, terpenoids, amphinol, steroids, ergosterol, lectins, and more, have been found to be present in *cordyceps*. Of these, cordycepin is the primary active ingredient that has been examined the most for both its potential as a nutraceutical and its potential as a medicine (Mehra *et al.*, 2017).

Importance

A number of pharmaceutical and nutraceutical preparations derived from *Cordyceps* dry powder are marketed and contend to protect hepatic and renal functions, enhance intracellular energy exchange, boost oxygenation and natural endurance, eliminate toxins from the body, regulate blood glucose levels and lipid profiles, slow down the aging process, promote the body's natural energy metabolism, and support the immune system.

Regular use of *C. sinensis* can help prevent infections, colds, and flues because it can reduce phlegm and cough, asthma, and bronchial disorders. Lung fibrosis has been treated with *Cordyceps* spp. and because of these factors, especially in individuals with severe acute respiratory syndrome (SARS). Also, Cordycepin, has shown potential against the SARS-CoV-2 strain of COVID-19 (Shweta *et al.*, 2023).

Immunomodulators are the compounds that helps to control the immune system of the body. There are various compounds in *Cordyceps* spp. that possesses the immunomodulatory activity by manipulating intracellular signaling of cells (Das *et al.*, 2021). Immuno-stimulatory action of a compound is explicated by its competence to trigger the immune system of the living organism through inducing or activating its components. Polysaccharides from *C. militaris* (L.) exhibits immunostimulatory activity by inducing phagocytosis, NO production, respiratory burst, and secretion of IL-1 β and IL-2 (from macrophages).

Cordyceps species have been used to treat weakness and exhaustion, reducing altitude sickness symptoms and providing a surge of vitality. Regular use of *C. sinensis* prevents infections, colds, and flues since it can reduce cough and phlegm, asthma, and bronchial disorders. Competitive athletes therefore used it to alleviate weakness and exhaustion while increasing their stamina and vitality. It is widely known for improving athletes' physical stamina by boosting ATP synthesis.

Cordyceps exhibits broad-spectrum antibacterial properties and can inhibit cell growth, trigger cell apoptosis, and offers antioxidant, anticancer, and anti-inflammatory effects. *Cordyceps sinensis* is regarded as highly valuable in medicine and is used in the treatment of various conditions, including cancer, diabetes, lung diseases, heart disorders, sexual dysfunction, and kidney-related ailments. The polysaccharide from *C. sinensis* prevents the growth of tumors by altering the antioxidative activity of the host by increasing the brain and liver's SOD activity. It also reduces blood sugar levels therefore, helps in controlling diabetes.

Conclusion

With the potential to treat a number of deadly illnesses, cordyceps and its bioactive constituents and metabolites are like gold mines. In addition to helping to generate enough amounts of bioactive compounds such as cordycepin and cordycepic acid, developing a new technique for cordyceps that can cultivate species other than *Cordyceps militaris* may also contribute to lowering the cost of this expensive medicinal mushroom. Although more research is required to fully uncover its underlying mechanisms and potential therapeutic uses.

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AVOCADO FLOWERING PHYSIOLOGY: REGULATORY MECHANISMS AND MANAGEMENT STRATEGIES FOR SUSTAINABLE PRODUCTION

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Introduction

Avocado (*Persea americana* Mill.) belongs to the Lauraceae family and has emerged as a progressively significant subtropical fruit crop globally. Avocados, native to Central America and Mexico, are currently grown in diverse tropical and subtropical areas for their nutrient-dense fruit, abundant in unsaturated fats, vitamins, and minerals. Understanding the fruit's flowering physiology is essential for optimal cultivation given its unique flowering behavior, which could directly impact the productivity (Davenport, 1986). Avocados have been classified into three races—Mexican, Guatemalan, and West Indian—with distinct adaptive characteristics displayed by each. Commercial varieties such as 'Hass,' 'Fuerte,' 'Bacon,' and 'Zutano' are often hybrids of these races, particularly Guatemalan-Mexican crosses, which display varying flowering patterns and environmental adaptations (Salazar-García *et al.*, 2023).

Floral biology and flowering behaviour

- **Protogynous dichogamy**

The avocado flower is structurally complete (bisexual) but exhibits a unique phenomenon called protogynous dichogamy (Davenport, 1986). Although the male and female organs of the avocado blossom are both functioning, they operate at different periods within one single flower. Over two days, each bloom opens twice: first as a functionally female blossom and again as a functionally male flower. The stigma is open to pollen during the female phase, but the pollen produced by the flower itself has not yet been discharged. Pollen is released during the male phase, although the stigma is usually no more receptive (Rendón-Anaya *et al.*, 2023).

A and B flowering types

- **Type A flowering pattern:** Flowers open as female in the morning of the first day, close by noon, and reopen as male in the second afternoon. Examples include Hass, Lamb Hass, Pinkerton, Reed, and Gwen.
- **Type B flowering pattern:** Flowers open as female in the afternoon of the first day, close during the night, and reopen as male the next morning. Examples include Fuerte, SirPrize, Bacon, and Zutano (Gaurha *et al.*, 2024).

Theoretically, when various cultivars are grown together, these complementary flowering patterns improve the chance of cross-pollination. The timing of flower openings follows this pattern with clocklike precision when the temperature is at its ideal level above 21°C (Davenport, 1986).

Effect of temperature on flowering

In avocados, the main environmental trigger that causes flowering is low temperatures. Floral induction is inhibited by higher temperatures (over 25°C), but it is encouraged by exposure to

day/night temperatures between 15/10°C and 23/18°C for several months, according to studies (Salazar-García *et al.*, 2023). Floral growth can be greatly hindered by brief exposure to temperatures as high as 30°C. With warmer winters possibly influencing floral induction and yields, this temperature sensitivity explains seasonal and regional variations in avocado flowering and has impacts for climate change. The timing and coordination of flower openings are also influenced by temperature. Flower openings become erratic and delayed when temperatures drop below 21°C, which may result in overlap between the male and female stages on the same tree (Gaurha *et al.*, 2024).

Molecular mechanisms of flowering regulation

- **FT (FLOWERING LOCUS T), AP1 (APETALA1), LFY (LEAFY):** Upregulated during floral induction, marking the transition from vegetative to reproductive growth (Ziv *et al.*, 2014).
- **DAM (DORMANCY-ASSOCIATED MADS-BOX):** Downregulated at floral bud break, suggesting a role in ending bud dormancy (Ben-Tal *et al.*, 2024).
- **SPL9, CO, SEP2/AGL4:** Also implicated in regulating the timing and identity of floral organs (Salazar-García *et al.*, 2023).

Alternate bearing and hormonal regulation

Heavy cropping in one year limits flowering and yield in the subsequent year, indicating avocado's strong inclination toward alternate (biennial) bearing. A substantial fruit load raises auxin (IAA) and its conjugate levels in buds, which suppresses flowering gene expression and activates the floral repressor PaTFL1, according to recent studies (Ben-Tal *et al.*, 2024).

Orchard Management for Enhanced Flowering

- **Pollination management :** Fruit set depends on the effectiveness of pollination. Although avocado flowers can self-pollinate, cross-pollination, which is made possible by synchronizing Type A and B cultivars and making sure there is sufficient bee activity, typically results in higher fruit set (Heard *et al.*, 2021). According to research, bees typically operate in tiny areas between one and three trees, with just a small number (2-4%) going farther to transport pollen between rows (Hormaza, 2014).
- **Temperature management:** Warmer winters can cause irregular or less frequent flowering, while dryness might interfere with pollination and flower development. Adaptive techniques are being researched, such as choosing cultivars with varying temperature needs or modifying orchard microclimates (Sedgley, 1987).
- **Alternate bearing management:** The following season's flowering may be hindered by heavy fruit loads. In order to reduce alternate bearing and encourage more reliable yields, crop loads may be managed by selectively thinning the fruit. Light penetration and flower development are improved by regular pruning. The energy-intensive processes of flowering and fruit development depend on plants receiving enough carbohydrate reserves (Ben-Tal *et al.*, 2024; Cowan *et al.*, 2019).

Summary

Avocado flowering physiology is regulated by a complex interaction between genetic pathways involving key floral regulators and environmental cues, particularly temperature. The complementary flowering patterns of cultivars of the A and B types and the distinctive protogynous dichogamy of avocado flowers combine to form an intriguing system intended for promoting cross-pollination in natural environments. In order to maximize fruit set, productivity, and orchard

management, especially as climate variability rises, it is essential to understand these mechanisms. Recent developments in molecular biology offer new methods for monitoring and regulating avocado flowering, which could lead to increased sustainability and yield.

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IMPACT OF BIO-ENRICHMENT ON LARVAL SURVIVAL AND GROWTH PERFORMANCE

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Abstract

The application of bio-enrichment techniques to aquaculture systems has gained prominence as a sustainable strategy for improving larval survival and growth performance. This article provides a comprehensive discussion on the impact of bio-enriched diets on the early developmental stages of larvae, emphasizing key factors such as survival rates, growth performance, and overall health outcomes. Bio-enrichment involves the use of biologically active additives, including probiotics, prebiotics, and micronutrients, designed to enhance the nutritional profile of live-feeds. Various experimental trials conducted under controlled conditions revealed significant improvements in larval survival rates, attributed to the enhanced resistance to stress and disease conferred by bio-enriched diets. Additionally, larvae exhibited accelerated growth trajectories, with marked increases in length and weight compared to those fed conventional diets. Microbial analysis also indicated improved gut health, suggesting that bio-enrichment facilitates better nutrient absorption and metabolic efficiency. This approach not only optimizes the yield and quality of aquaculture products but also reduces dependence on chemical additives, thereby promoting environmental sustainability.

Keywords : Aquaculture nutrition, Bio-enrichment, Larval survival, Microalgae, Probiotics.

Introduction

Bio-enrichment refers to the process of enhancing the nutritional profile of live feed organisms, such as microalgae, rotifers, and Artemia, by incorporating essential nutrients like fatty acids, vitamins, and probiotics (Joseph, 2003). This technique is widely used in aquaculture to improve the health and growth performance of aquatic species during their early developmental stages. In aquaculture, bio-enrichment plays a crucial role in ensuring the survival and optimal growth of larvae. By enriching live feeds, farmers can provide larvae with a balanced diet that meets their specific nutritional requirements. This leads to improved resistance to diseases, better gut health, and enhanced metabolic efficiency. Additionally, bio-enrichment contributes to higher survival rates and faster growth trajectories, which are essential for the sustainability and productivity of aquaculture systems. It also reduces the reliance on chemical additives, promoting environmentally friendly practices in the industry. Larval survival and growth performance are critical factors in aquaculture, as they directly influence the sustainability and profitability of the industry. High survival rates ensure that a greater proportion of larvae reach maturity, reducing losses and optimizing resource utilization. This is particularly important in commercial aquaculture, where the production of healthy juveniles is essential for meeting market demands. Growth performance, on the other hand, determines the efficiency of larval development and the quality of the final product.

Faster and healthier growth trajectories lead to shorter production cycles, allowing farmers to maximize yield while minimizing costs. Additionally, robust growth performance is often associated with improved resistance to diseases and environmental stressors, enhancing the overall health and viability of the stock. Together, larval survival and growth performance play a pivotal role in ensuring the success of aquaculture operations. They contribute to the economic viability of the industry while promoting sustainable practices that align with environmental conservation goals. By focusing on these parameters, farmers can address challenges such as feed optimization, water quality management, and disease prevention, ultimately advancing the aquaculture sector. This article examines how bio-enriched diets improve larval survival, growth, and health during early stages, enhancing disease resistance and metabolic efficiency as a sustainable feeding method.

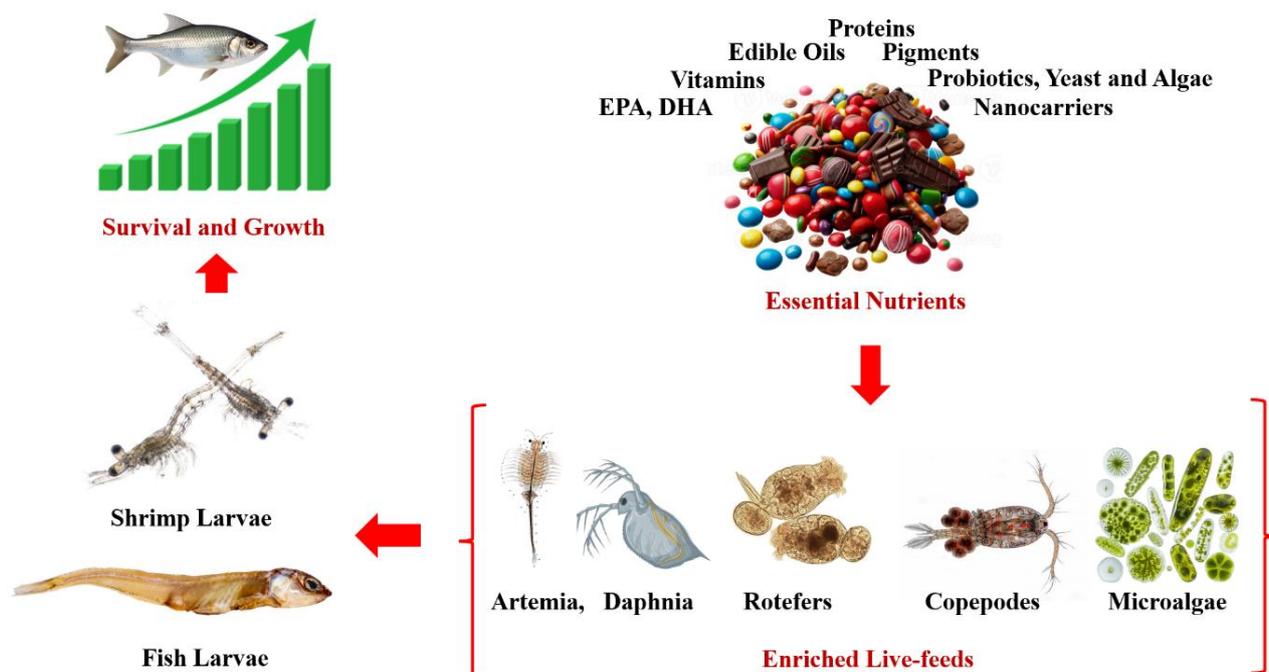


Figure 1: Process of bio-enrichment

Need of Bio-Enrichment

The need for bio-enrichment arises from the challenges in aquaculture during the early developmental stages of aquatic organisms, where their nutritional requirements are highly specific and critical. Natural live feeds, such as Artemia, rotifers, and microalgae, often lack sufficient levels of essential nutrients like fatty acids, proteins, vitamins, and probiotics. Without adequate nutrition, larvae are more prone to poor growth, higher mortality rates, and susceptibility to diseases. Bio-enrichment addresses these challenges by enhancing the nutritional profile of live feeds, ensuring larvae receive a balanced diet that supports optimal growth, survival, and metabolic efficiency. It also helps improve immunity, resistance to stress, and gut health, all of which are crucial for the viability of larval stocks. Furthermore, bio-enrichment contributes to the sustainability and productivity of aquaculture by reducing dependency on chemical additives, antibiotics, and non-renewable feed sources. In essence, bio-enrichment is essential for bridging the nutritional gaps in natural feeds, improving hatchery success rates, and advancing the sustainability of modern aquaculture practices.

Steps for Effective Bio-Enrichment

1. Selection of Live Feeds: Choose suitable live feeds such as Artemia (brine shrimp), rotifers, copepods, or microalgae based on the dietary needs of the target larvae. Ensure the live feeds are in good health and at the appropriate life stage for enrichment.

2. Preparation of Enrichment Media

- Create a nutrient-rich solution containing essential fatty acids (e.g., DHA, EPA), proteins, vitamins, and probiotics.
- Commercially available enrichment products or custom formulations can be used. For example: Lipid emulsions: 2-3 mL per liter of water for Artemia (Pratiwy *et al.*, 2021).

3. Enrichment Process

For Artemia:

- Hatch Artemia cysts in saltwater under aeration.
- After hatching, transfer the nauplii to a separate tank containing the enrichment media.
- Maintain aeration and allow the Artemia to feed on the enrichment solution for 12-24 hours.

For Rotifers:

- Add the enrichment media directly to the rotifer culture tank.
- Allow the rotifers to ingest the nutrients for 6-12 hours.

For Microalgae:

- Fortify microalgae cultures with additional nutrients like trace elements or vitamins during their growth phase.

4. Monitoring and Optimization

- Regularly monitor the enrichment process to ensure the live feeds are absorbing the nutrients effectively.
- Check parameters like dissolved oxygen, pH, and temperature to maintain optimal conditions.
- Adjust the duration of enrichment based on the specific requirements of the live feed and larvae.

5. Harvesting Enriched Feeds

- After the enrichment period, harvest the live feeds by filtering or sieving them from the culture water.
- Rinse the enriched feeds with clean water to remove any residual enrichment media.

6. Feeding to Larvae

- Provide the enriched live feeds to the larvae in appropriate quantities and intervals.
- Ensure the feeds are fresh and not overfed to avoid water quality issues.

Key Considerations

- Maintain strict hygiene to prevent contamination during the enrichment process.
- Use species-specific enrichment protocols to meet the unique dietary needs of the larvae.
- Avoid over-enrichment, as excessive nutrients can lead to water quality deterioration.
- Regularly monitor environmental parameters such as temperature, salinity, and dissolved oxygen to optimize enrichment efficiency and ensure feed quality.
- Ensure proper storage and handling of enrichment media to preserve nutrient integrity and prevent degradation.

Bio-Enrichment Techniques in Aquaculture

- A. **Nutritional enrichment**, are crucial for improving the dietary value of live feeds in aquaculture. This involves enhancing live-feeds by incorporating essential nutrients such as lipids, proteins, and vitamins. Lipids, including omega-3 and omega-6 fatty acids, play a vital role in energy supply and physiological functions. Proteins ensure that larvae receive adequate amino acids for growth, tissue repair, and development. Vitamins like A, D, E, and C help boost immunity, improve stress resistance, and prevent nutritional deficiencies. These techniques collectively aim to enhance larval health, survival rates, and growth performance while supporting sustainable practices in aquaculture.
- B. **Microbial and probiotic enrichment** focuses on enhancing the gut microbiota of larvae through the introduction of beneficial microorganisms. This approach aims to improve the digestive health and overall metabolic efficiency of larvae, which are critical for their survival and growth during early developmental stages. By enriching live-feed with probiotics, such as *Lactobacillus spp.* and *Bacillus spp.*, the balance of gut microbiota is optimized, leading to better nutrient absorption and immunity against pathogens. This method reduces reliance on antibiotics and promotes sustainable aquaculture practices, ensuring healthier larvae and improved production outcomes.
- C. **Microalgae enrichment** often refers to the process of enhancing microalgae with additional nutrients to further boost their nutritional profile. This involves fortifying microalgae with essential fatty acids (e.g., DHA and EPA), proteins, or vitamins to maximize their value when used as feed for aquatic larvae. The enriched microalgae then serve as a highly nutritious live feed, supporting larval survival, growth, metabolism, and immunity. It's a complementary approach that highlights the versatility of microalgae both as a nutrient-rich feed source and as a medium for bio-enrichment.
- D. **Nanotechnology approaches** represent innovative nutrient delivery methods in aquaculture, offering precise and efficient ways to enhance larval nutrition. These methods involve the use of nanocarriers or nanoparticles to encapsulate essential nutrients such as lipids, proteins, and vitamins, ensuring their targeted delivery and sustained release within the larval gut. By improving nutrient bioavailability and stability, nanotechnology minimizes feed wastage and optimizes the absorption process, leading to enhanced growth performance and survival rates. Additionally, these techniques help in delivering functional additives, such as immune-boosting compounds or disease-prevention agents, further supporting larval health. As an emerging field, nanotechnology holds significant potential to revolutionize nutrient delivery in aquaculture, promoting sustainability and efficiency.

Table 1: Comparative Analysis of Bio-Enrichment Methods in Aquaculture

Enrichment Method	Description	Advantages	Limitations
Nutritional Enrichment	Enhancing live-feeds with lipids, proteins and vitamins.	Improves survival, growth and health.	Requires precise formulations; Resources intensive.
Microbial and probiotic Enrichment	Introducing beneficial microorganisms to optimize gut microbiota and immunity	Enhances nutrient absorption and disease resistance.	Need careful monitoring to maintain microbial balance.

Enrichment Method	Description	Advantages	Limitations
Microalgae-based Enrichment	Enriching microalgae with essential nutrients with EPA, DHA and vitamins.	Provides essential lipids for energy and development; sustainable.	Cultivation can be labour intensive and environmentally dependent
Nanotechnology Approaches	Using nanocarriers for precise nutrient delivery and sustained release.	Improves nutrients bioavailability; reduce feed wastage.	Still experimental; higher costs involved.

Effects of Bio-Enrichment on Larval Survival and Growth

- A. **Bio-enrichment significantly enhances hatchery success rates** by improving larval survival, growth performance, and overall health during early developmental stages (Anantharaja, 2007; Simanjuntak, 2022). By enriching live feeds with essential nutrients such as fatty acids, proteins, vitamins, and probiotics, bio-enrichment ensures that larvae receive a balanced and highly nutritious diet. This leads to better resistance against diseases, improved gut health, and enhanced metabolic efficiency, all of which are critical for larval viability. The application of bio-enrichment also addresses challenges such as poor nutrient absorption and susceptibility to environmental stressors, which are common in hatchery settings. By optimizing the nutritional profile of live feeds, bio-enrichment reduces mortality rates and accelerates growth, resulting in a higher yield of healthy juveniles. This not only boosts the productivity of hatcheries but also contributes to the sustainability of aquaculture practices by minimizing the need for chemical additives and antibiotics. Overall, bio-enrichment plays a pivotal role in achieving consistent and reliable outcomes in hatchery operations, making it an indispensable tool for modern aquaculture.
- B. **Bio-enrichment has a profound influence on metabolism**, particularly during the early developmental stages of aquatic organisms (Simanjuntak *et al.*, 2022). By enhancing the nutritional profile of live feeds with essential nutrients such as fatty acids, proteins, vitamins, and probiotics, bio-enrichment optimizes metabolic processes. This leads to improved nutrient absorption, energy utilization, and overall physiological efficiency. The introduction of probiotics further supports gut microbiota, which plays a critical role in regulating metabolic pathways and boosting immunity. Enhanced metabolism not only accelerates growth rates but also strengthens resistance to environmental stressors and diseases, ensuring better survival outcomes. Bio-enrichment, therefore, serves as a key strategy for promoting metabolic health and sustainability in aquaculture systems.
- C. **Bio-enrichment plays a vital role in enhancing immunity** during the early developmental stages of aquatic organisms (Dey *et al.*, 2015). By incorporating probiotics and essential nutrients into live feeds, bio-enrichment strengthens the gut microbiota, which is a key component of the immune system. A balanced gut microbiota improves the production of immune cells and enhances the organism's ability to resist pathogens and environmental stressors. Additionally, bio-enrichment provides critical vitamins and minerals that support the immune response, ensuring better survival rates and overall health. This approach not only reduces the reliance on antibiotics but also promotes sustainable aquaculture practices by fostering natural immunity in larvae.

D. **Bio-enrichment enhances stress resistance** in aquatic organisms by fortifying their physiological and immune systems (Souza *et al.*, 2019). By incorporating essential nutrients like fatty acids, vitamins, and probiotics into live feeds, bio-enrichment strengthens the larvae's ability to cope with environmental stressors such as temperature fluctuations, salinity changes, and pathogen exposure. Probiotics, in particular, play a key role in maintaining a balanced gut microbiota, which is crucial for reducing oxidative stress and improving overall resilience. This improved stress resistance not only boosts survival rates but also ensures healthier and more robust growth, contributing to the success of aquaculture practices.

Challenges and Limitations

Bio-enrichment in aquaculture faces challenges related to cost, scalability, and accessibility. The cost of bio-enrichment techniques can be high due to the need for specialized nutrients, equipment, and processes, making it less feasible for small-scale operations. Scalability is another issue, as expanding bio-enrichment practices to larger facilities often requires significant investment in infrastructure and technology, which may not be economically viable for all producers. Accessibility is also a concern, particularly in regions with limited access to advanced bio-enrichment materials or expertise, which can hinder the adoption of these methods. Addressing these challenges is essential for making bio-enrichment more sustainable and widely applicable in aquaculture systems.

Future Perspectives in Bio-Enrichment

The future direction of bio-enrichment in aquaculture involves leveraging advancements in biotechnology, precision nutrition, and sustainable practices. Emerging technologies such as nanotechnology and encapsulation methods are anticipated to enhance nutrient delivery efficiency, ensuring targeted and sustained release of essential nutrients. Eco-friendly and cost-effective enrichment materials, such as plant-based or algae-derived nutrients, address environmental concerns while supporting sustainability. Species-specific enrichment protocols aim to optimize feed formulations to cater to the unique dietary needs of aquatic organisms, complemented by artificial intelligence and data analytics for refining processes, scalability, and accessibility. Balancing innovation with sustainability, bio-enrichment is poised to drive aquaculture as a reliable and environmentally responsible source of food production. AI-driven enrichment strategies enhance efficiency and precision in aquaculture by tailoring nutrient delivery to species-specific needs, predicting larval growth patterns, and enabling real-time adjustments to protocols. Automated systems monitor water quality, feed utilization, and larval behaviour while integrating data from environmental sensors and genetic profiles to improve survival rates and growth. These innovations reduce resource wastage, promote eco-friendly practices, and expand opportunities for sustainable aquaculture development. Sustainable bio-enrichment practices focus on ecological conservation by minimizing environmental impact and enhancing the nutritional value of live feeds. Techniques such as controlled dosing and eco-friendly additives i.e., plant-based nutrients, algae-derived compounds, and probiotics ensure reduced nutrient runoff, maintain water quality, and foster biodiversity. These approaches support natural gut microbiota, reduce reliance on antibiotics, and promote healthier aquatic ecosystems, balancing productivity with conservation goals.

Conclusion

Bio-enrichment involves enhancing the nutritional quality of live feeds, such as rotifers and Artemia, by enriching them with essential nutrients like fatty acids, vitamins, and minerals. This process

ensures that larvae receive optimal nutrition during their early developmental stages, which is crucial for their survival and growth. Studies have shown that bio-enriched live feeds significantly improve larval survival rates, boost growth performance, and enhance overall health. For instance, enriching live feeds with omega-3 fatty acids like DHA and EPA has been found to support better development and resilience in fish larvae. Additionally, bio-enrichment can help address challenges such as nutrient deficiencies and environmental stressors, making it a sustainable approach in aquaculture practices.

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BIOLOGICAL EXTRACTION OF CHITIN AND CHITOSAN FROM SEAFOOD WASTE: SUSTAINABLE SOLUTION FOR WASTE VALORIZATION

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Abstract

Fish and seafood processing industries generate huge quantity of waste which contains a valuable biopolymer, chitin, particularly in crustacean shells, and is used in various industries due to its versatility and beneficial properties. This article will explore a low-cost, eco-friendly biological method for extracting chitin and its derivative, chitosan, from seafood waste. By using lactic acid bacteria, fungi or proteolytic enzymes, this process reduces its adverse impact on the environment, avoid harsh chemicals and maintains the structural integrity of chitin. The biological method offers sustainable solutions for chitin production and waste reduction, making it a promising substitute for conventional chemical extraction techniques. As research advances, the possible uses of chitin and chitosan in the food, pharmaceutical and agricultural sectors as well as in environmental management are anticipated to grow, supporting a more circular and sustainable economy.

Key words: Chitin, Chitosan, Eco-friendly, Seafood waste

Introduction

With growing seafood processing industries, release of various by products like skin, head, shells, tails, scales etc is also increased. A significant amount of solid waste is produced during the processing and as a result, a sizeable portion of the overall catch is discarded as processing leftovers (Coppola *et al.*, 2021). Despite the fact that certain by-products are used, the majority is disposed of in waste, which poses a disposal and pollution problem. Fish and shellfish processing activities in India generate a significant amount of waste, with the largest proportion produced during shrimp processing (Mohanty *et al.*, 2020) and majority of this will go unused and wasted or turned into low-value products like animal feed and fertilisers.

Chitin, a linear polymer made up of (1-4)-linked 2-acetamido-2-deoxy β -D-glucopyranose units is frequently abundant in seafood waste (crustacean, insect, arthropod exoskeletons and molluscs) (Akinwale and Akinluwade, 2020). In nature, chitin is the second most abundant polysaccharide after cellulose and is most prevalent in the marine habitat (Souza *et al.*, 2011). It is mainly extracted from shrimp (because shrimps are normally sold as headless or peeled or both) and crab shells. The major shell components are chitin, proteins, lipids, pigments and trace elements and in order to obtain purified chitin, proteins, minerals and other components must be separated (Pal *et al.*, 2014). The N-deacetylated form of chitin is chitosan and it has been extensively employed in a variety of industries, from the food industry and agriculture to pharmaceuticals and medical (Bertrand *et al.*, 2024).

**Fig 1: Chitin and Chitosan**

Extraction methods

The chemical extraction method is the traditional and commercially recognised method of extracting chitin and chitosan. This method normally involves several important steps which include demineralisation using hydrochloric acid (HCl). In order to deproteinise raw materials, proteins are removed by treating them with an alkaline solution, such as sodium hydroxide (NaOH). Lastly, the chitin is deacetylated by subjecting it to a strong alkaline solution, often NaOH, at high temperatures in order to extract chitosan (Varun *et al.*, 2017). Although this chemical process is quite effective in converting shrimp waste into chitin and chitosan, it has a number of drawbacks:

- It can alter the molecular structure of chitin, affecting its properties such as molecular weight, intrinsic properties, crystallinity and degree of acetylation.
- Using strong acids and bases in chemical extraction processes requires further neutralisation and purification steps, which increases the overall cost.
- Chitin may be subjected to high temperatures and strong acids during chemical treatments, which could cause the polymer chain to degrade or become desaturated.
- Chemical processes may introduce impurities or residues that are unsuitable for use in therapeutic applications. Chitin and its derivatives must meet stringent safety and purity standards before being used in medical devices, wound dressings or pharmaceutical delivery systems.
- Chemical processes often use high temperatures and pressures, which increases energy costs and has a negative impact on the environment.

Consequently, biological approaches are becoming more and more popular as they provide a more economical and ecologically friendly option. An advanced method for removing biopolymer from crustacean shells is called biological extraction. This process does not denature the chitin and produces oligomers with the ideal level of polymerisation for various uses. As the use of high temperatures and harsh chemicals is avoided, it can result in high yields of pure chitin (Verardi *et al.*, 2023).

Biological extraction

1. Demineralisation

To remove minerals from the crustacean shells, they are first cleaned and crushed into smaller pieces and treated with lactic acid bacteria that will produce organic acids during fermentation, which dissolve the minerals in the shell matrix (Mohan *et al.*, 2022). Proteases and other acidic enzymes can also be employed because they help demineralise by carefully rupturing mineral bonds

(Kaur and Dhillon, 2015). After neutralising the resultant mixture, the leftover solid material is cleaned and allowed to dry.

2. Deproteinization

Two main techniques like enzymatic extraction and fermentation are usually used to remove proteins. Proteolytic bacteria, including *Serratia* species, *Bacillus subtilis* and *Pseudomonas aeruginosa* are used in fermentation. The extracellular proteases that these microbes produce effectively hydrolyse the proteins found in seafood waste (Islam *et al.*, 2023). Conversely, proteolytic enzymes such as papain, trypsin and pancreatin which can be obtained from microorganisms or plants are used in enzymatic extraction (Kozma *et al.*, 2022). During the chitin extraction process, these enzymes help to break down proteins. Following that, acetone or organic solvent mixtures are used to carry out the decolourisation process and the protein fragments are eliminated by filtering the resultant mixture. The remaining chitin is cleaned and dried.

3. Deacetylation

It uses chitin deacetylase to remove acetyl groups. There are several methods by which chitin deacetylase can enzymatically deacetylate chitin. One method is to use microbial sources of chitin deacetylase, like fungi or bacteria, which can be grown and used to generate large amounts of the enzyme (Kaur and Dhillon, 2015). As an alternative, chitin deacetylase can be obtained from organic materials like crab shells, which are abundant in chitin and chitinase enzymes (Desai *et al.*, 2023). Usually, the procedure involves treating chitin with a chitin deacetylase solution under controlled temperature, pH and reaction time. The resultant mixture is then cleaned and dried to produce chitosan.

Table: Comparison of chemical and biological methods for chitin and chitosan extraction

	Chemical method	Biological method
Demineralization	Hydrochloric acid	Lactic acid bacteria or protease from microbes
Deproteinization	Sodium hydroxide	Proteolytic bacteria or proteases derived from plant or microbial sources
Deacetylation	Sodium hydroxide	Chitin deacetylase enzyme
Key advantages	<ul style="list-style-type: none"> • Short processing time • Used at industrial scale • Complete removal of organic salts 	<ul style="list-style-type: none"> • High quality end product is obtained • Environment friendly • Removed minerals and proteins may be used as human and animal nutrients
Key disadvantages	<ul style="list-style-type: none"> • Not environment friendly • Solubilized proteins and minerals cannot be used as human and animal nutrients 	<ul style="list-style-type: none"> • Time consuming (can take several days) • Limited to laboratory scale studies

Applications of chitin and chitosan

Chitin and chitosan are versatile biopolymers with a wide range of applications. Their unique properties, such as biocompatibility, biodegradability and antimicrobial activity, make them valuable in both traditional and innovative uses. The following are some of the most significant uses of chitin and chitosan:

- **Water treatment:** Used for the removal of oils, grease and toxic metal ions from contaminated water (Dave *et al.*, 2021).
- **Active pharmaceutical ingredients:** Used as devices for drug administration and exhibit muco-adhesive properties (Dave *et al.*, 2021).
- **Food industry:** Chitosan is nontoxic, biocompatible and bio-functional molecule that can be used as a natural food preservative (Kozma *et al.*, 2022).
- **Cosmetics:** Used in skin and hair care products as they acts as hydrating agents and prevent the skin from drying out (Piekarska *et al.*, 2023).
- **Agriculture:** Chitin and its derivatives can reduce soil-borne diseases and also help in retaining nutrients in the soil (Román-Doval *et al.*, 2023).
- **Waste water treatment:** Adsorption has been proven to be a reliable and cost-effective substitute for removing contaminants from wastewaters and chitosan can be used as a bio sorbent for heavy metal ions (Piekarska *et al.*, 2023).
- **Biodegradable packaging:** Materials based on chitin are being investigated as environmentally friendly substitutes for traditional plastics in packaging applications, which reduces plastic waste (Kozma *et al.*, 2022).

Future prospects

The biological extraction of chitin and chitosan from seafood waste has a lot of promise for the future because of its sustainability, ability to reduce waste and compliance with the growing environmental concerns. This approach meets the growing demand for environmentally friendly chitin extraction methods. Furthermore, using seafood waste promotes a circular economy by optimising the use of an underutilised resource while simultaneously reducing the burden on landfills. As research and technology advance, the versatility of chitin and chitosan is expected to play a crucial role in various industries, further driving the shift towards sustainable and environmentally conscious practices.

Conclusion

A sustainable and environmentally favourable substitute for conventional chemical procedures is the biological extraction of chitin and chitosan from seafood waste, which preserves the integrity of the biopolymer while lowering the environmental impact of chitin production. Additionally, the technique encourages effective use of seafood waste, reducing disposal problems and assisting in the valorisation of waste.

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BIOLUMINESCENCE: A BIOCHEMICAL SYMPHONY OF LIGHT

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Abstract

The fascinating natural process by which living things emit light is called bioluminescence. When an enzyme called luciferase catalyzes the oxidation of a small molecules called luciferin, an excited-state species that emits light is produced. This process is known as bioluminescence. Because different luciferin–luciferase couples emit light at different wavelengths, they can be used in a variety of applications. Bioluminescence serves a variety of biological purposes, including luring prey, attracting mates, and discouraging predators. It has been observed in organisms such as fireflies, some jellyfish, and deep-sea fish. The purpose of this article is to inform readers about bioluminescence and its uses.

Introduction

Bioluminescence is a remarkable natural process where living organisms generate and emit light. This trait has been evolutionarily preserved, especially among marine species, as well as certain bacteria, fungi, and land-dwelling insects. It serves various functions, including luring prey, deterring predators, and attracting potential mates. Naturally produced light comes from two primary types of systems: bioluminescent systems, which consist of separate luciferase enzymes and luciferin molecules, and photoproteins, where the light-producing chromophore is incorporated into the protein and light emission is initiated by modifications in the external environment of the protein.

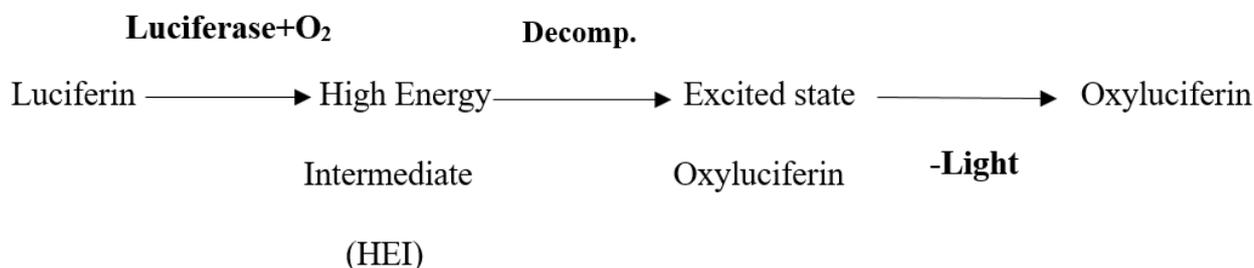
Although over 40 bioluminescent systems are known, the detailed structures of luciferins and their corresponding luciferases have been determined for only 11 of them. Research into understanding the mechanisms of these luciferin-luciferase pairs remains ongoing, alongside efforts to discover new pairs. Typically, a bioluminescent reaction involves a luciferase enzyme, its luciferin substrate, and an oxidizing agent—usually molecular oxygen. In some cases, additional energy sources like ATP or NADH are also required. D-luciferin from fireflies was discovered in the middle of the 20th century, it was one of the first luciferin structures to be recognized. It was later discovered that the deep-sea shrimp *Oplophorus gracilirostris* possesses the luciferin coelenterazine and its corresponding luciferase.

Luciferin, their luciferases and mechanism

While each bioluminescent insect species possesses a unique luciferase enzyme, they all utilize the same substrate, D-luciferin, which is present in approximately 40 different species, including fireflies, click beetles etc.

Luciferin reacts with oxygen to produce a highly reactive compound known as a high-energy intermediate (HEI). In all identified cases, this HEI is a peroxide, featuring a weak and unstable bond between two oxygen atoms. When this bond breaks, it drives the molecule into an excited

electronic state via a conical intersection between the ground and excited energy surfaces. At this point, oxyluciferin is formed in an excited state. As oxyluciferin transitions back to its ground state, it emits light—this emission corresponds to the energy difference between the excited and ground states. The result is the luminous phenomenon known as bioluminescence.



TYPES OF PROTEINS INVOLVED IN BIOLUMINESCENCE EMISSION

There are five different luciferins that account for most of the known bioluminescent species. They are dinoflagellate luciferin (related to the chlorophyll structure), firefly luciferin (requires ATP for bioluminescence), coelenterazine (extremely common), bacterial luciferin (derivative of riboflavin), and vargulin (found in Ostracods). fluorescent proteins that are known to contribute to the production of high illumination include the luminazine protein discovered in *Photobacterium phosphoreum* and GFP in jellyfish.

Functions of Bioluminescence in Nature

1. Counter Illumination (Camouflage)

There is a brightness gradient that many species can perceive in the deep sea, despite the fact that it appears completely dark to us. Predators swimming below can discover the shadow made by fish swimming higher up. Therefore, the ventral side of some fish, such as *Parapriacanthus ransonneti*, emits a modest bioluminescent light that dissipates the shadow.

2. Attracting prey

Deep-water anglerfish (Ceratioidei), which inhabit depths ranging from 1000 to 4000 meters, are ambush predators much like those found in shallower waters. They use a modified fin ray resembling a fishing rod, tipped with bait (called an esca), to lure in prey. Unlike some shallow-water species, the esca in most deep-sea anglerfish doesn't produce light on its own. Instead, it glows through a symbiotic relationship with bioluminescent bacteria.

3. Defense against predators

This usually involves the release of a glowing mucus that frequently sticks to the attacker. Touching small ostracods (*Vargula hilgendorffii*) causes them to glow effectively. For example, brittle stars (*Plutonaster bifrons*) can divert an attacker by ejecting a luminous arm. Instead of an ink cloud, deep-sea squids (*Octopoteuthis deletron*) create a bright bioluminescent cloud.

Applications of Bioluminescence

1. Gene Expression and Protein Protein Interaction

Bioluminescent systems particularly luciferase based assays are extensively used for monitoring gene expressions and protein protein interactions and Their high sensitivity and low background noise make them ideal for high-throughput screening in drug discovery.

2. In Vivo Imaging

Bioluminescent imaging enables non-invasive visualization of cellular and molecular processes in live animals. This technique is invaluable for tracking disease progression, evaluating therapeutic responses.

3. Hygiene Control

In the food and healthcare industries, bioluminescence assays are utilized to assess cleanliness by detecting ATP, an indicator of biological residues, ensuring compliance with hygiene standards.

4. Biosensors for Environmental Monitoring

Bioluminescent bacteria serve as biosensors to detect pollutants and toxins in various environments. Their luminescence decreases in the presence of harmful substances, providing a rapid and sensitive assessment of environmental health.

Conclusion

Bioluminescence is a remarkable natural phenomenon where living organisms produce light through chemical reactions. Found in various marine species, fungi, and some terrestrial insects like fireflies, bioluminescence serves multiple ecological purposes such as attracting mates, deterring predators, and luring prey. This natural light emission not only highlights the complexity and adaptability of life but also holds potential for scientific and medical applications, including bio-imaging and environmental monitoring. As research continues, bioluminescence remains a glowing example of nature's ingenuity and its potential to inspire innovative technologies.

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ENHANCING POSTHARVEST LOSS REDUCTION THROUGH IMPROVED TECHNOLOGIES

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Abstract

Postharvest losses represent a significant challenge to global food security, particularly in developing countries where infrastructure and technological advancements are limited. This article assessed the crucial role of improved storage technologies in postharvest management. It explores a range of storage strategies, highlighting their impact on reducing losses, maintaining quality, and extending the shelf life of agricultural produce. The article further considers the economic and social implications of adopting improved storage technologies, emphasizing their potential to enhance food availability, improve livelihoods, and contribute to sustainable agricultural practices. Finally, it addresses the challenges associated with technology adoption and proposes solutions to promote the wider application of improved storage technologies for effective postharvest management.

Keywords: Postharvest, Management, Storage Technologies, Postharvest and Losses

Introduction

Postharvest losses, encompassing quantitative reductions in yield and qualitative degradation of agricultural produce, severely impact global food security. Estimates suggest that up to one-third of food produced globally is lost or wasted annually (FAO 2011; Sheahan, and Barrett, 2017). These losses are particularly acute in developing nations, where they can reach as high as 50% for fruits and vegetables (Affognon *et al.*, 2015). These losses are driven by a combination of factors, including improper handling, inadequate transportation, poor storage infrastructure, and pest infestations. Effective postharvest management strategies are therefore essential to minimize these losses and ensure that food reaches consumers in optimal condition. Storage plays a pivotal role in postharvest management. Traditional storage methods, often relying on natural ventilation and rudimentary structures, offer limited protection against spoilage, pests, and environmental fluctuations. However, advancements in storage technologies have yielded a diverse range of solutions that can significantly reduce postharvest losses and prolong the shelf life of agricultural produce. This paper aims to provide a comprehensive overview of the role of improved storage technologies in postharvest management, focusing on their effectiveness, economic viability, and potential for wider adoption.

The Significance of Postharvest Losses:

Postharvest losses have far-reaching implications beyond simply reducing the quantity of available food. They contribute to:

- **Food Insecurity:** Losses diminish the supply of nutritious food, exacerbating hunger and malnutrition, especially in regions with limited food production capacity (Affognon *et al.*, 2015).

- **Economic Losses:** Farmers suffer financial losses due to reduced yields, impacting their income and livelihoods. This can discourage agricultural production and contribute to rural poverty (Hodges *et al.*, 2011).
- **Environmental Impact:** Wasted food represents a significant waste of resources, including land, water, energy, and fertilizers, used in its production. The decomposition of wasted food in landfills generates greenhouse gases, contributing to climate change (Gustavsson *et al.*, 2011).
- **Nutritional Deficiencies:** Postharvest losses can disproportionately affect nutrient-rich fruits and vegetables, leading to deficiencies in essential vitamins and minerals in the population (Sheahan & Barrett, 2017).

Therefore, addressing postharvest losses is crucial for achieving food security, promoting sustainable agriculture, and improving the livelihoods of farming communities.

Impact of Improved Storage Technologies on Postharvest Management:

The adoption of improved storage technologies have a significant positive impact on postharvest management:

- **Reduced Postharvest Losses:** Improved storage technologies can significantly reduce losses due to spoilage, pests, and mechanical damage. Studies have demonstrated substantial reductions in losses for various crops following the introduction of improved storage methods (Kumar & Kalita, 2017).
- **Extended Shelf Life:** Improved storage technologies can extend the shelf life of agricultural produce, allowing for longer storage periods and wider distribution.
- **Improved Quality:** Controlled atmosphere and modified atmosphere storage can maintain the quality of produce by slowing down respiration, enzymatic activity, and microbial growth.
- **Increased Availability:** Extended shelf life allows for the availability of produce during off-season periods, contributing to food security and dietary diversity.
- **Improved Income for Farmers:** Reduced losses and higher quality produce translate into higher prices and increased income for farmers.
- **Reduced Environmental Impact:** Minimizing postharvest losses reduces the need for additional agricultural production, conserving resources and reducing greenhouse gas emissions.

Challenges and Considerations for Technology Adoption:

Despite the numerous benefits of improved postharvest technologies, the adoption of improved storage technologies faces several challenges:

- **High Initial Investment Costs:** Some storage technologies, such as cold storage and CA storage, require significant capital investment, which can be a barrier for smallholder farmers.
- **Energy Requirements:** Refrigerated storage and controlled atmosphere systems require energy input, which can be costly and environmentally unsustainable if the energy source is not renewable.
- **Technical Expertise:** Operating and maintaining advanced storage technologies requires technical expertise, which may be lacking in some regions.
- **Awareness and Training:** Farmers need to be educated about the benefits and proper use of improved storage technologies.

- Infrastructure Limitations: Inadequate transportation infrastructure and unreliable electricity supply can hinder the effective use of some storage technologies.
- Market Access: Farmers need access to markets that offer fair prices for high-quality produce stored using improved technologies.

Strategies to Promote the Adoption of Improved Storage Technologies

To overcome the challenges and promote the wider adoption of improved storage technologies, the following strategies are recommended:

- Government Subsidies and Incentives: Governments can provide financial assistance to farmers to help them invest in improved storage technologies.
- Research and Development: Continued research and development are needed to develop low-cost, energy-efficient, and locally adapted storage technologies.
- Extension Services and Training Programs: Agricultural extension services can provide training to farmers on the proper use and maintenance of improved storage technologies.
- Public-Private Partnerships: Collaborations between governments, private companies, and research institutions can facilitate the development, dissemination, and adoption of improved storage technologies.
- Access to Credit and Financing: Providing access to affordable credit can enable farmers to invest in improved storage infrastructure.
- Infrastructure Development: Investing in transportation infrastructure and electricity supply is essential for supporting the effective use of improved storage technologies.
- Promoting Renewable Energy Sources: Encouraging the use of renewable energy sources for powering storage facilities can reduce energy costs and environmental impact.

Conclusion

Improved storage technologies play a critical role in postharvest management, offering effective solutions to reduce losses in food, maintain quality, and extend the shelf life of agricultural produce. The adoption of these technologies can significantly contribute to food security, improve livelihoods, and promote sustainable agricultural practices. While challenges remain in terms of cost, technical expertise, and infrastructure, targeted interventions such as government subsidies, research and development, extension services, and public-private partnerships can promote the wider adoption of improved storage technologies. By embracing innovation and investing in effective postharvest management strategies, farmers and food handlers can reduce food losses, enhance food availability, and build a more sustainable and food-secure future.

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REVOLUTIONIZING SUSTAINABILITY: CIRCULAR ECONOMY PATHWAYS FOR A GREENER TOMORROW

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Abstract

The transition from a linear to a circular economy in agriculture is essential for enhancing productivity while mitigating climate change. By emphasizing resource efficiency, waste reduction, and ecosystem regeneration, circular agriculture minimizes environmental impact while ensuring long-term sustainability. Integrated farming systems play a crucial role in this approach, optimizing resource use and enhancing climate resilience. Adopting circular economy principles can revolutionize agricultural practices, contributing to food security, biodiversity conservation, and global sustainability goals.

Introduction

The traditional linear “take-make-dispose” model of agriculture, heavily reliant on external inputs and resulting in significant waste, is unsustainable in the face of climate change and resource scarcity. Agriculture is a major contributor to global greenhouse gas (GHG) emissions and resource consumption. The circular economy, emphasizing resource efficiency, waste reduction, and regeneration, offers a promising alternative. This approach aims to develop closed-loop systems that ensure the prolonged utilization of resources, maximize their value extraction, and minimize environmental footprint. Transitioning to a circular model can pave the way for mitigate climate change while ensuring food security.

Definition

The circular economy (CE) in agriculture focuses on closing nutrient and resource cycles by sustainable practices that reduce waste, enhance resource efficiency, and support ecosystem regeneration. This approach aligns agricultural productivity with environmental conservation.

Historical development and theoretical foundations

Origins: Rooted in concepts like industrial ecology, cradle-to-cradle design, and biomimicry.

Theoretical contributions

Industrial Ecology: Symbiotic relationships between industries where waste from one becomes a resource for another.

Cradle-to-Cradle: Products designed with the end-of-life stage as a starting point, emphasizing biological and technical cycles.

Biomimicry: Designing systems inspired by natural processes, such as nutrient cycles in ecosystems.

Key principles of circular economy in agriculture Resource efficiency

- ✓ **Minimize external inputs:** Reduce reliance on synthetic fertilizers, pesticides, and other external inputs that deplete natural resources and harm the environment.
- ✓ **Optimize resource use:** Efficiently utilize water, energy, and other resources through practices like precision agriculture, rainwater harvesting, and renewable energy sources.
- ✓ **Design out waste**
- ✓ **Minimize food waste:** Reduce food loss and waste at all stages of the food supply chain, from production to consumption.
- ✓ **Utilize byproducts:** Transform agricultural byproducts (e.g., crop residues, animal manure) into valuable resources like compost, biogas, or animal feed.
- ✓ **Closed-loop systems:** Create systems where waste from one process becomes an input for another, reducing waste and maximizing resource use.
- ✓ **Regenerate natural systems**
- ✓ **Soil health:** Implement practices that improve soil health, such as cover cropping, crop rotation, and organic fertilization, to enhance soil fertility and carbon sequestration.
- ✓ **Biodiversity:** Promote biodiversity by diversifying crops, integrating livestock, and creating habitats for beneficial insects and pollinators.
- ✓ **Water conservation:** Implement water-saving techniques like drip irrigation and rainwater harvesting to conserve water resources and reduce water pollution.
- ✓ System integration
- ✓ **Integrated farming systems:** Combine crop production, livestock rearing, and other agricultural activities to create synergistic systems where outputs from one enterprise become inputs for another.
- ✓ **Agroforestry:** Integrate trees and shrubs with crops and livestock to provide shade, improve soil fertility, and enhance biodiversity.

By adhering to these principles, the circular economy in agriculture can contribute to a more sustainable, resilient, and productive food system.

Circular economy strategies and frameworks

Frameworks

The 9R framework: Recycle, Reduce, Refurbish, Refuse, Remanufacture, Repair, Repurpose, Rethink, Reuse.

Butterfly diagram: Illustrates biological and technical cycles, emphasizing the flow of materials through closed loops.

Business models:

Product-as-a-service (PaaS): Leasing or subscription models instead of outright ownership.

Sharing economy: Platforms for shared use of resources (e.g., car-sharing, tool libraries).

Reverse logistics: Systems for returning products for repair, refurbishment, or recycling.

Benefits of circular economy in agriculture



Role of circular economy in mitigating climate change

- ✓ **Reduced greenhouse gas emissions**
- ✓ **Regenerative agriculture:** Practices like composting and cover cropping in circular agriculture systems can improve soil health and increase carbon sequestration in the soil.
- ✓ **Bio-based products:** Utilizing renewable biomass resources to produce bio-based products can help sequester carbon, provided these products are managed sustainably.
- ✓ **Reduction in carbon footprint:** Reducing input use directly decreases emissions from production and transportation.
- ✓ **Energy Efficiency:** Encouraging renewable energy use and energy recovery from waste.
- ✓ **Increased renewable energy use**
- ✓ Waste-to-energy technologies
- ✓ Industrial symbiosis: Improved climate resilience
- ✓ **Resource security:** By reducing reliance on finite resources, the circular economy can enhance resource security and climate resilience, particularly in the face of climate-related disruptions.
- ✓ **Biodiversity conservation:** By promoting sustainable land use practices and reducing pollution, the circular economy can help protect biodiversity and enhance ecosystem resilience, which are crucial for climate change adaptation.
- ✓ **Land use and ecosystem preservation:** Reduced need for resource extraction protects forests, wetlands, and other carbon sinks.
- ✓ **Waste Management:** Diverting organic waste from landfills reduces methane emissions. Recycling metals and plastics reduces energy use compared to primary production.

Circular practices in agriculture

Soil health management

- Application of compost, biochar, and green manure to enhance soil fertility.
- Crop rotation and intercropping to improve nutrient cycling.

Water management

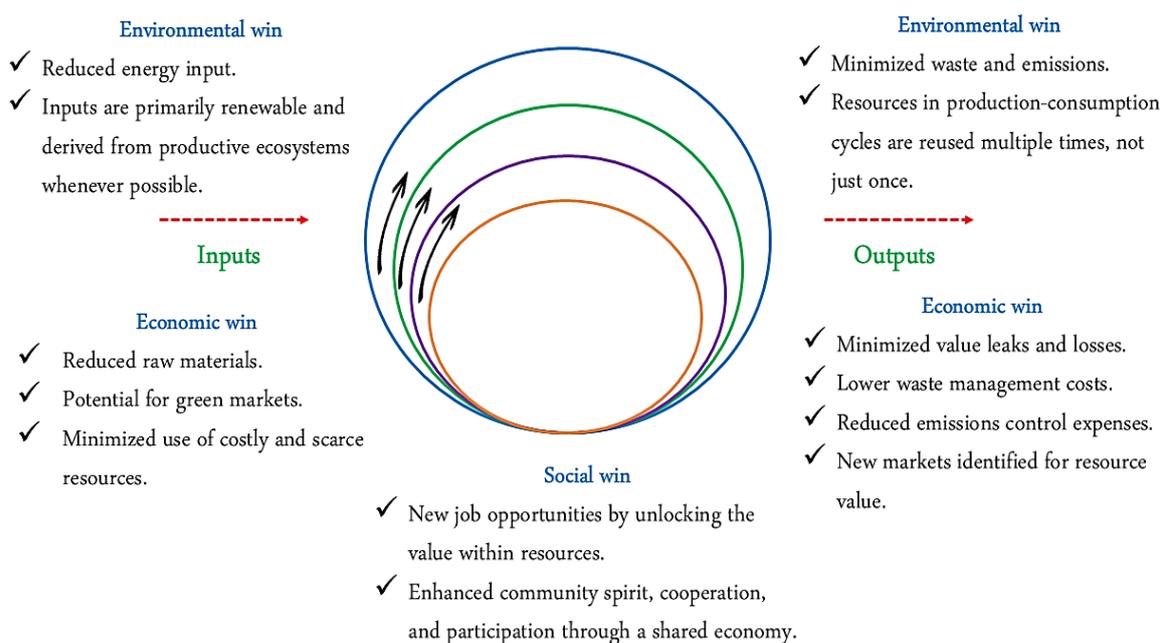
- Use of rainwater harvesting and drip irrigation to conserve water.
- Recycling wastewater for irrigation.

Energy efficiency

- Adoption of renewable energy sources like solar-powered irrigation systems.
- Use of agricultural waste for bioenergy production.

Nutrient recycling

- Returning crop residues and animal manure to fields.
- Using microbial inoculants to enhance nutrient availability.

**Circular economy for sustainable agriculture****Integrated farming systems: A circular approach**

Climate change, land fragmentation, nutritional security, and the growing human population are among the most pressing challenges in agriculture, further exacerbated by declining soil health. Addressing these issues requires sustainable and cost-effective strategies, with the adoption of an Integrated Farming System (IFS) emerging as a prominent solution. The integration of farming systems with livestock offers a means to enhance economic returns per unit area and time, particularly benefiting small and marginal farmers. This approach optimally utilizes agricultural waste through efficient recycling, thereby reducing environmental pollution. Moreover, incorporating livestock components alongside crop production facilitates the sustainable production of eggs, milk, and meat, thereby contributing to both nutritional security and a stable farm income. Given these advantages, there is an urgent need to develop eco-friendly, ecologically sustainable, and economically viable IFS models to ensure long-term agricultural sustainability.

Key components of integrated farming systems

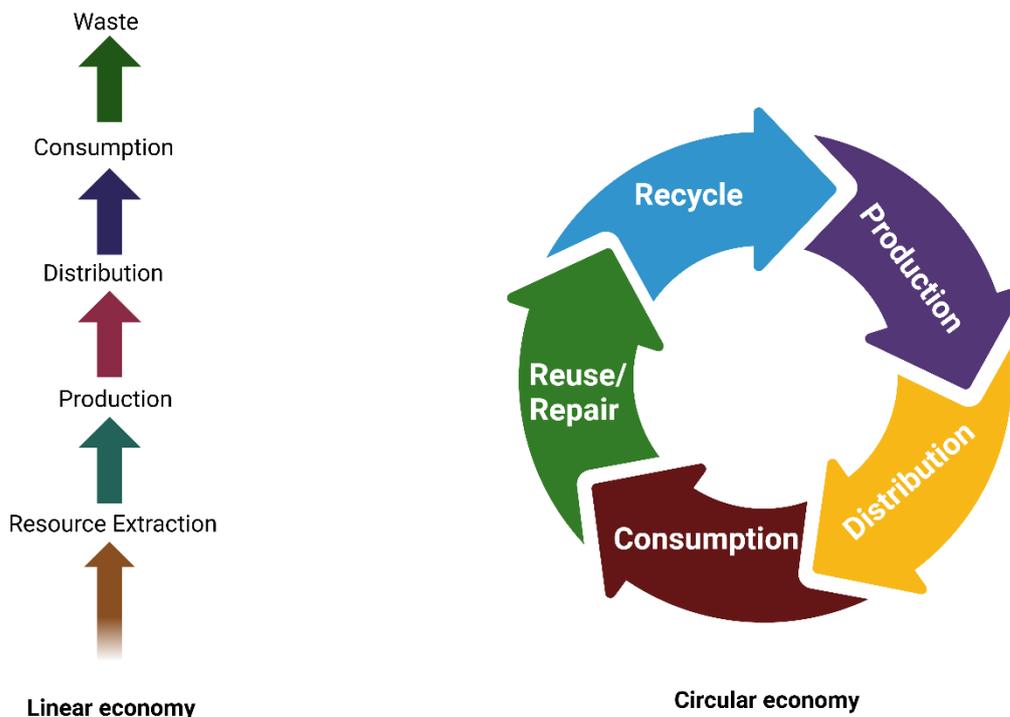
Crop diversification, Livestock integration, Aquaculture integration, Agroforestry, Water management

Indicators for measuring circularity in agriculture

- Nutrient use efficiency: Amount of nutrients recycled within the system.
- Water use efficiency: Ratio of water used to crop yield.
- GHG emissions intensity: Emissions per unit of agricultural output.
- Soil organic carbon content: Indicator of soil health and carbon sequestration.
- Waste recovery rate: Proportion of agricultural waste converted into useful products.

Conclusion

The circular economy offers a transformative approach to agriculture, enabling farmers to maximize production while minimizing environmental impact. By embracing integrated farming systems and other circular economy practices, farmers can create sustainable and resilient agricultural systems capable of addressing challenges related to climate change and resource scarcity. Moreover, by maximizing resource utilization and minimizing waste, the circular economy serves as an effective strategy for climate change mitigation and the development of sustainable agricultural economies. Embracing circular agriculture can revolutionize the sector and contribute significantly to global sustainability goals. Circular economy in agriculture offers a pathway to sustainable food production, aligning environmental conservation with economic growth. Integrated farming systems are central to this approach, fostering resource efficiency, climate resilience, and waste reduction.



CLONAL BREEDING: ENHANCING CROP THROUGH GENETIC UNIFORMITY

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Abstract

Clonal breeding is a genotypic propagation method that maximizes crop productivity through genetic consistency in plant populations. Through avoiding sexual reproduction, the technique sustains desired genotypic and phenotypic characteristics, e.g., increased yield, disease resistance, and environmental tolerance, without genetic recombination. Processes such as vegetative propagation, tissue culture, and grafting facilitate bulk propagation of superior genotypes in plants like potatoes, bananas, and sugarcane. Yet, diminished genetic diversity makes it more susceptible to pathogens evolving and environmental stresses, constraining long-term adaptability. Improved molecular genetics, such as marker-assisted selection and CRISPR-mediated genome editing, present new avenues to improve clonal breeding by strengthening disease resistance and adding controlled genetic variations. Blending genomic technologies with clonal propagation can maximize agricultural productivity while overcoming the shortcomings of genetic homogeneity.

Keywords: Clonal breeding, genetic uniformity, asexual reproduction, vegetative propagation, tissue culture, CRISPR, marker-assisted selection.

Introduction

Clonal breeding is a vital method in contemporary agriculture that allows for the reproduction of genetically high-quality plants with intact desirable characteristics like high yield, disease resistance, and stress tolerance. While sexual reproduction creates genetic diversity, clonal propagation guarantees genetic homogeneity, which makes it especially useful for perennials like bananas, sugarcane, and potatoes (Beyene *et al.*, 2021). The maintenance of elite genetic lines in clonally propagated crops has played a key role in stabilizing food production systems globally (Underwood & Mercier, 2022).

One of the major benefits of clonal breeding is its capability to quickly proliferate high-quality genotypes using methods like somatic embryogenesis, micropropagation, and apomixis (Simmonds, 2020). Yet the clonal population's genetic homogeneity is risky, mainly with respect to disease susceptibility. Past experiences, such as the Irish potato blight, reflect the susceptibility of genetically similar crops to epidemic outbreak of pathogens (Cornaro *et al.*, 2023). Technical developments in molecular breeding, such as genomic selection and CRISPR-mediated genome editing, have been combined with clonal breeding to bring about desired genetic enhancements with the retention of clonal benefits (Gaynor *et al.*, 2017; Xiong *et al.*, 2023). These technologies augment agricultural resilience, positioning clonal breeding as a key tool for global food security under climate change.

Advantages of Clonal Breeding

- **Genetic Homogeneity**

Clonal propagation guarantees that all the progeny has the same genetic material, thus producing a uniform crop with similar yield, quality, and agronomic performance. This

uniformity is especially desirable for commercial farming, where consistency in factors like growth rate, fruit size, and harvest time is extremely important (Jansky *et al.*, 2016; Meuwissen *et al.*, 2001)

- **Disease Resistance**

Some of the selected clones can be bred to exhibit increased resistance against pests and diseases, minimizing the use of chemical pesticides. For instance, genomic selection in clonally reproduced crops like cassava has resulted in increased resistance against viral and fungal diseases (Ly *et al.*, 2013). Moreover, genomic approaches enable the selection and multiplication of resistant genotypes without sacrificing the potential yield (Muñoz *et al.*, 2014).

- **High Yield Potential**

One of the major benefits of clonal breeding is its capacity to maximize and stabilize high-yield potential in subsequent generations. In contrast to seed propagation, in which genetic recombination can cause yield performance variability, clonal propagation guarantees that superior genotypes with high productivity are maintained unchanged (Jansky *et al.*, 2016). This approach is very useful for plants like potatoes, cassava, and bananas where consistency of production is very important for commercial scale production (Miller & Gross, 2011).

Further, clonal multiplication increases productivity through the maintenance of elite genetic qualities that lead to increased yields, including enhanced nutrient acquisition, abiotic stress tolerance, and optimized photosynthetic performance (Kumar *et al.*, 2012). Finally, advances in genomic selection and marker-assisted breeding have, in recent years, further intensified clonal breeding approaches, which allow breeders to select and multiply high-yielding varieties more accurately (Ly *et al.*, 2013). Consequently, clonal breeding continues to be highly relevant to advancing agricultural efficiency and global food security.

- **Faster Propagation**

Clonal propagation greatly speeds up plant propagation by avoiding the genetic recombination and variation that comes with sexual reproduction. Conventional breeding techniques take several generations to stabilize favorable traits, while clonal propagation enables the instant and mass multiplication of superior genotypes with excellent agronomic characteristics (Kumar *et al.*, 2012). This is particularly beneficial for perennial or slow-growing crops, like sugarcane, cassava, and fruit trees, where quicker propagation shortens the period of time to gain full commercial level production (Miller & Gross, 2011).

In addition, sophisticated methods such as micropropagation and somatic embryogenesis have supplemented the efficiency of clonal propagation even further. These biotechnology approaches facilitate the generation of disease-free, genetically uniform plants at a significantly higher speed than conventional methods (Jansky *et al.*, 2016). Furthermore, tissue culture protocols also provide for year-round propagation under controlled conditions, eliminating seasonal constraints and providing a steady supply of planting material (Ly *et al.*, 2013). Through speeding up the breeding process, clonal propagation supports greater agricultural productivity and sustainability.

- **Preservation of Desirable Traits**

Clonal propagation guarantees that desirable traits, including drought resistance, fruit quality, and disease resistance, are not altered over generations. In contrast to seed-based propagation, which can introduce genetic variation and undermine desirable traits, clonal

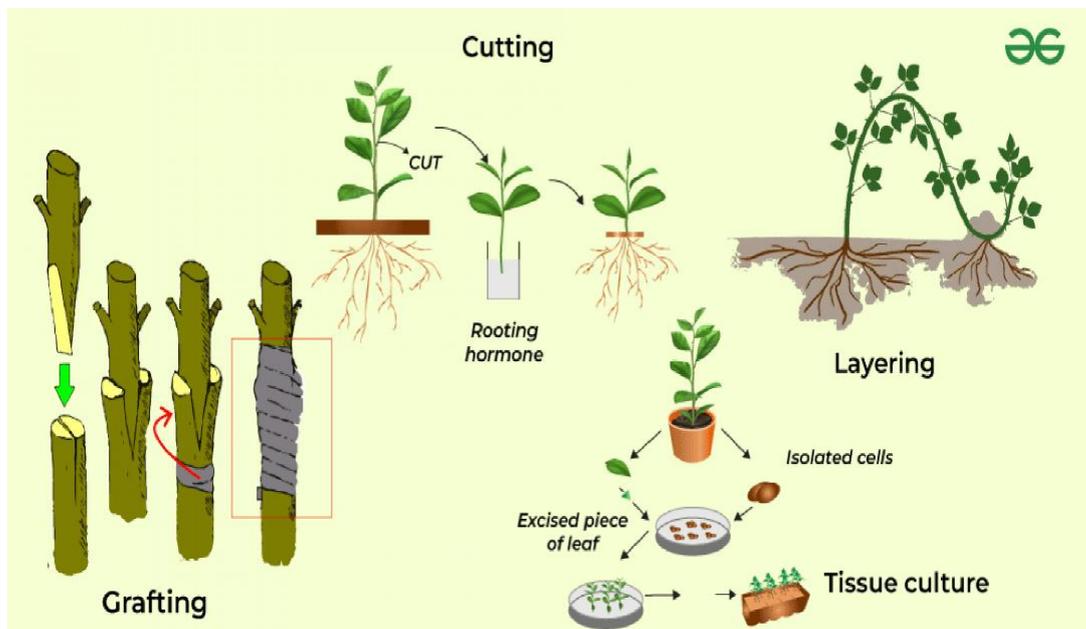
breeding enables the direct continuation of elite genotypes, enhancing long-term agricultural stability (Leitch & Leitch, 2008).

Methods of Clonal Breeding

Vegetative propagation:

Vegetative propagation is a common means of clonal propagation in which new crops are derived from vegetative structures like stems, roots, leaves, tubers, bulbs, and runners. The method ensures the absolute genetic copy of the parent crop and maintains important agronomic characteristics like superior yield, resistance to diseases, and environmental tolerance (Bonga & von Aderkas, 1992).

This is especially useful for plants that fail to produce viable seeds or have extensive generational cycles. Potato tubers and cassava stem cuttings, for instance, are widely utilized for propagation because they can develop into mature plants without genetic variation (George *et al.*, 2024). Moreover, in fruits such as bananas and apples, vegetative plant propagation by suckers or grafting ensures desired fruit quality and growth traits (Johnson & Veilleux, 2001).



Source: inspiredpencil.com

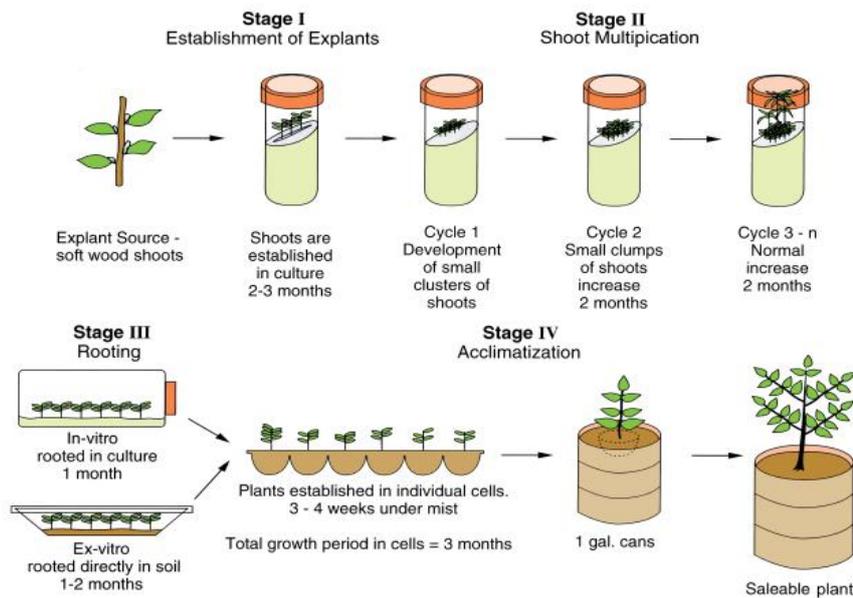
Vegetative propagation also has the advantage of preserving elite genotypes in forestry, providing for even tree development and wood quality. Additionally, improved biotechnology, including hormone treatments and controlled environments, have increased propagation efficiency, resulting in increased crop productivity and sustainability (Murashige & Skoog, 1962).

Tissue culture (Micropropagation)

Tissue culture, or micropropagation, is a sophisticated technique of clonal propagation that allows for the rapid increase of genetically uniform plants under sterile laboratory conditions. The process includes in vitro cultivation of plant tissues, organs, or cells on nutritional media with added plant growth regulators. By avoiding the limitations of conventional breeding, tissue culture makes possible the commercial production of high-yielding and disease-free plant genotypes (George *et al.*, 2024).

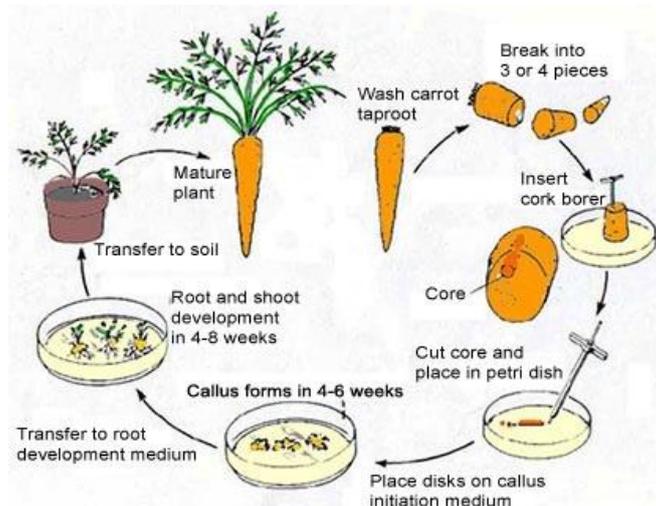
The procedure generally encompasses a number of important steps:

- i) Initiation, when explants (e.g., shoot tips or meristematic tissues) are sterilized and placed in culture media.
- ii) Multiplication, when cell division is provoked by using cytokinin and auxin hormones.
- iii) Rooting, encouraging root development for plantlet establishment.
- iv) Acclimatization, when plantlets are gradually acclimated to outside environments before being moved to the field (Murashige & Skoog, 1962).



Source: www.onlinebiologynotes.com

Tissue culture is especially useful in propagating hard-to-cultivate crops like bananas, orchids, and oil palm. It provides uniformity of favorable characteristics like resistance to disease, enhanced nutritional value, and stress tolerance. It also contributes significantly to the conservation of threatened and rare plant species by allowing large-scale propagation with little genetic variation (Kaepler *et al.*, 2000).



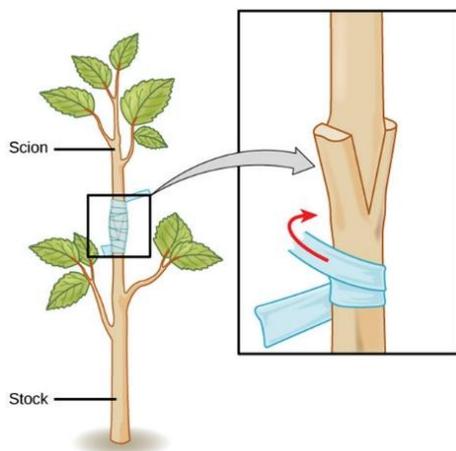
Source: www.quora.com

In addition, this method has the effect of hastening breeding programs through the rapid insertion of new and enhanced cultivars. Its complementarity with molecular breeding technologies like genetic transformation and somatic embryogenesis has further increased its scope in contemporary agriculture, making it the foundation of sustainable crop production (Johnson & Veilleux, 2001).

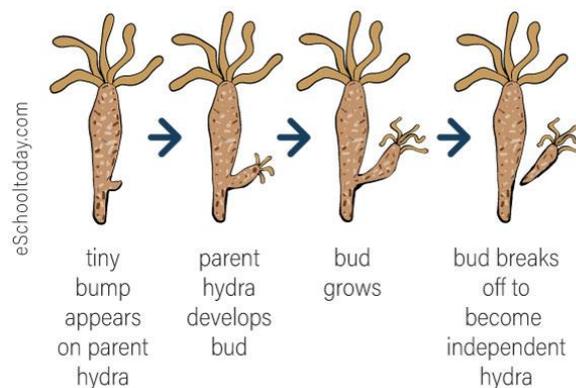
Grafting and Budding:

Grafting and budding are significant methods of clonal breeding that entail uniting two contrasting parts of a plant to improve productivity, stress tolerance, and disease resistance. In grafting, the top of the plant (scion) is joined with the bottom portion with developed roots (rootstock), enabling the resultant plant to have the qualities of both parent plants as preferred (Johnson & Veilleux, 2001). This is a widely employed practice in fruit trees like apples, citrus, and grapes, wherein better fruiting varieties are grafted onto strong rootstocks to enhance growth performance and environmental tolerance (George *et al.*, 2024).

Budding is a grafting method specifically used in the insertion of one bud from the scion into the rootstock. This process is very efficient in propagating plants such as roses, peaches, and avocados. It promotes mass propagation that is uniform, and the maturity period as well as the period for fruiting is decreased (Kaepler *et al.*, 2000).



Source: Morningchores.com



Source: eSchooltoday.com

Both budding and grafting aid in increasing crop production through genetic consistency, which provides consistent quality of fruit and enhancing plant resistance against soilborne diseases. Besides, other current innovations like micrografting and tissue-culture-supported grafting have extended further to enhancing the efficiency of the methods, which has made them essential components of commercial horticultural and forestry programs globally (Murashige & Skoog, 1962).

Application of clonal breeding in agriculture:

1. Staple Crops (Potatoes, Bananas, Sugarcane, Cassava)

Clonal breeding is extensively practiced in staple crops where disease resistance and uniformity are key. Potatoes, for example, have clonally propagated varieties that guarantee tuber quality and resistance to diseases such as late blight (Jansky *et al.*, 2016). Bananas, which have no viable seeds, are also propagated clonally to preserve uniform fruit quality and resistance to diseases such as Fusarium wilt (Jones, 1965). Sugarcane is advantaged by clonal propagation through maintaining high-sugar-yielding genotypes and elevating resistance against pests (Jannoo *et al.*, 1999). Clonal propagation of cassava using stem cuttings improves productivity while genetic resistance to viral disease is sustained (Ly *et al.*, 2013).

2. Tree Crops (Apple, Grape, Coffee)

Clonal reproduction is necessary for perennial tree fruits to guarantee that fruit size, taste, and quality are equal. Apple development is dependent upon clonal rootstocks to offer improved disease tolerance and maximize the vigor of trees (Kumar *et al.*, 2012). Clonal reproduction in grapevines ensures uniform wine quality and retains advantageous features like berry size and taste (Miller & Gross, 2011). In coffee too, vegetative reproduction through somatic embryogenesis maintains high yield and disease-free plants (Muranty *et al.*, 2015).

3. Large-Scale Commercial Farming

Clonal propagation facilitates extensive industrial agriculture through the swift multiplication of superior cultivars. This practice is essential in commercial plantations where consistency in plant traits results in uniform production cycles and quality (Meuwissen *et al.*, 2001). Genetic variability removal allows farmers to maximize planting density, mechanization, and harvesting techniques, thereby enhancing economic viability.

Disadvantages and limitations of clonal breeding:

Susceptibility to Diseases

Clonal propagation leads to genetically similar plants, which make them more vulnerable to epidemic diseases and insects. All clones having the same gene pool, they do not have the diversity that can help some individuals resist infections. For instance, the Irish potato famine was complicated by the extensive cultivation of genetically similar potatoes, which rendered the crop extremely vulnerable to *Phytophthora infestans* (Gepts and Hancock, 2006; Brescghello, 2013). This absence of diversity continues to be a real challenge in today's clonal breeding schemes (Heinemann *et al.*, 2014).

Loss of evolutionary adaptability

Lack of genetic recombination in clonally propagated crops hinders their potential to evolve according to changing environmental factors, such as climate variability and emerging diseases. This lowered adaptability could lead to a decrease in long-term sustainability of clonal crops over sexually reproducing species that have the capability to evolve over generations naturally (Borlaug, 1983; Kasha and Kao, 1970).

High Initial Costs

Tissue culture and controlled propagation methods involve heavy initial investment in laboratory facilities, trained personnel, and disease-free plant material. Although clonal breeding may be economical in the long run, the initial investment may be beyond the reach of small farmers (Moose and Mumm, 2008; Rauf *et al.*, 2010).

Dependency on Parental Plant Quality

If the parental plant has any undesirable traits, such as susceptibility to disease or poor yield, these weaknesses will be perpetuated in all cloned offspring. Unlike sexual reproduction, where beneficial mutations and genetic recombination can introduce variability, clonal breeding cannot overcome inherent genetic limitations (Jackson *et al.*, 1985; Kirschner and Štěpánek, 1994).

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CONCEPT OF CONTROLLED TRAFFICKING FARMING SYSTEMS IN INDIA

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Abstract

Traffic induced soil compaction, as well as the associated negative effects on soil structure and soil functions can be reduced by the use of permanent traffic lanes for all field vehicles – known as Controlled Traffic Farming (CTF). Annett *et al.*, (2019). The world is currently facing many challenges includes ensuring food security, minimizing environmental damage, and ensuring sustainable agriculture production. About 68 million ha of land worldwide has been affected with soil compaction which could rise potentially in the coming years. Rashmi *et al.*, (2019). As the farmers are facing many challenges such as water scarcity, soil degradation, and climate change. Controlled trafficking farming system is a management tool which is used to reduce the damage to soils caused by heavy or repeated agricultural machinery passes on the land. This system mainly occurs in large scale land holdings and can be reduced by some agronomical methods like conservation tillage, crop rotation, sub soiling and growing cover crops.

Keywords: Controlled Trafficking Farming, Soil compaction, traffic lanes

Introduction

CTF involves designating permanent traffic lanes for farm machinery, separating them from crop zones. This simple yet effective approach reduces soil compaction, promotes soil health, and increases crop productivity. It creates two zones, non-trafficked crop beds and cropped or non-cropped traffic lanes, both of which are optimized for their different functions. Disorganized or random traffic causes an increase in the bulk density of any given soil, which increases its strength and reduces its porosity (Chamen *et al.*, 2010). CTFS has gained attention in states like Punjab, Haryana, and Uttar Pradesh, where intensive agricultural practices and large-scale farming are common. Adoption of such systems has also been explored in other states with issues related to soil health and water management.

Benefits of Controlled Traffic Farming

The main benefit of controlled traffic farming is to reduce soil compaction which is mainly caused in large land holdings where a huge use of heavy farm machinery. This leads to decreased soil health affecting crop yield and crop growth. There are some of the benefits of controlled traffic farming listed below;

Reduced Soil Compaction: By confining traffic to specific lanes, CTF minimizes soil compaction, preserving soil structure and promoting healthy root growth.

Increased Crop Yields: With reduced soil compaction and improved soil health, crops grow stronger and more resilient, leading to increased yields.

Improved Soil Health: CTF promotes soil biota, organic matter, and water infiltration, creating a more sustainable and productive soil ecosystem.

Reduced Fuel Consumption: By optimizing machinery use and reducing soil compaction, CTF can lead to significant fuel savings.

Besides CTF systems, soil compaction can be reduced by loosening the soil using subsoiler once after every 4-5 years and planting deep rooted crops. Sub-soiling is done in compacted soils with hardpans or compacted layers that restrict root growth and soils with poor drainage, leading to waterlogging or erosion. Deep-rooted crops: Crops with deep root systems, like alfalfa or corn that benefit from improved subsoil conditions. Sub-soiling may not be effective in all soil types, such as sandy soils and is most effective when soil is relatively dry. Specialized equipment, like subsoilers or deep rippers, is required. Cover crops are plants grown between crop cycles to protect and enhance the soil. Examples: Winter Cover Crops like Winter rye, Hairy vetch, Clover Various types, like red clover or white clover, offer nitrogen fixation and soil benefits. Summer Cover Crops like Buckwheat, Sorghum-Sudan grass, Cowpeas.

Cover Crops have so many benefits including soil erosion control to protect topsoil from wind and water erosion, soil health improvement which adds organic matter, improves structure, and increases fertility. Weed suppression outcompetes weeds for resources, reducing herbicide use, pest and disease management which attracts beneficial insects and reduces pest pressure and helps mitigate climate change impacts by sequestering carbon and improving soil water-holding capacity. The figure 1 shows the effects of heavy farm machinery on soil properties and traffic ability.

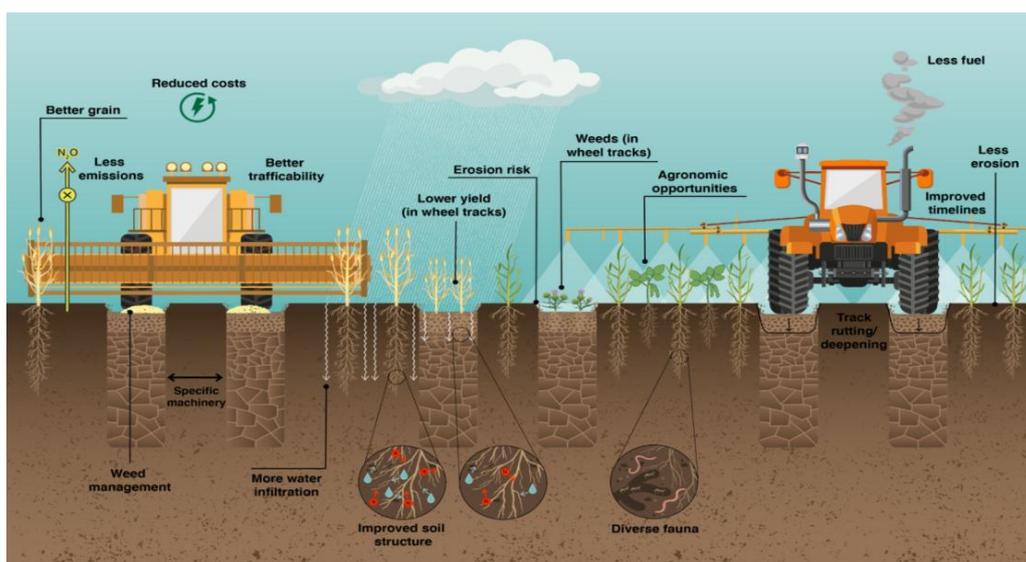


Fig 1. Effects of Controlled Traffic Farming in Field

Methods to adopt Controlled Traffic Farming System

There are some steps to achieve controlled traffic system While CTF offers numerous benefits, implementing it require careful planning and investment, farmers should:

Designate Traffic Lanes: Identify permanent traffic lanes, typically using GPS guidance, to ensure accurate and consistent machinery movement.

Separate Crop Zones: Divide the farm into crop zones, each with its own specific management practices, to optimize crop growth and reduce soil compaction.

Adapt Machinery: Modify farm machinery to fit within designated traffic lanes, minimizing soil compaction and reducing crop damage.

Assess Soil Conditions: Evaluate soil type, moisture levels, and compaction to determine the best CTF approach.

Invest in Guidance Systems: Utilize GPS guidance and auto-steering systems to ensure accurate machinery movement.

Match implement widths so that adjacent passes are in the same place for all machines working in the field.

Match the track widths (the distance between wheel centers on the same [axle](#)) of all field machinery and keep machines in exactly the same place year in year out.

Achieve tramlines and using RTK positioning systems.

Traffic lanes or tramlines are the specific machinery pathways in the field which is shown below



Fig 2. Tramlines

Methods to reduce soil compaction

There are many agronomical methods to reduce traffic induced soil compaction which includes conservation tillage, growing cover crops like Buckwheat, Sorghum-Sudan grass, Cowpeas, crop rotation and sub soiling one after every 4-5 years in the field. Some are given below in Fig 3.

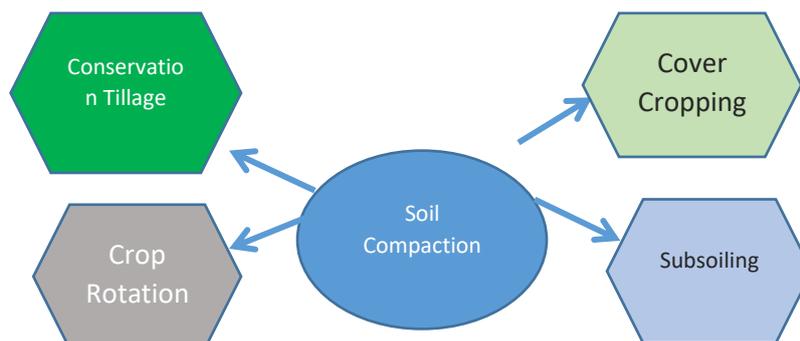


Fig 3. Methods to reduce soil compaction

CTF Calculator as a planning tool

Matching machinery width and tracks to establish a controlled traffic farming system can be a daunting prospect, particularly where current machinery is of variable dimensions. The '[CTF Calculator](#)' is a useful web-based tool that can assist farmers and their consultants with machinery investment planning. The calculator estimates the percentage area of the paddock that is 'wheeled' by different machinery combinations, and calculates the estimated areas impacted and thus the benefit of managing compaction through the adoption of controlled traffic farming. Users enter their current machinery specifications into the calculator for each farming operation – for example, seeding tractor, air cart and bar, or spreading tractor and spreader to determine the area wheeled for each farming operation, and an overall combined wheeled percentage for all operations over the season.

Users can choose to select from a library of pre-loaded machinery options, or specify their own current tyre size, track gauge (i.e. tyre centre to centre dimension) and operating width. The user can then compare various combinations of proposed new and modified machinery to match track gauges and reduce wheeling percentage in the calculator.

Conclusion

Controlled trafficking farming systems can be an effective strategy for improving sustainability in Indian agriculture, enhancing soil health, and conserving water. However, it requires appropriate investment, training, and infrastructure for broader adoption. This system can be adopted in large land holdings where heavy machineries are used which cause soil compaction. CTFS has gained attention in states like Punjab, Haryana, and Uttar Pradesh, where intensive agricultural practices and large-scale farming are common. Adoption of such systems has also been explored in other states with issues related to soil health and water management.

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IMPORTANT PESTS AND DISEASES OF DRAGON FRUIT

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Abstract

Dragon fruit (*Hylocereus* sp.), belonging to the Cactaceae family, is a tropical and subtropical fruit recognized for its vibrant appearance and nutritional values. Its popularity is steadily rising among growers due to increasing consumer demand. In nature, no organism is entirely free from natural enemies. Despite its attractiveness and market potential, dragon fruit cultivation encounters various biotic challenges, including insect pests and diseases. While this exotic fruit is generally less affected by major pest and disease issues, effective management strategies are still crucial to maintaining healthy plants and high-quality fruits. This overview explores key arthropod pests, diseases, and their management tactics, emphasizing recent advancements and integrated pest management (IPM) strategies.

Key words: Biotic stress, Dragon fruit, Insect pests, Diseases

Introduction

Dragon fruit, or pitaya, is a tropical fruit gaining worldwide popularity for its distinctive appearance and health benefits. Originally from Central and South America, it has successfully adapted to various regions with favourable climates, such as Southeast Asia and Australia. There is a great scope of cultivation of dragon fruits in eastern India (Jena *et al.*, 2024). Its characteristic climbing vines and broad, flat pads make it susceptible to numerous pests and diseases. Proper management is essential to preserving plant health and maximizing yield. This review explores the primary insect pests and diseases affecting dragon fruit while assessing current management strategies.

Insect Pests

1. Mealybugs (Pseudococcidae)

Mealybugs are a significant pest of dragon fruit, characterized by their white, waxy coating. They feed on plant sap, causing wilting and reduced fruit quality. The most common species affecting dragon fruit are *Pseudococcus longispinus* and *Pseudococcus cryptus*.

2. Scale Insects (Coccoidea)

Species like *Aonidiella aurantii* and *Saissetia coffeae*, are problematic for dragon fruit, attaching themselves to plant stems and leaves (Kondo *et al.*, 2009). In west Bengal, *Coccus viridis* (Green) have been reported to infest pink and white fleshed fruits in close association with red ants and mealy bugs (Kar *et al.*, 2023). Carrillo *et al.* (2021) has reported the presence of soft scale insect, *Philephedra tuberculosa* Nakahara and Gill on fruits and hard scale, *Diaspis echinocacti* (Bouche) on stem and fruits in South Florida.

3. Spider Mites (Tetranychidae)

Spider mites, including *Tetranychus urticae*, are a concern for dragon fruit growers. They cause stippling and webbing on leaves, leading to reduced photosynthesis and plant health (Enns, 2020).

4. Tissue feeders

Damage by ants have been reported by Karunakaran *et al.* (2019) from India. Though the colonies get attracted to the excreted honey dew over plant surfaces, high population can cause severe damage to stem, flowers and fruits. During rainy season fruit flies (*Bactrocera* sp.) pose threat to dragon fruits. The infested fruits turn brown at the contact point of skin and flesh and fruit dropping also seen. Two species of beetles viz., *Protaetia* sp., and *Hypomeces squamesus* have been recorded to damage dragon fruits. Young and old branches, flower buds and fruits are usually attacked by the beetles. Nine moth species have been found to feed and cause damage in dragon fruit in Taiwan, including *Porthesia taiwana*, *Hemerophila atrilineata*, *Spodoptera litura*, *Helicoverpa armigera*, *Trichoplusia* sp., *Amsacta lactinea*, *Olepa schleiini*, *Orgyia postica*, and *Ostrinia* sp. (Huang and Chiu, 2021).

5. Other sucking pests

Two aphid species such as, *Aphis craccivora* Koch. and *A. gossypii* Glover have been found to feed on flowers and fruits in US and Vietnam (Carrillo *et al.*, 2021). The incidence of thrips have been recorded in countries like Malaysia, US and Vietnam. The shaded stem and fruits and normally infested with the pest. Surface scarification are the symptoms of this pest.

Integrated Insect Pest Management Practices

- Conducting regular inspections, maintaining clean cultivation, removing weeds, and eliminating residual plant materials can help prevent early infestations of mealybugs, ants, beetles, and fruit flies.
- Applying azadirachtin extracts has proven effective against ants and thrips. Insecticidal soaps and neem oil work well against mealybugs, while horticultural oils and systemic insecticides effectively control scale insects.
- In certain countries, methyl eugenol traps and baiting chemicals are widely used to manage fruit flies, whereas light traps are effective in capturing adult beetles.
- Using sticky materials on plant stems can prevent infestations of mealybugs and ants. Scraping off scale insects and using high-pressure water sprays can help control their populations. Additionally, handpicking caterpillars based on their density is a viable method of control.
- Various natural predators contribute to pest management. Lady beetles and lacewings feed on sucking pests, while *Cryptolaemus montrouzieri* is particularly effective against mealybugs. Parasitic wasps like *Encarsia perniciosi* help manage scale insect populations, making them valuable in dragon fruit cultivation. Similarly, predatory mites such as *Phytoseiulus persimilis* are used to control spider mites.
- Maintaining optimal humidity levels and avoiding overhead irrigation can help reduce mite infestations.
- As dragon fruit is still an emerging and underutilized crop in countries like India, the availability of labelled pesticides for controlling arthropod pests and diseases remains limited. However, in other countries where registered insecticides are accessible, expert recommendations can enhance pest management and improve yield. For instance, in Vietnam, clothianidin, thiamethoxam, and abamectin are commonly used to control thrips.

Diseases

Fungal diseases

Anthracnose is most reported disease among various fungal pathogens infecting dragon fruits. Various species of *Colletotrichum* such as, *C. gloeosporioides*, *C. aenigma*, *C. siamense*, *C.*

karstii and *C. truncatum* cause anthracnose. Ganeshan *et al.* (2023) has reported about the association of *Lasiodiplodia* species causing stem rot in dragon fruit in the coastal belt of Odisha, the eastern India. The stem rot disease was characterized by yellowing of the stem, followed by softening of the stem tissues with fungal fructifications of the pathogen in the affected tissues. *Fusarium oxysporum* causes the basal rot of dragon fruit. However different species harbours different species of *Fusarium* spp. as endophytes. The dreaded pathogen *Bipolaris cactivora* has been reported in Israel, China (fruits imported from Vietnam), Thailand, Taiwan, US, Korea, and Japan causing both pre- and post-harvest rot diseases.

Botrytis rot, caused by the fungus *Botrytis cinerea*, is a significant disease in dragon fruit. It appears as gray, fuzzy mold on fruit and stems, especially under high humidity conditions. Powdery mildew, caused by *Leveillula taurica*, is characterized by white, powdery spots on leaves and stems. It reduces plant vitality and fruit quality. Phytophthora root rot, caused by various *Phytophthora* species, leads to wilting and plant decline. It thrives in poorly drained soils and can be devastating if not managed.



Fig. Symptom of Anthracnose on leaves of dragon fruit
(location- Bhubaneswar, Odisha)

Bacterial diseases

Soft rot and stem rot caused respectively, by *Enterobacter cloacae* and *Paenibacillus polymixa* are the two bacterial diseases of dragon fruits (Zhang *et al.*, 2017). The former has been reported in Malaysia and the latter in China. Both diseases start with a water-soaked appearance in the infected tissues. Bacterial soft rot-infected stems show yellowish to brownish soft rot symptoms.

Viral diseases

Cactus virus X has been associated with virus disease symptoms in dragon fruits. It has been detected in dragon fruit in the US, Taiwan, Korea, Japan, China and is widely distributed in Malaysia.

Integrated Disease Management

- Improving air circulation and avoiding excessive watering can help prevent Botrytis rot. Increasing plant spacing and reducing humidity can help mitigate powdery mildew. Ensuring

well-drained soil and avoiding overwatering are crucial preventive measures against *Phytophthora*.

- Applications of *Trichoderma* sp. can help to suppress *Botrytis cinerea*. Beneficial microbes like *Bacillus subtilis* can suppress powdery mildew. Incorporating beneficial organisms like *Trichoderma harzianum* can reduce Phytophthora root rot.
- Fungicides such as sulphur or copper-based products are effective in managing botrytis and powdery mildew disease. Fungicides such as metalaxyl and fosetyl-Al are effective against *Phytophthora*.

Conclusion

In the Indian context, pests such as mealy bugs, aphids, and termites pose significant challenges to dragon fruit cultivation (Nangare *et al.*, 2020). Effective management through an integrated approach—combining cultural, mechanical, biological, and chemical methods—is crucial for maintaining plant health and maximizing yields. Ongoing research and innovation in pest control strategies will further strengthen the sustainability and productivity of dragon fruit farming in India, ensuring its long-term viability as a profitable agricultural venture.

Conflict of interests: The author has declared that no conflict of interest exists.

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ENTREPRENEURSHIP IN FISHERIES: CHALLENGES, OPPORTUNITIES

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Entrepreneurship is the process of identifying opportunities, taking risks, and creating value by innovating, organizing, and managing resources to bring new ideas, products, or services to the market.



Fig: Fish Processing Industry

In the context of fisheries, entrepreneurship involves leveraging the potential of aquatic resources to create sustainable and profitable ventures. This can range from small-scale fish farming and processing to large-scale aquaculture operations and technology-driven solutions for the seafood industry. Entrepreneurs in this sector play a crucial role in addressing global challenges such as food security, nutritional security, environmental sustainability, and economic development.

The fisheries sector is a vital component of the global economy, providing livelihoods for millions of people and serving as a critical source of food as well as nutritional security. With the growing demand for seafood and the depletion of natural fish stocks, entrepreneurship in

fisheries has emerged as a promising avenue for innovation, sustainability, and economic growth. However, this sector is not without its challenges. This article explores the opportunities and challenges faced by entrepreneurs in the fisheries industry.

Opportunities in Fisheries Entrepreneurship:

i. Growing Demand for Fish and Seafood

The global demand for seafood is on the rise, driven by population growth, increasing health consciousness, and the recognition of fish as a rich source of protein and omega-3 fatty acids. Entrepreneurs can tap into this demand by exploring value-added products such as processed fish, ready-to-eat meals, and fish-based supplements.

ii. Aquaculture Expansion

With wild fish stocks under pressure, aquaculture (fish farming) has become a key area of opportunity. Entrepreneurs can invest in sustainable aquaculture practices, including the farming of high-demand species like Major carps, Cat fishes, shrimp, and tilapia. Innovations in feed, breeding techniques, and water management offer further avenues for growth.

iii. Technology and Innovation

The integration of technology in fisheries, such as IoT-enabled monitoring systems, drones, and blockchain for supply chain transparency, presents significant opportunities. Entrepreneurs can develop or adopt these technologies to improve efficiency, reduce waste, and ensure traceability in the seafood supply chain.

iv. Sustainable Practices

Consumers and governments are increasingly prioritizing sustainability. Entrepreneurs who adopt eco-friendly practices, such as reducing bycatch, minimizing carbon footprints, and promoting responsible fishing, can differentiate themselves in the market and attract environmentally conscious customers.

v. Export Potential

Many developing countries with rich marine resources have the potential to expand their seafood exports. Entrepreneurs can play a pivotal role in bridging the gap between local fisheries and international markets by improving processing, packaging, and logistics.

Challenges in Fisheries Entrepreneurship**i. Environmental Concerns**

Overfishing, habitat destruction, and climate change pose significant threats to the fisheries sector. Entrepreneurs must navigate these challenges by adopting sustainable practices, but this often requires significant investment and expertise.

ii. Regulatory Hurdles

The fisheries industry is heavily regulated to protect marine ecosystems and ensure food safety. Entrepreneurs must comply with complex regulations, which can vary by region and species. Overcoming the barriers of these regulations may be time-consuming and costly for the entrepreneurs.

iii. Access to Capital

Starting or scaling a fisheries business often requires substantial upfront investment in equipment, technology, and infrastructure. Many entrepreneurs, especially in developing countries, struggle to secure financing due to the perceived risks associated with the sector.

iv. Market Volatility

Fish prices can be highly volatile due to factors such as seasonal availability, weather conditions, and global market trends. Entrepreneurs must develop strategies to manage this volatility, such as diversifying their product offerings or entering into long-term contracts.

v. Lack of Infrastructure

In many regions, inadequate infrastructure for storage, transportation, and processing leads to significant post-harvest losses. Entrepreneurs must invest in cold storage facilities, efficient logistics, and modern processing units to overcome these challenges.

vi. Skill Gaps

The fisheries sector requires specialized knowledge in areas such as marine biology, aquaculture, and supply chain management. Entrepreneurs often face difficulties in finding skilled labor or may need to invest in training programs for their workforce.

Strategies for Success in Fisheries Entrepreneurship**i. Embrace Sustainability**

Entrepreneurs should prioritize sustainable practices to ensure long-term viability. This includes adopting eco-friendly fishing methods, reducing waste, and obtaining certifications such as the Marine Stewardship Council (MSC) label.

ii. Leverage Technology

Investing in technology can improve efficiency, reduce costs, and enhance product quality. For example, data analytics can help optimize fishing operations, while blockchain can ensure transparency in the supply chain.

iii. Collaborate with Stakeholders

Building partnerships with governments, NGOs, and local communities can help entrepreneurs navigate regulatory challenges, access funding, and gain market insights.

iv. Focus on Value Addition

Entrepreneurs can increase profitability by moving up the value chain. This includes processing fish into higher-value products, such as fillets, smoked fish, or fish oil, and exploring niche markets like organic or premium seafood.

v. Invest in Training and Capacity Building

Addressing skill gaps through training programs can improve productivity and innovation. Entrepreneurs should also focus on educating consumers about the benefits of sustainable seafood.

Conclusion

Entrepreneurship in fisheries offers immense potential to drive economic growth, promote food security, and address environmental challenges. However, success in this sector requires a careful balance of innovation, sustainability, and resilience. By addressing the challenges and leveraging the opportunities, entrepreneurs can play a transformative role in shaping the future of the fisheries industry. As the world continues to grapple with the dual pressures of population growth and environmental degradation, fisheries entrepreneurship will remain a critical area of focus for sustainable development. Entrepreneurs in this field are not just business owners; they are innovators and stewards of aquatic resources, contributing to a healthier planet and a more prosperous future.

ADVANCED SILVICULTURE TECHNIQUES FOR PLANTATION FORESTRY

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Abstract

Advanced silvicultural practices in plantation forestry are designed to enhance tree growth, improve quality, and increase productivity, all while balancing ecological and economic priorities. With the incorporation of technologies like remote sensing and spatial analysis, modern silviculture has become more precise and efficient. This article highlights the latest silvicultural innovations used in Indian plantation forestry, with a focus on cutting-edge approaches such as precision silviculture, genetic improvement programs, mixed-species plantations, and climate-resilient forestry strategies.

Keywords: Silviculture, plantation forestry, technological integration, productivity.

Introduction

Plantation forestry combines scientific techniques with practical knowledge to grow, manage, and maintain trees for diverse outputs. In India, plantation forests have traditionally played a vital role in satisfying the growing need for timber, fuelwood, and non-timber forest products, while also addressing environmental issues like soil erosion and land degradation (Gupta *et al.*, 2021). Historically, Indian plantation forestry focused on fast-growing exotic species like Eucalyptus and Acacia, but recent concerns about biodiversity loss and climate change have spurred interest in advanced silvicultural techniques that prioritize ecological balance alongside timber productivity (MoEFCC, 2020). The evolving landscape of Indian plantation forestry requires a combination of traditional knowledge and modern scientific techniques to achieve sustainable management and resilience. Advanced silvicultural practices offer innovative solutions to meet these objectives by integrating cutting-edge technologies with natural resource management practices. The evolving landscape of Indian plantation forestry requires a combination of traditional knowledge and modern scientific techniques to achieve sustainable management and resilience. Advanced silvicultural practices offer innovative solutions to meet these objectives by integrating cutting-edge technologies with natural resource management practices.

1. Site Preparation and Soil Management

Effective site preparation is the cornerstone of successful plantation establishment, and in India, site-specific management is gaining importance. Various techniques are employed based on soil

types, climate, and topography. In arid and semi-arid regions, soil conservation practices such as contour bunding, water harvesting pits, and mulching are commonly used to conserve soil moisture and reduce erosion (Rao *et al.*, 2019). In addition to conventional soil preparation, modern practices in India incorporate soil amendments such as biochar and vermicompost, which improve soil fertility, enhance nutrient availability, and stimulate microbial activity (Sharma & Bhatnagar, 2020). Furthermore, controlled burning is occasionally used for forest floor clearing in certain regions, though it must be carefully managed to avoid unintended negative consequences on soil and air quality.

2. Selection of Species and Genotypes

A major advancement in Indian forestry has been the adoption of improved planting materials. Clonal propagation of species like *Eucalyptus*, *Acacia*, and *teak* ensures traits such as faster growth and better wood quality. Hybrid variants, especially of *Eucalyptus*, are being increasingly cultivated for timber and energy needs (Murugesan *et al.*, 2018). Research institutions like FRI have played a key role in distributing improved clones of bamboo and teak (FRI, 2022). Nonetheless, the emphasis on exotic species has prompted concerns regarding their impact on native biodiversity, emphasizing the need for balance (Gupta *et al.*, 2021).

3. Precision Silviculture and Smart Forestry

The integration of precision silviculture is one of the most transformative advancements in plantation forestry, and it is becoming increasingly important in India. Remote sensing tools and Geographic Information Systems (GIS) allow for efficient mapping of plantation areas and provide valuable insights into the health and growth rates of trees. By using satellite imagery and drones, plantation managers can monitor canopy cover, detect pest infestations, and assess water stress in real time, enabling timely intervention (Nair & Kumar, 2021). In addition, Internet of Things (IoT) sensors embedded in trees and soil can monitor variables such as soil moisture, temperature, and nutrient levels (Patel *et al.*, 2020). This technology facilitates site-specific management, adjusting watering, fertilization, and pest control according to the precise needs of each tree or section of the plantation.

4. Mixed-Species and Multi-Strata Plantations

Incorporating diverse species in plantations brings ecological advantages such as improved biodiversity, soil enrichment, and resistance to pests. For instance, combining *Dalbergia* with *Melia dubia* boosts nutrient levels and crop yields (Chavan *et al.*, 2021). Multi-strata models, featuring trees, shrubs, and groundcover, are increasingly promoted under India's agroforestry policy (GoI, 2014). States like Kerala and Tamil Nadu have successfully integrated high-value crops like turmeric and ginger alongside timber species, improving both income and environmental outcomes.

5. Intensive Silviculture Practices

Intensive silviculture in India is being adopted primarily in high-productivity species like *Eucalyptus*, *Acacia* and *Casuarina*. Practices such as closer planting densities, fertilization, and thinning are employed to maximize growth and improve wood quality. Research in India has demonstrated that growth regulators like gibberellic acid can increase height growth and volume production in species like *Acacia* and *Casuarina* (Ramesh *et al.*, 2019). Furthermore, natural pest control methods, such as introducing biological agents and predator species, are gaining ground as alternatives to chemical pesticides, aligning with sustainable forestry goals.

6. Climate-Smart Silviculture

To counteract the effects of climate change, India is adopting climate-smart practices in forestry. Techniques like planting drought- and heat-resistant species and assisted migration are being tested in states like Rajasthan and Gujarat (Singh *et al.*, 2020). Water-saving methods, including mulching and rainwater harvesting, are also gaining ground. Hardy species such as *Hardwickia binata* and *Anogeissus latifolia* are preferred in water-scarce zones for their adaptability.

7. Silviculture for Ecosystem Services

In addition to timber production, India's plantations are increasingly being managed for ecosystem services. This includes enhancing carbon sequestration, water regulation, and soil conservation. The Green India Mission and CAMPA (Compensatory Afforestation Management and Planning Authority) are funding afforestation efforts that aim to restore degraded lands and enhance biodiversity (MoEFCC, 2020). Agroforestry is another area gaining attention, as it helps diversify income for farmers while simultaneously contributing to carbon sequestration. In regions like Himachal Pradesh, agroforestry systems incorporating *Pinus roxburghii* (Chir pine) and *Quercus* spp. (oak) provide both timber and non-timber forest products, thereby increasing the resilience of the rural economy (Gupta *et al.*, 2021).

8. Challenges and Future Prospects

Despite the advancements in silvicultural practices, several challenges remain in the Indian context. Land tenure issues, especially in tribal areas, limit access to land for plantation forestry. Furthermore, monoculture plantations still pose risks of pest outbreaks and soil degradation. Additionally, many smallholder farmers lack the knowledge or resources to implement advanced silvicultural techniques. However, the future of Indian plantation forestry looks promising. With continued research, policy support, and the adoption of modern technologies, India can make significant strides toward sustainable plantation management (Kumar *et al.*, 2021).

Conclusion

The future of plantation forestry in India is heavily reliant on advanced silvicultural techniques that integrate technology, ecological principles, and climate-adaptive practices. By embracing these practices, India can enhance the productivity, sustainability, and ecological value of its plantation forests, making a significant contribution to both economic development and environmental sustainability.

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ARTIFICIAL VS. NATURAL FLAVOURS: BENEFITS, APPLICATIONS, AND CURRENT SCENARIO

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Abstract

Natural and artificial flavours are critical elements in the food industry, greatly improving taste and overall customer appeal. This review goes into the fundamental differences between these two flavor groups, focusing on their origins, chemical structures. The article examines the chemical properties of natural and artificial flavors, as well as their impact on sensory quality and product development. It also investigates new advances in flavour synthesis, encapsulation, and novel delivery technologies that improve flavor stability, performance, and consumer pleasure. The review also discusses the health and safety implications of both types of flavors, highlighting both hazard and advantages. The review also discusses the health and safety implications of both types of flavors, highlighting potential hazards and advantages. As the demand for clean-label, sustainable products grows, consumer preferences and evolving regulatory guidelines are highlighted, influencing industry trends. Ultimately, this article offers insights into the scientific advancements and challenges shaping the future of flavour innovation.

Keywords: Artificial flavours, natural flavours, consumer perception, food safety.

Introduction

Flavour is a central aspect of food enjoyment and acceptance, influencing consumer choices and product success. The use of flavours in the food industry is a complex and evolving field, driven by both technological advances and changing consumer preferences. Flavours whether natural or artificial play a crucial role in enhancing the sensory appeal, palatability, and marketability of food products. Natural flavours are typically derived from essential oils and extracts of plants or animals, while artificial flavours are synthesized from various compounds in the laboratory to achieve specific taste profiles. Despite widespread beliefs that natural flavours are inherently safer or healthier, scientific analysis reveals that both natural and artificial flavours can be chemically identical, and the distinction often lies in their source rather than their structure or safety.

Consumer perceptions, however, tend to favour natural flavours, associating them with authenticity and health benefits, even though artificial flavours offer advantages such as cost-effectiveness, consistency, and stability in processed foods. Regulatory authorities like the FDA evaluate both types of flavours for safety, but labelling practices and proprietary formulations can make it difficult for consumers to discern the exact ingredients used in their foods. Recent studies have shown that while artificial flavours may differ in physical properties such as viscosity they can

closely mimic the taste of natural counterparts, though consumer preference still leans toward natural options.

In the current scenario, the debate between artificial and natural flavours is shaped by scientific, regulatory, and market considerations, making it essential to understand their benefits, applications, and the realities behind their use in the global food industry.

Definitions and Classification

Natural Flavours

A natural flavor constitutes a flavoring agent that is sourced from organic origins, encompassing fruits, vegetables, herbs, spices, meat, poultry, seafood, or dairy products. The U.S. Food and Drug Administration (FDA) articulates that natural flavors are those that have been extracted, distilled, or otherwise processed from natural raw materials employing methodologies such as enzymatic practices, fermentation, or mechanical techniques including cold-pressing. These flavorings are designed to preserve the inherent essence or characteristics of the original source material and are frequently utilized to enhance or modify the sensory properties (taste and aroma) of consumables.

Natural flavors are differentiated from artificial flavors, which are chemically fabricated to imitate the taste profiles of their natural counterparts. Natural flavoring agents are regarded as more intricate due to their composition, which often encompasses a blend of diverse compounds that collectively yield a more genuine and multi-dimensional taste experience (Sluss, 2009). These flavorings may exist in either liquid form (as essential oils, extracts, or distillates) or solid form (as desiccated herbs or spices).

For instance, natural vanilla flavor is conventionally extracted from the vanilla bean, whereby the beans undergo curing, fermentation, and subsequent extraction to obtain the distinctive flavor profile. The extraction procedure entails the application of solvents such as alcohol or glycerin to isolate the flavor compounds from the beans, culminating in the production of vanilla extract. The natural vanilla flavor is deemed superior to its artificial equivalent, which is produced synthetically through the chemical synthesis of vanillin, a compound present in both vanilla and lignin (a constituent of wood).

An illustration of a natural fruit flavor is the orange flavor obtained from orange zest. The zest of oranges is mechanically removed and subsequently processed via cold pressing or steam distillation to capture the essential oils that impart the fruit's characteristic citrus aroma and flavor. This technique guarantees that the flavor retains the intricate profile of the fresh fruit's sensory attributes, including the presence of additional compounds, such as terpenes and aldehydes, which contribute to the overall flavor experience.

Artificial Flavours

An artificial flavor constitutes a flavoring agent that is synthesized through chemical processes to replicate the sensory attributes of natural ingredients. In contrast to natural flavors, which originate from botanical or zoological sources, artificial flavors are manufactured in controlled laboratory settings through the amalgamation of synthetic chemicals, aimed at emulating the distinctive tastes associated with natural substances (Holmes, 2017). The production of these synthetic compounds is generally more economically viable, and they are employed to deliver uniform and stable flavors across a diverse array of food and beverage products.

Artificial flavors can be engineered to replicate the flavors of fruits, vegetables, spices, and even intricate flavor profiles, such as "buttery" or "cheesy" characteristics. The primary benefit of artificial flavors resides in their capacity to furnish a consistent and reproducible taste across extensive production volumes, rendering them particularly advantageous in the context of mass-produced goods (Sluss, 2009). Additionally, they typically exhibit a more prolonged shelf life relative to natural flavors, which may deteriorate over time due to exposure to environmental factors such as light, heat, or oxygen.

A pertinent illustration of an artificial flavor is vanillin, the chemical compound that predominantly imparts the flavor of vanilla. While natural vanilla flavor is procured from the beans of the vanilla orchid, artificial vanilla (commonly referred to as vanillin) is often synthesized from guaiacol or lignin, which are substances derived from wood or petrochemical sources. This synthetic rendition of vanilla flavor is frequently utilized in a broad spectrum of baked products, frozen desserts, and confectioneries, largely attributable to its markedly lower production cost in comparison to natural vanilla extract (Vijayalakshmi et al., 2019).

Artificial flavors are subjected to regulation by food safety organizations such as the U.S. Food and Drug Administration (FDA), which ensures the safety of these substances for human consumption when utilized in accordance with prescribed guidelines. Consumers are skeptical of artificial tastes despite their widespread use, especially in light of growing trends and a preference for natural ingredients and clean-label products.

Chemistry and Innovation

Chemical Composition

Natural Flavor

Natural flavors consist of intricate combinations of volatile organic compounds (VOCs) that originate from either plant or animal sources. These compounds encompass esters, aldehydes, alcohols, ketones, terpenes, lactones, and phenolic compounds, which work together to produce distinct aromas and flavors. For example, the flavor profile of natural strawberries is characterized by significant esters like ethyl butanoate and methyl hexanoate, imparting sweet and fruity notes (Schwieterman et al., 2014). Limonene, a primary monoterpene found in citrus oils, lends a fresh, lemony scent that is commonly associated with oranges and lemons. The makeup of natural flavorings varies due to several factors, such as the type of plant, its ripeness, the climate, and the extraction technique employed. Typically, hundreds of VOCs can be detected in minimal quantities, and their subtle interactions contribute to the distinctive flavor profile found in natural foods.

Artificial Flavor

Artificial flavors are made from chemically produced compounds designed to imitate the sensory experiences of natural flavors. Their composition is usually less complex, often consisting of only one or a few prominent molecules. A well-known example is isoamyl acetate, which is utilized to replicate the flavor of bananas. While natural bananas contain this ester, the artificial banana flavor usually has a significantly higher concentration, leading to a more intense and sometimes exaggerated aroma (Torres et al., 2010). Another commonly used synthetic compound is vanillin, which is produced from guaiacol or lignin-based materials to replicate the flavor of natural vanilla. While natural vanilla extract consists of over 200 volatile compounds, artificial vanilla generally depends solely on vanillin to provide the characteristic sweet and creamy flavor.

Advances and Innovations

Recent developments in flavor technology have significantly improved the production of both natural and artificial flavors. In the area of natural flavors, innovations such as microbial

fermentation have made it possible to biosynthesize intricate compounds like vanillin from basic sugars, providing a sustainable alternative to conventional extraction techniques (Sukaew, 2024). Enzyme-assisted extraction also enhances the efficiency of flavor isolation from plants, thereby minimizing environmental impact. For artificial flavors, the application of machine learning has transformed flavor design by predicting and optimizing flavor profiles, as seen in the enhanced formulation of artificial strawberry flavors (Ji et al., 2023). Moreover, electronic nose technologies are utilized to maintain consistent quality and monitor artificial dairy flavors, especially in products like vanilla and butter, where precision in flavor is crucial (Yakubu et al., 2022). These advancements in the production of both natural and artificial flavors lead to increased sustainability, accuracy, and efficiency within the food industry.

Benefits and Drawbacks

Artificial Flavours

Benefits:

Cost-efficient: Artificial flavours are generally more affordable to produce compared to natural flavours, making them ideal for large-scale production in mass-market products.

Consistency: They offer **stable, predictable flavours** that don't fluctuate due to environmental conditions like climate or seasonal changes.

Customization: Manufacturers can easily adjust the intensity and composition of artificial flavours to suit specific consumer preferences or products.

Drawbacks:

Perceived Health Concerns: Some artificial flavours have been linked to health risks, leading to public scepticism. Although they are typically deemed safe by regulatory bodies, the long-term effects of consuming synthetic chemicals remain controversial.

Lack of Authenticity: Artificial flavours often lack the complexity of natural flavours, which may result in a less **genuine** taste experience for consumers who seek authentic flavour profiles.

Natural Flavours

Benefits:

Healthier Perception: Natural flavours are often considered healthier by consumers due to their natural origin, without any synthetic chemicals.

Complex and Rich Sensory Profiles: They offer a richer and more diverse taste and aroma due to the variety of compounds present in the source material, which is difficult to replicate synthetically.

Drawbacks:

High Cost: The production of natural flavours is more expensive due to the extraction process and the cost of raw materials, making them less affordable for mass-market products.

Instability: Natural flavours are more sensitive to temperature and light, which can cause them to **degrade** or lose potency over time.

Nutritional and Health Aspects

Numerous flavor compounds found in fruits, vegetables, and herbs; such as terpenes, phenolics, and volatiles containing sulphur, exhibit antioxidant, anti-inflammatory, and antimicrobial properties. For instance, the sulfur compounds present in garlic and onions, responsible for their unique pungent taste, have been linked to benefits for the cardiovascular and immune systems

(Ayseli & Ayseli, 2016). Similarly, polyphenolic compounds that contribute to the bitter and astringent flavors in foods like green tea or dark chocolate are recognized for their ability to scavenge free radicals and provide anti-aging benefits. Flavor precursors such as amino acids and reducing sugars play a role in Maillard reactions during cooking, generating not only complex flavors but also bioactive compounds that may have nutraceutical properties. For example, certain products resulting from Maillard reactions demonstrate antioxidant activity; however, excessive production (particularly at elevated temperatures) can lead to harmful substances like acrylamide, underscoring the importance of balanced thermal processing (Ayseli & Ayseli, 2016). In health and wellness products, flavor compounds are essential for enhancing palatability and promoting the consistent consumption of nutritionally enriched or functional foods. Salta and Du (2024) emphasize the intentional incorporation of natural flavors in items like plant-based drinks, protein bars, and dietary supplements, which frequently contain bioactive ingredients that can have unpleasant tastes. Natural flavors such as vanilla, cocoa, and berry extracts not only enhance flavor but can also offer additional antioxidant benefits, making them significant dual-purpose elements in the design of health-oriented products. Furthermore, the rising demand for clean-label and fortified foods has spurred innovation in the utilization of natural flavors with built-in health advantages. For instance, extracts from citrus peels used for flavoring are also abundant in flavonoids that promote cardiovascular health and bolster immune function (Salta & Du, 2024).

Applications in the Food Industry

Flavors are fundamental to the food industry, enhancing sensory appeal, masking off-notes, and contributing to consumer preference. Their application spans a wide array of food categories, playing both functional and marketing roles.

In the beverage industry, flavors are critical for creating distinctive profiles. For instance, citrus oriented beverages, flavors like orange and lemon are added to carbonated drinks such as Fanta or Sprite, while herbal extracts are used in flavoured waters and energy drinks to meet consumer demand for wellness.

The confectionery industry uses both natural and artificial flavors to diversify its offerings. Strawberry, mint, and chocolate flavors are common in chewing gums and candies like Mentos or Skittles, where flavor intensity and longevity are key to consumer satisfaction.

In dairy products, flavors enhance variety and help mask unpleasant notes from fermentation or protein additions. For example, vanilla and mango flavors are added to yogurts, and chocolate or caramel flavors are popular in ice creams like those offered by Häagen-Dazs or Amul.

Snack foods also rely heavily on flavorings. Cheddar cheese and sour cream & onion are iconic examples used in chips like Lays or Pringles. These flavors provide a consistent taste experience despite variations in raw materials or processing methods.

In the meat and savory food sector, smoky, peppery, or grilled flavors are added to processed meats like sausages and bacon, and are especially important in plant-based products such as Beyond Meat or Impossible Burgers to mimic traditional meat profiles.

Baked goods like cookies and cakes often include flavors such as butter, cinnamon, or banana to evoke homemade appeal or seasonal variations, seen in products like Oreo's seasonal pumpkin spice edition or banana bread muffins.

Beyond traditional foods, flavors are crucial in nutraceuticals and health products. For example, children's multivitamins are often flavored with grape or orange to make them more palatable, and protein powders typically come in chocolate, vanilla, or coffee variants to enhance acceptability (Du & Yang, 2024).

These examples reflect how flavors, whether derived from natural or synthetic sources, are integral to the success and functionality of modern food products across a broad spectrum of categories.

Consumer Perception and Market Trends

Consumer perception significantly influences the tendency to choose natural flavors over artificial ones. Numerous consumers connect "natural" with being "healthier" and "safer," often motivated by a preference for clean labels and transparency in food manufacturing. Consumer opinions tend to favor natural flavors, linking them with health benefits, environmental sustainability, and authenticity. This preference is in line with the growing demand for "clean label" products, as consumers look for ingredients they believe are less processed and devoid of artificial additives (Goodman, 2017). Research indicates that although natural and artificial flavors may be chemically the same, consumers often prefer natural labels due to emotional and psychological connections to nature and well-being (Salta & Du, 2024). As a result, the food industry is increasingly focusing on the development of natural flavors to satisfy this preference, using cutting-edge technologies such as fermentation and enzymatic processing (Ayseli & Ayseli, 2016; Ji et al., 2023). Regulatory bodies like the European Food Safety Authority (EFSA) have also influenced market trends by providing thorough guidelines and assessments to ensure the safety of both natural and artificial flavoring substances (EFSA, 2021; EFSA Panel on Food Additives and Flavourings [FAF], 2022, 2024). At the same time, artificial flavors remain prevalent in certain areas of the food industry because of their affordability, stability, and uniformity, particularly in large-scale production environments (Yakubu et al., 2022). In summary, consumer perception largely favors natural flavors due to connections with health and sustainability, even though the health advantages over artificial flavors remain uncertain.

Regulatory and Safety Considerations

The oversight of food flavorings is essential for guaranteeing their safety for consumers. Regulatory bodies, such as the European Food Safety Authority (EFSA), have implemented specific guidelines for the evaluation and approval of food flavorings. As stated in the EFSA Administrative Guidance (2021), any agent that enhances food—including flavorings—must go through a thorough safety review. This review involves submitting a scientific dossier that demonstrates the safety of the compound based on its chemical makeup, metabolism, toxicity, and intended application. Only substances considered safe through this stringent process are permitted for use in food items. The EFSA Panel on Food Additives and Flavourings (FAF) plays a significant role in maintaining safety standards by regularly evaluating flavoring substances. One such assessment, Flavouring Group Evaluation 80, Revision 2 (2024), aims to evaluate large categories of chemically similar flavoring agents. This evaluation uses methods like the Threshold of Toxicological Concern (TTC) approach, which aids in determining acceptable exposure levels based on the chemical structure of flavorings, alongside exposure estimates to evaluate potential public health risks. These group assessments enable EFSA to efficiently review multiple flavoring substances while upholding high safety standards. Furthermore, EFSA's 2022 scientific guidance offers additional clarity on the data necessary for a thorough risk evaluation of flavorings used in food products. The guidance highlights the requirement for solid toxicological data, including studies on genotoxicity and comprehensive

dietary exposure assessments. This ensures that any potential health risks associated with flavorings are completely understood before they gain approval for use in food products. In terms of food labeling, the differentiation between "natural" and "artificial" flavors has led to ongoing discussions, particularly regarding consumer expectations and regulatory definitions. Goodman (2017) explores the confusion surrounding the term "natural" in food labeling, especially in relation to "natural flavors." This uncertainty, as indicated by Goodman, often results in misunderstandings among consumers, who may view "natural" flavors as safer or healthier, even though both natural and artificial flavoring substances are governed by similar regulatory standards. The author argues that more precise labeling guidelines are necessary to better inform consumers and minimize the potential for misleading marketing claims. In summary, these regulatory frameworks and ongoing safety assessments by EFSA, coupled with perspectives from industry professionals like Goodman (2017), highlight the significance of rigorous safety evaluations and clear labeling to safeguard consumers and ensure that flavorings, whether from natural or artificial sources, are safely utilized in food products.

Table 1. Intended Use and ADI (acceptable daily intake) of Common Flavor Enhancer

INS No.	Name	Intended Use	ADI	Reference
620	Glutamic acid	Flavor enhancer	30 mg/kg body weight (b/w) per day	EFSA, 2017
621	Monosodium Glutamate	Flavor enhancer	< 6 g/day	Thongsepee at al., 2022
627	Disodium Guanylate	Flavor enhancer	N/A, GRAS	EFSA, 2017
631	Disodium Inosinate	Flavor enhancer	N/A, GRAS	EFSA, 2017

Note: N/A: not available, GRAS: generally required as safe

Transparency Issues, Health Concerns, and Current Scenario

Transparency Issues

A key issue in the discussion surrounding natural versus artificial flavors is the insufficient transparency in labelling. Although natural flavors are frequently promoted as healthier or safer alternatives, consumers are often left without clear information regarding the specific sources or chemical composition of the flavoring agents used. Manufacturers are not required to disclose the exact constituents of natural flavor mixtures, which may include processing aids such as solvents or carriers that are not necessarily "natural" themselves (Goodman, 2017). This lack of disclosure contributes to consumer distrust, especially when products marketed as containing "natural flavors" may still include synthetic additives or undergo extensive processing. The absence of comprehensive labeling further blurs the line between natural and artificial flavors, leading to widespread consumer misconceptions and confusion about what each term genuinely represents (Goodman, 2017; EFSA, 2021).

Health Concerns

Health risks associated with both natural and artificial flavoring agents have raised significant concerns. Artificial flavors, typically synthesized from chemical compounds, are linked to potential allergies, hyperactivity, and toxic effects with prolonged exposure. For example, some synthetic flavor compounds, commonly used in processed foods and beverages, have been scrutinized for

their possible adverse effects on children's behavior and overall health. Despite being approved as Generally Recognized As Safe (GRAS) by regulatory agencies, there is still uncertainty regarding the long-term health impact of these chemicals, which may contribute to the growing consumer skepticism toward them (Ramesh & Muthuraman, 2018).

On the other hand, natural flavors, often considered a healthier alternative, still pose risks due to the complex processes involved in their extraction. These flavors may require the use of solvents or enzymes that could introduce potentially harmful substances, which may trigger allergic reactions or sensitivities, even though the source is natural (Ramesh & Muthuraman, 2018). Furthermore, natural flavors can undergo significant chemical alterations during processing, reducing their safety profile when compared to their raw, unprocessed forms.

Current Scenario

The current situation regarding artificial and natural flavors is influenced by a major change in consumer preferences towards natural ingredients, primarily due to health concerns and an increasing desire for clean-label products. As people become more health-aware, there is a rising trend toward organic and natural flavors, driven by a wish for transparency and perceived health advantages (Ayseli & Ayseli, 2016). Nonetheless, artificial flavors still account for a significant share of the market because of their affordability, consistent flavor delivery, and convenience for large-scale food manufacturing (Ramesh & Muthuraman, 2018). Regulatory agencies such as the FDA and EFSA ensure that both types of flavors comply with safety regulations, but the push for increased transparency is urging manufacturers to disclose more information about the origins and components of flavor compounds (Goodman, 2017). Advances in technology, particularly in biotechnology and fermentation, are enhancing the cost-efficiency, stability, and sustainability of natural flavors, making the distinctions between the two increasingly unclear (Ji et al., 2023; Salta & Du, 2024). Despite the rising interest in natural flavors, sustainability issues remain as both artificial flavors, often sourced from petrochemicals, and natural flavors, which can be related to farming practices, pose environmental concerns (Ayseli & Ayseli, 2016). To sum up, the flavor industry is walking a fine line between the heightened appetite for natural ingredients and the practicality of artificial alternatives, with regulatory and technological developments shaping the future of food flavorings (Ramesh & Muthuraman, 2018; Goodman, 2017).

Conclusion

The discussion surrounding artificial versus natural flavors remains a key topic within the food and beverage sector. Each type provides unique benefits, natural flavors resonate with consumers' desires for clean-label and health-oriented products, while artificial flavors offer uniformity, cost efficiency, and greater availability. Nonetheless, both categories encounter challenges. Natural flavors frequently grapple with issues related to limited supply, increased costs, and reduced stability during processing. On the other hand, while artificial flavors have technological advantages, they often face consumer doubt and regulatory examination due to safety concerns and their synthetic nature. Additionally, advancing analytical techniques have uncovered the intricacies involved in flavor identification and reproduction, which further adds to the complexity of the situation. In the end, the decision between artificial and natural flavors hinges on a careful consideration of product objectives, regulatory frameworks, financial factors, and consumer demands. As flavor science continues to evolve, integrating sustainable practices, enhancing extraction methods, and effectively communicating with consumers will be crucial for addressing challenges and fostering future progress in this dynamic industry.

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GILOY (*Tinospora cordifolia*): TREASURE OF HEALTH**Rahul Yadav*, Sachin Kumar and Chandana S**

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*Corresponding Email: rahulyadav02072000@gmail.com**Abstract**

Tinospora cordifolia commonly known as Giloy is a medicinal plant with a rich history of use in Ayurvedic medicine. The Indian farmers can boost their income by cultivating Giloy commercially, as it requires minimal investment in pesticide and chemicals. The plant's medicinal value is enhanced when it climbs on tree like Neem, as it absorbs their beneficial properties. This vine characterized by its betel leaf-shaped, dark green foliage, possesses anti-inflammatory, antioxidant, and anti-pyretic properties. The plant's various parts, including roots, leaves, and stems, are utilized to prevent and treat various health ailments, such as arthritis, diabetes, urinary diseases, and digestive problems. Giloy's immunomodulatory effects enhance the body's defense against disease, and its adaptogenic properties help maintain homeostasis. Giloy has been recommended as a complementary therapy to boost immunity against Covid-19. With its broad spectrum of bioactive compound, including glucoside, tinosporin, and mineral, Giloy is a valuable addition to traditional and modern medicine.

Keywords: Adaptogenic, Bioactive Compound, Immunomodulatory, Medicinal Plant**Fig: 1** climbing on tree**Fig: 2** Selling in the Market**Botanical Classification****Kingdom:** Plantae**Class:** Magnoliopsida (Dicotyledons)**Family:** Menispermaceae**Species:** *Tinospora cordifolia***Division:** Tracheophyta (Vascular Plant)**Order:** Ranunculales**Genus:** *Tinospora*

Introduction: Giloy (*Tinospora cordifolia*), a climbing vine found predominantly in forests and shrubs, has been utilized in Ayurvedic medicine for centuries due to its extensive medicinal properties. Cultivating Giloy on a commercial scale offers Indian farmers an opportunity to enhance their income while minimizing expenditure on chemical fertilizers and pesticides. The vine is recognized for its adaptability and ability to absorb medicinal qualities from the trees it climbs, with those growing on Neem (Fig.1 *Azadirachta indica*) considered the most potent. Giloy is rich in bioactive compounds like glucoside, tinoporin, palmerin, tinosporic acid, and essential mineral such as calcium, magnesium, iron, zinc, and phosphorus. These constituents contribute to its anti-inflammatory, antioxidant, and antipyretic properties. The plant has demonstrated efficacy in managing a range of health conditions, including chronic inflammation, arthritis, diabetes, urinary disorders, digestive issues, and detoxification through blood purification. Giloy is an immunomodulatory agent, enhancing the body's defence mechanisms against infections. It is among the few Ayurvedic herbs that balance the three doshas- Vata, Pitta, and Kaph. During the COVID-19 pandemic, it gained attention for its potential to strengthen immunity, leading to increased recommendation by healthcare professional.

Benefits of Consuming Giloy : There are widely regarded for its numerous health benefits, owing to its rich composition of bioactive compound.

I. Boosting Immunity: Giloy is known to strengthen the body's immune system, making it particularly beneficial for individuals who frequently experience illnesses. Regular consumption of Giloy in the form of juice or tablets has been shown to improve the body's resistance to infections and promote overall vitality.

II. Diabetes Management: Research suggests that Giloy acts as hypoglycemic agent, making it effective in managing type-2 diabetes. It assists in reducing elevated blood glucose levels by enhancing insulin secretion and lowering insulin resistance. Consequently, Giloy serves as a valuable natural remedy for individual struggling with diabetes.

III. Asthma Relief: Consuming Giloy tablets or chewing its stem is considered beneficial for individuals suffering from asthma. Its anti-inflammatory properties help alleviate symptoms like shortness of breath, chest tightness, and wheezing.

IV. Digestive Health: It has traditionally been used to manage digestive issues such a constipation, indigestion, and acidity. Consuming a decoction of Giloy or a teaspoon of its powder mixed with warm water can help alleviate these gastrointestinal disorders and promote overall digestive health.

V. Eye Health: Giloy is believed to improve eyesight and treat certain eye disorders, Washing the eyes with water boiled with Giloy or using its decoction as an eyewash can help address fungal and parasitic infections of the eyes.

VI. Relief for Cough: Due to its anti-allergic properties, Giloy is effective in treating persistent coughs. Preparing a decoction of Giloy and consuming it with honey three to four times a day can help alleviate chronic cough.

VII. Support in Jaundice Management: It is considered beneficial in managing jaundice. Consuming a powder prepared from dried Giloy leaves or mixing crushed Giloy leaves with curd and buttermilk can assist in alleviating the symptoms of jaundice.

VIII. Treatment of Anemia: Rich in iron, Giloy helps address iron deficiency anemia, a condition commonly observed in women. Regular intake of 10-15 ml of Giloy juice mixed with honey or water can assist in increasing hemoglobin levels and boosting overall immunity.

IX. Antipyretic Properties: Giloy has been recognized for its antipyretic effects, making it effective in managing chronic and recurrent fevers, including those caused by malaria, dengue, and swineflu. Regular use can help reduce the frequency and severity of such fevers.

X. Management of Arthritis: The anti-inflammatory and anti-arthritic properties of Giloy make it effective in reducing symptoms associated with arthritis. Regular consumption can help alleviate joint pain and stiffness, provide relief to individuals suffering from rheumatoid arthritis and related conditions.

Methods of Giloy Consumption and Potential Risks:

It can be consumed in various forms, each offering its unique therapeutic benefits. When consumed as juice, the leaves and vines of Giloy should be thoroughly cleaned, crushed to extract the juice, and then boiled in hot water.

After cooling, the juice can be consumed to enhance immunity and address various health conditions. In the form of a decoction, Giloy vine should be cleaned and boiled in water along with five basil leaves (*Ocimum tenuiflorum*), two cloves (*Syzygium aromaticum*), and four black peppercorns (*Piper nigrum*). Once cooled, this decoction can be consumed twice daily to address respiratory issues, digestive disorders, and boost overall health.

Giloy is also available in tablet form (Commonly known as **Giloy Vati**), which can be easily accessed in the market. The recommended dosage for adults is two tablets twice a day, while children are generally advised to consume one tablet twice daily. However, it is essential to adhere to the guidance of a healthcare professional for precise dosage.

Additionally, Giloy can be consumed as a powder, prepared by drying and grinding its leaves and stem. The powder can be taken with warm water or honey to support digestion and enhance overall health. While it is generally considered safe, excessive or uncontrolled consumption may lead to adverse effects. Overconsumption can result in digestive issues, including indigestion and a burning sensation in the stomach. Individuals with diabetes should exercise caution, as Giloy can significantly lower blood sugar levels, potentially leading to hypoglycemia. Pregnant women are advised to avoid its use due to limited research on its safety during pregnancy. Therefore, it is recommended to consult a healthcare professional before incorporating Giloy into one's diet, especially for those with underlying health conditions.

Conclusion

Giloy holds significant therapeutic potential, recognized both in traditional Ayurvedic practices and contemporary medicine. The plant's diverse bioactive compounds such as glucoside, tinosporin, and essential minerals, contribute to its anti-inflammatory, antioxidant, and antipyretic properties. These attributes make Giloy effective in managing a wide range of health conditions, including arthritis, diabetes, digestive disorders, and urinary diseases. Additionally, its immunomodulatory and adaptogenic effects enhance the body's defense mechanism and help maintain physiological balance. Cultivating Giloy on a commercial scale presents a valuable economic opportunity for Indian farmers, requiring minimal investment in chemical inputs while yielding high medicinal value. The vine's ability to absorb and amplify the beneficial properties of host trees, especially Neem, further underscores its therapeutic significance. The increasing interest in Giloy as a complementary therapy during the COVID-19 pandemic has reinforced its role in boosting immunity and promoting overall health.

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HOW TO ANALYSE DESCRIPTIVE STATISTICS IN MS EXCEL?

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Abstract

Descriptive statistics are important in condensing and describing data to aid in decision-making in research and business environments. Microsoft Excel has a variety of tools to use when analyzing descriptive statistics, from inherent functions and the Data Analysis ToolPak. This paper presents the most important steps to carry out descriptive statistical analysis in Excel, including measures of central tendency (mean, median, and mode), measures of dispersion (standard deviation, variance, range), and data distribution information. It also discusses how to represent data through histograms, box plots, and line charts to interpret better. With Excel's analytical power, users can effectively deal with large sets of data and obtain useful information. It is crucial that researchers, students, and professionals dealing with data-driven activities master these techniques.

Keywords: Descriptive statistics, MS Excel, Data Analysis ToolPak

Introduction

Descriptive statistics play a vital role in summarizing and interpreting data in an efficient manner. Microsoft Excel has some very useful functions to compute the important descriptive statistics like mean, median, mode, standard deviation, and variance. The following assignment discusses how to work on descriptive statistics through Excel.

1. Importance of Descriptive Statistics

1.1 Simplifying Complex Data

Raw information tends to be enormous and difficult to understand. Descriptive statistics turn this complexity into comprehensible summaries by employing measures like mean, median, mode, variance and standard deviation. Simplification serves to find trends and patterns that may prove elusive to perceive otherwise.

1.2 Facilitating Data Visualization

Descriptive statistics simplify data comprehension by presenting data in visual forms such as graphs, charts, and tables. These forms of presentation improve understanding and communication of findings, enabling stakeholders to better understand the story behind the data.

1.3 Supporting Decision-Making

By averaging historical information, descriptive statistics give organizations an understanding of trends and variability. These understandings inform business strategies, resource assignments, and process enhancements.

1.4 Identifying Data Characteristics

Descriptive statistics emphasize important features of a dataset, including its central tendency (mean, median, mode) and variability (range, standard deviation). This enables researchers to understand the data structure and ready it for additional analysis or hypothesis generation.

1.5 Detecting Errors and Outliers

Descriptive analysis may identify typos or outliers in datasets, maintaining data quality prior to the use of more complex statistical techniques or predictive modeling.

1.6 Building a Foundation for Inferential Statistics

Descriptive statistics are the initial step in statistical analysis. They are necessary summaries that researchers utilize to decide on suitable inferential procedures for making conclusions about populations using sample data.

1.7 Enhancing Communication

Summarized facts are more convenient to convey to varied audiences. In research reports or business statistics, descriptive statistics make sure findings are displayed in a logical and effective manner.

2. Descriptive Statistics: Understanding

Descriptive statistics assist in condensing large datasets, giving an overview of data distribution, central tendency, and variability. Important descriptive statistics are:

- **Mean: The average of a data set.**
- **Median: The middle value when data is sorted.**
- **Mode: The most frequently occurring value.**
- **Standard Deviation: Measures the spread of data points from the mean.**
- **Variance: Indicates data variability.**
- **Minimum and Maximum: The smallest and largest values in the dataset.**
- **Range: Difference between the maximum and minimum values.**

3. Data Preparation in Excel

Before performing analysis, follow these steps:

1. Organize your data in columns with clear headers.
2. Ensure no blank rows or irrelevant data entries are present.
3. Select the data range for analysis.

4. Steps to Perform Descriptive Statistics in Excel

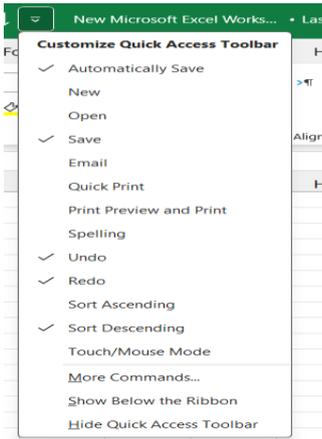
A. Using the Data Analysis Toolpak

1. Enable Data Analysis ToolPak:

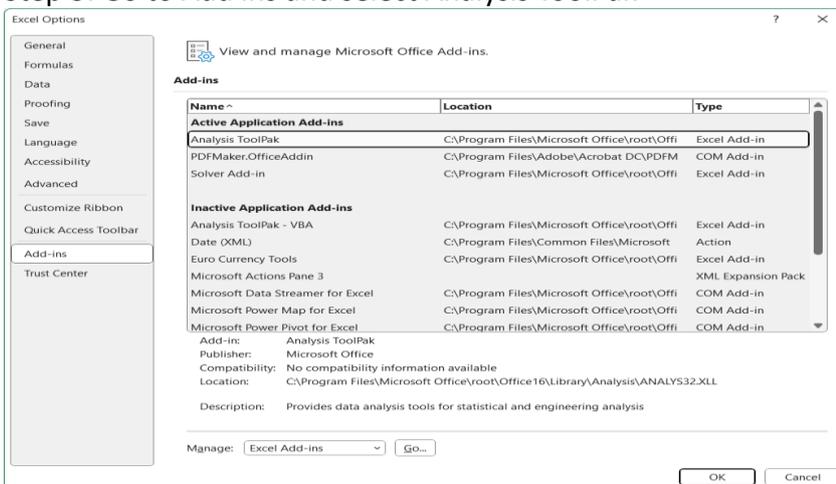
Step 1: Select Customize Quick Access Toolbar



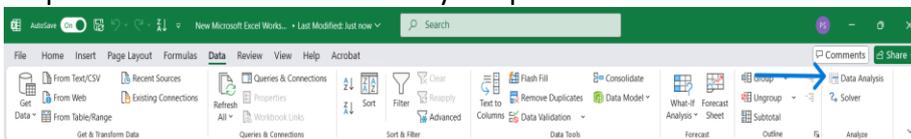
Step 2 : Select More Commands



Step 3: Go to Add ins and select Analysis ToolPak



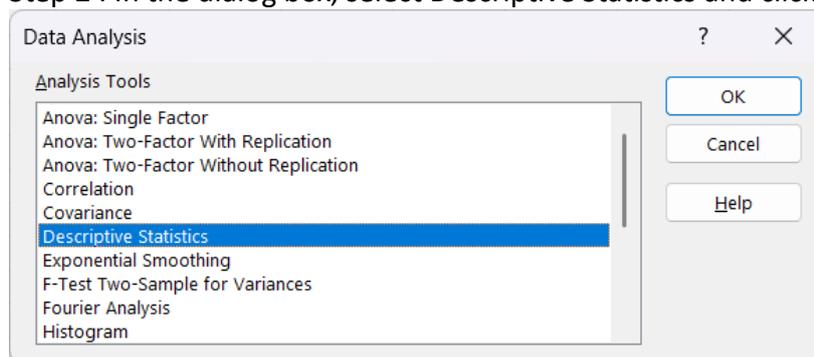
Step 4: You will see the Data Analysis option in the Data Tab



2. Running Descriptive Statistics:

Step 1 :Go to the Data tab and select Data Analysis.

Step 2 : In the dialog box, select Descriptive Statistics and click OK.



Step 3 : Select the data range under Input Range and check the Summary Statistics box and specify the output range.

Step 4 : Click OK to generate the descriptive statistics report.

<i>Marks</i>	
Mean	88
Standard Error	1.715128761
Median	89
Mode	91
Standard Deviation	6.860515044
Sample Variance	47.06666667
Kurtosis	1.980743678
Skewness	-1.083036792
Range	28
Minimum	70
Maximum	98
Sum	1408
Count	16
Largest(1)	98
Smallest(1)	70
Confidence Level(95.0%)	3.655710418

B. Using Excel Functions

Alternatively, you can calculate each statistic using Excel functions:

- =AVERAGE(range) — Calculates Mean
- =MEDIAN(range) — Calculates Median
- =MODE.SNGL(range) — Identifies the Mode
- =STDEV.P(range) — Calculates Population Standard Deviation
- =STDEV.S(range) — Calculates Sample Standard Deviation
- =VAR.P(range) — Calculates Population Variance
- =VAR.S(range) — Calculates Sample Variance
- =MIN(range) and =MAX(range) — Find Minimum and Maximum values
- =QUARTILE(range, 1/2/3/4) — Identifies data quartiles

5. Interpreting Results

Once the descriptive statistics report is generated:

- Examine the Mean for average trends in data.
- Identify data symmetry or skewness by comparing the Mean and Median.
- Analyze Standard Deviation for variability; higher values indicate greater data dispersion.
- Use Minimum and Maximum values to assess data boundaries.

6. Visualization Tools for Descriptive Statistics

To enhance interpretation:

- Use Histograms to visualize frequency distribution.
- Apply Box and Whisker Plots to highlight data spread and outliers.
- Use Line Graphs or Bar Charts to compare multiple data series.

Conclusion

Microsoft Excel offers flexible tools to analyze descriptive statistics effectively. Using the Data Analysis ToolPak or separate functions, Excel makes data interpretation easier through systematic reports and graphical aids. Understanding these methods is crucial for successful data analysis in academic, research, and business environments.

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HYDROPONICS: A SUSTAINABLE APPROACH TO FRUIT NURSERY DEVELOPMENT

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Introduction

The United Nations projects that the global population will surpass nine billion by 2050 (Kaur and Chauhan, 2023). And half of the global cultivable land is likely to become unfit for farming creating huge question to our food security. Globally per person land availability is less than 0.2 hectare. Feeding population of 9 billion by converting wild habitats into farmland is impractical, as most cultivable land is already under cultivation. Agricultural expansion could cause ~30% of plant species to go extinct (Taiz, 2013), on addition there are many challenges in soil, like poor drainage, soil borne pathogens, nematodes, salinity, and adverse pH which not only hamper the growth of the plants but it becomes a mode for spread of diseases while importing seedlings from foreign nursery. Hydroponics or soilless culture is a technique of growing plants in any solid substrate or any aerated nutrient solution but without using soil (Hassan *et al.*, 2018). It can be a promising approach for sustainable fruit nurseries by using less water and space compared to traditional soil-based methods. It minimizes the need for pesticides and herbicides, reducing environmental impact. Controlled nutrient delivery improves plant growth and fruit yield. Additionally, hydroponics allows for year-round production of seedlings, enhancing food security and reducing dependency on seasonal cycles.

Types of hydroponics

Solution culture or Liquid hydroponics

- Nutrient film technique: In this system plant roots are exposed to a thin film (0.5mm thick) of nutrient solution flowing through a PVC or plastic channel. Seedlings in tailor-made pots with growing media absorb nutrients through their roots. Channels are typically 5-10 meters long, sloped at 1:50 to 1:70. Nutrient solution flows at 2-3 liters per minute, with regular monitoring of EC, pH, and TDS levels for optimal plant growth.
- Deep flow technique: It utilizes PVC pipes with a 2-3 cm deep nutrient solution flowing through them. Plants are grown in plastic pots attached at regular intervals along the pipes, which are elevated within a protected structure. Essential equipment including pumps, tanks, valves, timers, and nutrient monitors are housed on the structure's floor.
- Root dipping technique: Plants are grown in small pots filled with growing media, with the bottom 2-3 cm submerged in nutrient solution. Roots are suspended in the air and also submerged in the nutrient solution.
- Floating technique: Shallow containers (10 cm deep) are used. Small pots containing plants are fixed to Styrofoam and allowed them to float on nutrient solution.
- Capillary action technique: Porous substrates are used. Nutrient solution rises up by the means of capillary action to reach root area.

Solid media culture (Aggregate systems)

- Hanging bag technique: Cylindrical UV stabilized polythene bags (1 m high) filled with substrates are kept hanging in vertical manner in which micro sprinklers are attached inside for nutrient solution.
- Grow bag technique: Plants are grown in UV stabilized polyethylene grow bags (1m length, 15-20cm width, 8-10cm height) with 30-60cm spacing. Nutrients supply through stake drippers, and white UV resistant polythene on the floor optimize sunlight, humidity, and disease control, making it a cost-effective technique for plant cultivation.
- Trench or trough technique: Narrow trenches or above-ground troughs lined with waterproof materials (e.g., bricks, concrete) are used for plant cultivation, with depths starting at 30 cm. Media like coir dust, peat, vermiculite, or sand are employed. Nutrients are supplied via drip irrigation or manual application; excess is drained through perforated pipes.
- Pot technique: Plastic or clay pots filled with media tailored to crop needs, typically ranging from 1 to 10 liters in volume.

Aeroponics: Styrofoam panels with hanging roots are kept in dark chamber. Nutrients are directly supplied to the roots in the form of mist or fog.

Basic components of hydroponics

Infrastructure/controlled Environment: Traditional protected structures (greenhouses, nethouses) can be modified for hydroponics with slight adjustments. Additional components (stands, piping, containers) require 10-30% extra investment. Micro-climate (temperature, humidity, light intensity) is managed with systems like exhaust fans, cooling pads, and heaters. This can be of two types, either naturally ventilated-zero energy model greenhouse with natural ventilation from sides and top (suitable where climate is mild) or Semi-climate and climate-controlled design (most desirable for hydroponics).

Substrate: Strong material, other than soil, which alone or in blends can ensure preferable plant development conditions. Organic: Saw dust, wood chips, bark, sphagnum moss, cocopeat, Inorganic: Natural – sand, vermiculite, rockwool, perlite, gravel, and Synthetic - Hydrogel, foam mates, oasis.

Nutrient solution: Plants require 17 essential elements for their normal growth and development which is supplied in the form of nutrient solutions in hydroponics.

pH and Electrical conductivity (EC): pH determines the availability of the nutrient to the plants. Optimum pH for most of the plants is between 5.5 to 6.5. Electrical conductivity indicates solution strength and should be 1.5 to 2.5 dS/m in hydroponics. Imbalances in pH or EC can disrupt nutrient uptake, affecting plant growth and yield.

Aeration: Adequate oxygenation of the root zone is essential for promoting healthy root development and preventing issues such as root rot. Air pumps, air stones, or oxygen injectors needs to be installed to ensure sufficient oxygen levels in the nutrient solution.

Insights from Past Research

Several studies have explored the application of hydroponics in fruit nursery production, providing valuable insights into its effectiveness and benefits. For instance, Purohit *et al.* (2021), found that hydroponically hardened plantlets of kiwi fruit reduced the period of hardening by 45 days with

100% survival compare to conventional with only 50 % survival. Overall root and shoot of the plantlets were found superior in hydroponic condition. Toyosumi *et al.* (2021), also reported that all the growth parameters (Shoot dry weight, plant height, total root length, leaf area, shoot fresh weight) were found highest in the plantlets acclimatized under hydroponic condition. Further they also showed that hydroponically grown plants are 12 days prior in attaining same height (0.06m) with low mortality than the control. Vesga *et al.* (2021), demonstrated that aeroponics are also as efficient as germination trays for rooting of soft wood cuttings of peach treated with Indole 3-butyric acid potassium salt (K-IBA) and it is more efficient in resource utilization. While working on cuttings of coffee Lima *et al.* (2023) found positive significant difference in terms of cutting survival percentage, total leaf number, root length, dry matter content, leaf area, among the cuttings grown under hydroponic condition. Better vegetative growth and physiological performance (stomatal conductivity and chlorophyll content) were also found under hydroponics than the nursery poly bag. Souza *et al.* (2011), reported Okinawa rootstock of peach under hydroponic condition attained transplanting stage (15 cm height) in 30 days after germination (DAG) and grafting stage (4 mm diameter) in 61 DAG and within 116 DAG grafts were ready for transplanting. This system is also very useful for experimental and study purpose like screening against stresses or nutrient deficient analysis which is very difficult or not precise under soil condition where interaction of different factors exist. For instance, polyethyl glycol (PEG) induced drought experiment was conducted by Kadam *et al.* (2022), where they found CRH21-13/14 (Pumelo x Troyer citrange) tolerant against drought. Soil sticks to the roots of the plant making analysis of roots very difficult and labour intensive. However, plants grown under hydroponic condition are useful for root morphological and nutritional analysis as well as molecular studies (Zhou *et al.*, 2018).

Conclusion

In conclusion, hydroponics offers a promising solution for fruit nursery development by enhancing crop resilience, improving resource efficiency, and reducing labor dependency. It effectively excludes soil-borne diseases transferred through planting materials, ensuring healthier plants. The integration of AI and machine learning further optimizes growth conditions and nutrient management. With its sustainable, eco-friendly practices, hydroponics aligns with the future of agriculture. Continued advancements can revolutionize nursery production and support the sustainable growth of fruit crops worldwide.

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INDIGENOUS BLACK RICE LANDRACES: PROMISING SUPERFOOD FOR HEALTH AND NUTRITIONAL SECURITY IN THE NORTHEAST STATES, INDIA

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Abstract

Black rice, also known as “purple rice”, holds a blend of cultural heritage, nutritional wealth, and economic potential in India particularly in the northeastern and southern regions. It is becoming a valuable crop for farmers due to its increasing demand in both domestic and international markets. Being a powerhouse of nutrients and health benefits, black rice is marketed as a "Superfood" in this region. In some Indian communities, black rice is used in religious cuisine and offerings, especially during festivals and ceremonial events. Increased demand for organic and health-promoting foods positions black rice as a high-value crop for farmers. Its cultivation can enhance livelihoods and boost rural and local economies. As a promising superfood, it can play a critical role in nutritional security and supporting sustainable development. Investments in research & development, extension, and market infrastructure will further unlock its full potential, benefiting farmers and consumers.

Introduction

Rice is a major staple food for more than 3 billion people worldwide. This cereal crop has a wide genetic variability and diversity, with hundreds of pigmented varieties grown worldwide. Of the pigmented rice varieties, dark purple-colored rice usually termed Black rice (*Oryza sativa L. indica*), is known for its rich anthocyanin content in the pericarp layers (Kushwaha, 2016). Genetic evidence suggests that black rice is believed to have evolved by mutation of the *Kala4* gene during the diversification process of domesticated rice (Kumar and Murali, 2020). With a vibrant historical and cultural background, Black rice was often reserved for the royal and upper classes in ancient China, earning it the nickname of king’s rice, imperial rice, heaven rice, forbidden rice, and purple (gluten-free) rice (Ito and Lacerda, 2019; Mazumdar *et al.*, 2022). Black rice has received increasing attention due to its rich nutritional profile, sensory characteristics, and astonishing health benefits popularised as a “Super Food”. It also holds significant promise for addressing food and nutritional security (Das *et al.*, 2023). It is grown worldwide, especially in Southeast Asian countries such as China, India, Japan, Thailand, Indonesia, Malaysia, Bangladesh, and Sri Lanka. In India, black rice is aboriginally cultivated in northeast states, West Bengal, Uttar Pradesh, Odisha, Jharkhand, Karnataka, and Tamil Nadu. Increasing cultivation of this nutrient-dense rice in northeast hill states like Manipur, Assam, Meghalaya, Mizoram, and Tripura highlights its potential as a sustainable food and health-enhancing crop (Oikawa *et al.*, 2015; Bhardwaj *et al.*, 2023). Black rice is rich in nutritional and nutraceuticals but is not so prevalent among Indians because of its texture, appearance, and cooking time. Additionally, black rice is also not widely cultivated by Indian farmers in large areas compared with white, red, and brown rice varieties because of low yield and marketability. Besides, being organic by default some black rice genotypes are adapted to marginal and low-fertility soils,

making them suitable for cultivation in areas prone to environmental stress (Catherine and Bhagat, 2019).

Origin and Domestication: Historical Background of Black Rice

Black rice has a rich historical and cultural background tracing back thousands of years, primarily to Asia. Its origin and domestication are intertwined with the broader history of rice cultivation in Asia, particularly in China, India, and Southeast Asia (Mazumdar *et al.*, 2022). The domestication of black rice was driven by both practical agricultural considerations and cultural preferences for its unique qualities. The primary center of origin for black rice is believed to be China. The Yangtze River Valley is often cited as a critical region where rice domestication began around 8,000 to 9,000 years ago (Kushwaha, 2016). Genetic evidence suggests that black rice likely emerged as a specific variety during the diversification of domesticated rice in Asia (Kumar and Murali, 2020). It was prized for its rich nutritional content, medicinal properties, and unique flavor. Historical records from the Tang and Ming Dynasties (7th to 17th centuries) highlight its association with health benefits and its use in traditional Chinese medicine. After its initial domestication in China, black rice spread to other regions of Asia, including India, Thailand, and the Philippines (Oikawa *et al.*, 2015; Ito and Lacerda, 2019). The domestication and cultural significance of black rice reflects a blend of agricultural innovation and culinary tradition. Its historical association with royalty and its health-promoting qualities continue to influence its reputation as a "superfood" in contemporary diets. The ongoing cultivation and genetic research into black rice contribute to a deeper understanding of its origin and role in human history.

Northeast Indian Black Rice Cultivars

The northeast state of India, particularly Indo-Burma hotspots is a significant center of origin for the cultivation of indigenous black rice landraces, reflecting the rich agricultural heritage and biodiversity of the region (Kumar and Murali, 2020). The unique agro-climatic conditions, traditional farming practices, and cultural preferences have contributed to the development of diverse black rice cultivars, which are known for their health benefits, distinct aroma, and rich anthocyanin content (Das *et al.*, 2023). The indigenous black rice cultivars of Northeast India, with their rich history, unique flavor, nutritional benefits, and medicinal values (Bhardwaj *et al.*, 2023; Chen *et al.*, 2024), hold significant cultural and economic value. In northeast states, different traditional black rice varieties are locally cultivated in abundance. States like Assam, Meghalaya, Manipur, Tripura, and Mizoram produce ample amounts of black rice (Mazumdar *et al.*, 2022). These varieties are often known by different local names that vary from place to place (Table 1, Figure 1). Additionally, these can support the livelihoods of local and marginal farmers with significant contributions to food and nutritional security in these states.

Table 1. Details of some prominent indigenous black rice cultivars of the northeast states of India.

S. No.	Black Rice Cultivars	Region	Characteristics
1.	Chakhao amubi, Chakhao pungdol amubi,	Manipur	<ul style="list-style-type: none"> • Medium grain with a sticky texture • Distinct nutty aroma • Rich in iron, fiber, and antioxidants
2.	Chakhao Poireiton, Chakhao angouba	Manipur	<ul style="list-style-type: none"> • Long-grained variety • Aromatic and rich taste
3.	Kharika	Assam	<ul style="list-style-type: none"> • Short grain • Strong aroma and dark pigmentation

S. No.	Black Rice Cultivars	Region	Characteristics
4.	Kalabhaat	Assam, and Tripura	<ul style="list-style-type: none"> • Medium to long-grained rice • High anthocyanin content
5.	Kalanamak	Uttar Pradesh, West Bengal, Manipur	<ul style="list-style-type: none"> • Low glycemic index • Stronger aroma than basmati varieties
6.	Kalabati	Mizoram	<ul style="list-style-type: none"> • Aromatic and short-grained • Good source of fibre, protein, and iron
7.	Kavuni Arisi	Mizoram and Tripura	<ul style="list-style-type: none"> • Chewy texture and distinctive aroma • Dark purple to black colour
8.	Karuppu kavuni	Meghalaya	<ul style="list-style-type: none"> • Low glycemic index • Rich in nutrient and bioactive content

**Taichung****Mugi Dhan****Joha Rice****Pnah Long**

Figure 1. Some common indigenous Black rice landraces viz., Taichung (Meghalaya), Mugi Dhan (Assam), Joha Rice (Assam), and Pnah Long (Meghalaya).

Nutritional Superiority of Indigenous Black rice over other Rice

Indigenous black rice varieties, particularly those cultivated in regions like Northeast India, are known for their superior nutritional profile compared to other rice types, including white, red, and brown rice. Black rice varieties offer superior nutritional benefits, making them a valuable addition to a health-conscious diet (Kushwaha, 2016; Ito and Lacerda, 2019). Their higher antioxidant content, better fiber and protein levels, high minerals, rich in vitamins, and low glycemic index make black rice a functional food with significant health potential (Das *et al.*, 2023; Chen *et al.*, 2024). As global interest in superfoods continues to grow, black rice stands out as a powerhouse of nutrition, especially when compared to common white, red, and even brown rice.

Table 2. Summary of nutritional superiority of uncooked black rice over other rice (per 100g).

S. No.	Particulars	Black Rice	Brown Rice	Red Rice	White Rice
1.	Anthocyanin Content	High	Minimal	Minimal	Lack
2.	Antioxidant Activity	Very High	Moderate	Moderate	Low
3.	Carbohydrate	76.20	86.85	77.24	75.77
4.	Fat	2.15	3.16	2.92	2.50
5.	Dietary Fiber (g)	4.90	2.80	3.50	1.60
6.	Protein (g)	9.61	8.71	7.79	7.20
7.	Iron (mg)	3.50	2.20	5.50	1.20
8.	Zinc (mg)	3.16-17.51	0.60-2.80	0.05-3.30	0.5-1.30
9.	Glycemic Index	42-50	50-55	56-67	70-78

Source: Kushwaha (2016); Ito and Lacerda (2019); Das *et al.* (2023); Chen *et al.* (2024)

Medicinal Properties and Health Benefits of Indigenous Black Rice

Indian black rice, known for its distinct dark-purple to-black color thanks to its high anthocyanin content, possesses significant medicinal properties and health benefits. Indigenous black rice cultivars, such as Chakhao, Kalabati, Kharika, and Kalabhaat are widely recognized for their unique bioactive compounds (Catherine and Bhagat, 2019; Kumar and Murali, 2020; Bhardwaj *et al.*, 2023). Here are some notable medicinal properties and health benefits of these rice cultivars:

- a. **Rich in Antioxidants:** Black rice contains high levels of anthocyanins, which have powerful antioxidant properties. These compounds can help to neutralize free radicals, reducing oxidative stress and lowering the risk of chronic diseases like cancer and cardiovascular diseases.
- b. **Anti-Inflammatory properties:** Compounds found in black rice have anti-inflammatory effects, which can help to prevent arthritis and inflammatory bowel disease (Das *et al.*, 2023).
- c. **Antidiabetic Effects:** The low glycemic index of black rice, combined with bioactive compounds, helps in blood sugar regulation, making it beneficial for diabetes.
- d. **Heart Health:** High levels of anthocyanins reduce LDL levels, improve blood lipid profiles, and prevent atherosclerosis, thus supporting cardiovascular health (Kushwaha, 2016).
- e. **Neuroprotective Effects:** Antioxidant-rich black rice may protect neurons from oxidative damage, potentially reducing the risk of neurodegenerative diseases like Alzheimer's and Parkinson's (Ito and Lacerda, 2019).
- f. **Rich in Dietary Protein and Fiber:** Black rice genotypes contain significant amounts of protein (8-10%) and fiber, contributing to sustained energy release while aiding digestion, preventing constipation, and promoting gut health (Ito and Lacerda, 2019).
- g. **Liver Protection:** Black rice shows hepatoprotective effects due to antioxidant activities, and reducing liver damage caused by toxins (Kushwaha, 2016).
- h. **Weight Management:** The fiber content and bioactive compounds promote engorgement, helping in weight control and preventing obesity (Catherine and Bhagat, 2019).
- i. **Antimicrobial Properties:** Extracts of black rice exhibit antibacterial and antifungal properties, contributing to its potential use in fighting infections (Bhardwaj *et al.*, 2023).

The unique medicinal properties of Indian black rice make it a promising functional superfood supporting prodigious health benefits. However, further studies and clinical trials are needed to understand the nutraceuticals and health potential of black rice cultivars.

Cultivation of Black Rice in Northeast India: Opportunity and Challenges

Indigenous black rice variety is gaining popularity due to its high antioxidant properties, health benefits, and potential economic value (Das *et al.*, 2023). The northeast states with its diverse agro-climatic zones and traditional agricultural practices provide a favorable environment for the cultivation of black rice (Catherine and Bhagat, 2019). However, there are several opportunities and hidden challenges associated with its production and commercialization:

Opportunities

- Ideal agro-climatic condition for cultivating black rice.
- Rich in minerals, proteins, fibres, and antioxidants.
- Have nutraceutical potential.
- Prevent the risk of diabetes and obesity.
- Good for healthy cardiac/heart.

- Growing demand in domestic and international markets.
- Can double the income of local farmers.
- Can be traded using online platforms.

Challenges

- Nutritional and nutraceutical properties need to be standardized.
- Nutraceutical potential needs to be popularized.
- Efficient post-harvest processing and value chain addition should be developed.
- Can't be consumed in large quantities.
- No constant demand in domestic and international markets.
- Cultivated in less quantities.
- Limited funding and research efforts.
- Required specific agro-ecological conditions for cultivation.
- Government support/policies are needed for large-scale cultivation and marketing.

Conclusion and Future Perspectives

Black rice holds immense potential to address food and nutritional security challenges, especially in northeast India. By leveraging its rich nutritional profile, promoting cultivation, and developing market infrastructure, it can contribute significantly to health outcomes and sustainable agricultural development. Black rice in northeast states presents a promising opportunity for sustainable agricultural development, economic growth, and cultural preservation. High market demand for black rice as a premium nutritional and health product will enhance the incomes of local farmers, thus supporting rural livelihoods and boosting local economies. In addition, the diversification of black rice often promotes biodiversity in agricultural ecosystems, reducing dependency on a narrow range of staple crops for food and nutritional security. However, addressing the hidden challenges related to productivity, infrastructure, and market access is crucial for unlocking its full potential. Investing sustainability in agriculture and scientific efforts can make it more climate-resilient.

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MICROBIAL ENZYME SYNTHESIS: A GREEN ALTERNATIVE FOR INDUSTRIAL CATALYSIS

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Abstract

Microbial enzymes play a crucial role in the food industry due to their efficiency, specificity, and adaptability. These enzymes hydrolyze complex biomolecules, improving food processing and quality. Microorganisms—particularly fungi, bacteria, and yeast—are preferred for enzyme production over plant and animal sources because they grow rapidly, can be easily scaled, and are genetically modifiable. Submerged fermentation is commonly utilized for industrial enzyme production, as it offers high yields and better process control. Meanwhile, solid-state fermentation remains important for the production of certain fungal enzymes. This article reviews various microbial sources, fermentation methods, and strategies for process optimization, highlighting their significance in food microbiology and industrial applications.

Introduction

Enzymes hydrolyze complex molecules into simple monomers, such as carbohydrates into sugars, playing crucial roles in biochemical processes. Each enzyme is specific to its substrate, pH, and temperature for catalysis. The food-processing industry utilizes over 55 different microbial enzymes, including hydrolases, isomerases, lyases, oxidoreductases, and transferases. Commercial enzyme production mainly comes from fungi (60%), followed by bacteria (24%), yeast (4%), *Streptomyces* (2%), higher animals (6%), and plants (4%). Historically, enzymes from animal and plant sources were predominant and remain important for specific applications.

Microbial source is preferred over plants and animals for production of enzymes mainly because of the following reasons:

- 1) Enzymes can be produced on large scale and are economical
- 2) The process of extraction and purification of enzymes from microbial sources is easier in comparison with plant and animal sources
- 3) Microbial sources are capable of producing variety of enzymes in different environmental conditions in limited space and time period
- 4) Genetic manipulation is carried out to yield higher quantity of enzymes produced from microbial sources

In industrial enzyme production, submerged liquid conditions are preferred over solid-substrate fermentation due to higher yields and lower contamination. However, solid-substrate fermentation historically plays a crucial role in producing fungal enzymes like amylases, cellulases, proteases, and pectinases. Both batch and continuous sterilization techniques are used for medium sterilization. Froth formation can be controlled with antifoam agents, with batch fermentation being more common than continuous processes. Optimal growth conditions—such as substrate, oxygen supply, pH, and temperature—are maintained after inoculating the medium.

Fermentation

Throughout the fermentation process the bioreactor system must be operated under sterile conditions. In most production processes, the fermentation duration is variable approximately 2-7 days. Fermentation is a biochemical process that breaks down organic compounds into simpler substances like alcohol, acids, and gases. Parameters like temperature, pH, oxygen consumption and carbon dioxide formation are measured and controlled to optimize the fermentation process.

Methods of Fermentation**a. Submerged fermentation**

Submerged fermentation is the cultivation of microorganisms in liquid nutrient broth, used to produce industrial enzymes or pigments. This process occurs in large vessels (fermenters) containing a nutrient-rich broth and high oxygen levels. As microorganisms break down the nutrients, they release enzymes or pigments into the solution. The fermentation media is sterilized and consists of renewable raw materials like maize, sugars, and soya. Most industrial enzymes are secreted by microorganisms to break down carbon and nitrogen sources.

b. Solid state fermentation

Solid-state fermentation involves the cultivation of microorganisms on a many solid substrate, such as grains, rice and wheat bran, bagasse, and paper pulp. It includes:

- high volumetric productivity
- relatively high concentration of product
- less effluent generated
- simple fermentation equipment

Selection of substrate depends on

- cost and the availability of the substrate
- particle size (Smaller substrate particles offer a larger surface area for microbial growth, while larger particles enhance aeration and respiration but reduce surface area)
- level of moisture

	Submerged fermentation	Solid state fermentation
Definition	Fermentation carried out by microorganisms grown in a liquid medium	Fermentation occurs by microorganisms grown on a solid substrate
Cultivation of microorganism	On a liquid surface	On a solid surface
Microbial cells	Evenly distributed throughout the medium	Grow adhered to the solid surface
Culture medium	Always free-flowing	Not Free-flowing
Water content of the medium	>95%	40-80%
Nutrient distribution	Evenly distributed	Not even
Inoculum ratio	Low	High
Agitation	Essential	May or may not be involved

Table 1: Submerged fermentation & Solid-state fermentation

Types of fermentation process

a. Batch fermentation

Batch reactors are simplest type of mode of reactor operation. In this mode, the reactor is filled with medium and the fermentation is allowed to proceed. When the fermentation has finished the contents are emptied for downstream processing. The reactor is then cleaned, re-filled, re-inoculated and the fermentation process starts again.

b. Continuous fermentation

In continuous reactors, fresh media is continuously added and bioreactor fluid is continuously removed. As a result, cells continuously receive fresh medium and waste products and cells are continuously removed for processing. The reactor can thus be operated for long periods of time without having to be shut down.

Process of producing industrial microbial enzymes mentioned in Fig.1. and optimum conditions for industrial enzymes produced by microorganism mentioned in Table 2.

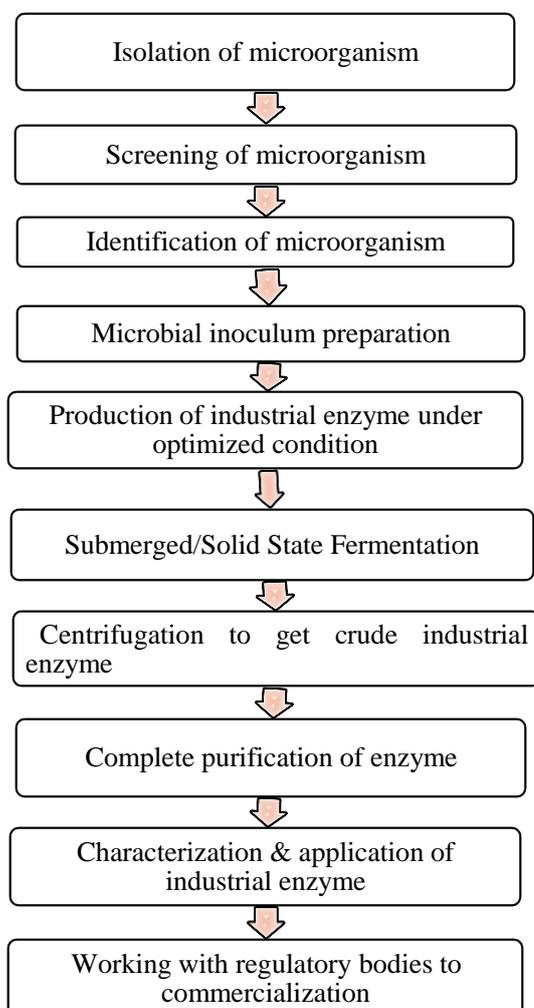


Fig.1: Production of industrial enzymes by microorganisms

Microorganism	Enzyme produced	pH	Temp.	Agitation (rpm)	Inoculum size (%)	Incubation period	Good C source	Preferred N source	Reference
Bacterial species									
<i>Bacillus cereus</i>	Protease	10	37	--	2.0	48 h	Glucose and skim milk	Peptone and yeast extract	Beena <i>et al.</i> , 2012
<i>Bacillus lehensis MLB2</i>	Phytase	5.5	30	100	2.0	24 h	Rice bran	Potassium nitrate	More, S.S. <i>et al.</i> , 2015
<i>Acinetobacter calcoaceticus 1-7</i>	Lipase	9	37	180	0.6	48 h	Starch, olive oil	Corn flour, bean flour	Wang H. <i>et al.</i> , 2012
<i>Pseudomonas stutzeri AS22</i>	Amylase	8	30	200		24 h	Potato starch	Yeast extract	Maalej H. <i>et al.</i> , 2013
Fungi									
<i>Mucor circinelloides F6-3-12</i>	Tannase	5.5	30	200	2.0	7 days	Green tea powder	Sodium nitrate	El-Refai H.A. <i>et al.</i> , 2017
<i>Stereum ostrea</i>	Laccase	5.5	30	180	--	12 days	Glucose	Peptone	El-Refai HA. <i>et al.</i> , 2017
<i>Aspergillus versicolor PF/F/107</i>	Protease	9	35	150	ns	4 days	Wheat bran	Sodium nitrate	Choudhary V., 2012
<i>Aspergillus niger</i>	Pectinase	4.5	30	150	ns	7 days	pectin	Peptone	Dhital R. <i>et al.</i> , 2013

Table 2: Optimum conditions for industrial enzymes produced by bacteria and fungi

Some microbial enzymes present in the market

1. Lipase from *Candida rugosa*



> L8525

L8525 ▶ Sigma-Aldrich.

Share

Lipase from *Candida rugosa*

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lyophilized powder, ≥40,000 units/mg protein

Synonym(s): Triacylglycerol acylhydrolase, Triacylglycerol lipase

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Pack Size	SKU	Availability	Price
1000000 units	L8525-1MU	In Stock From Bangalore Non-Bonded Warehouse	₹14,751.90
5000000 units	L8525-5MU	Estimated to ship on 29 March 2025 From Bangalore Non-Bonded Warehouse	₹56,798.70

About This Item

CAS Number:	9001-62-1
Enzyme Commission number:	3.1.1.3 (BRENDA, IUBMB)
EC Number:	232-619-9
MDL number:	MFCD00131509
UNSPSC Code:	12352204
NACRES:	NA.54

2. Clenzyme



Supplement Facts

Serving Size 1 Vegetarian Capsule

	Amount Per Serving
Enzyme Blend	94 mg**
Bacterial Protease (<i>Bacillus subtilis</i>) (whole)	18.5 mg (18500 FCC PC)
Alpha-Amylase (<i>Aspergillus oryzae</i>) (whole)	15.3 mg (2300 FCC DU)
Triacylglycerol Lipase (<i>Rhizopus oryzae</i>) (whole)	7.5 mg (525 FCC LU)
Fungal Protease (<i>Aspergillus oryzae</i>) (whole)	9.2 mg (9200 FCC HUT)
Glucosylase (<i>Aspergillus niger</i>) (whole)	8.7 mg (10.5 FCC AGU)
Cellulase (<i>Trichoderma longibrachiatum</i>) (whole)	8.6 mg (1550 FCC CU)
Bromelain (<i>Ananas comosus</i>) (pineapple stem)	7 mg (230000 FCC PU)
Papain (<i>Carica papaya</i>) (fruit)	5.5 mg (230000 FCC PU)
Hemicellulase (<i>Aspergillus niger</i>) (whole)	2.9 mg (2300 FCC HCU)
Pectinase (<i>Aspergillus niger</i>) (whole)	1.0 mg (9 endo-PGU)

** Daily Value not established.

Other ingredients: Microcrystalline cellulose, vegetarian capsule (carbohydrate gum [cellulose], purified water), magnesium stearate (vegetable grade).

FCC (Food Chemical Codex), PC (Bacterial Protease Unit), DU (Dextrinizing Unit), LU (Lipase Unit), HUT (Hemoglobin Unit on the Tyrosine Basis), AGU (Amyloglucosidase Unit), CU (Cellulase Unit), PU (Papain Unit), HCU (Hemicellulase Unit), PGU (Polygalacturonase Unit).

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MICROBIOLOGICAL STRATEGIES FOR CONTROLLING INSECT PESTS AND PATHOGENS IN AGRICULTURAL WAREHOUSES

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Abstract

Post-harvest losses in agricultural warehouses, primarily due to insect pests and microbial pathogens, threaten food security and economic stability. Traditional chemical control methods, though effective, pose risks of environmental contamination, pest resistance, pesticide residue and health hazards. Microbial control emerges as a sustainable alternative, utilizing beneficial bacteria, fungi, viruses and nematodes to target pests with high specificity while preserving grain quality. Unlike synthetic pesticides, microbial agents are biodegradable, residue-free, and compatible with IPM. Their ability to establish long-term pest suppression makes them a promising tool for eco-friendly storage solutions. However, challenges such as environmental sensitivity, formulation stability, and market adoption require further research and innovation. By integrating microbial control with modern storage practices, the agricultural sector can significantly reduce chemical dependency, enhance food safety, and promote sustainable warehousing solutions.

Keywords: Microbial control, post-harvest protection, sustainable storage, pest management.

Introduction

"Insect pests and diseases can destroy up to 30% of the world's food supply after harvest. Post-harvest losses due to microbial contamination, insect infestations, and fungal pathogens threaten global food security. Agricultural warehouses are vulnerable to these threats, emphasizing the need for effective pest and disease control strategies. Traditional methods like chemical fumigation and synthetic pesticides have concerns over pesticide residues, environmental pollution, and pest resistance. This has led to research for safer, sustainable alternatives. Proper storage and pest control measures are crucial to maintaining grain integrity and preventing economic losses."



Insects such as rice weevil (*Sitophilus oryzae*), lesser grain borer (*Rhizopertha dominica*) pulse beetle (*Callosobruchus chinensis*), sweet potato weevil (*Cylas formicarius*), rust-red flour beetle (*Tribolium castaneum*), khapra beetle (*Trogoderma granarium*) and rice moth (*Corcyra cephalonica*) feed on stored grains, causing both direct and indirect damage (Chandaragi *et al.*, 2022). In addition, fungal pathogens like *Aspergillus*, *Penicillium* and *Fusarium* produce **harmful mycotoxins** like aflatoxins and fumonisins, which can contaminate food supplies and lead to severe health complications.

The consumption of fumigants and pesticides, such as methyl bromide, has been shown with drawbacks. Despite their efficacy, these pesticides raise dangers to human health, pollute the environment and build insect resistance. Therefore, microbiological control methods offer a

promising and sustainable solution for protecting post-harvest grains in agricultural warehouses. Beneficial microorganisms, including entomopathogenic fungi, bacteria, and viruses, can effectively **target insect pests and pathogens** while minimizing the negative impacts associated with chemical pesticides. By integrating microbiological control into **post-harvest pest management strategies**, we can enhance food safety, reduce pesticide dependency, and promote environmentally friendly storage practices.

1. Microbial Control of insect-pest in Warehousing Agricultural Produce

Microbial control offers a sustainable and targeted alternative, utilizing beneficial microorganisms like bacteria, fungi and viruses to combat storage pests. Microbial insecticides work by infecting pests through the integument or digestive system, leading to their eventual death. *Bacillus thuringiensis* (*Bt*) produces insecticidal toxins that disrupt the gut lining of insect larvae, while fungi such as *Beauveria bassiana* and *Metarhizium anisopliae* invade insect bodies, causing lethal infections. They offer benefits such as,

- **Environmentally safe:** Non-toxic to humans, beneficial insects and wildlife.
- **Residue-free:** No harmful chemical residues on stored grains.
- **Sustainable control:** Some microbes persist in storage environments, providing long-term pest suppression.
- **IPM compatibility:** It can be integrated with physical and chemical control methods.
- **Improved grain quality:** Reduces fungal infection & promotes beneficial microbial activity.

2. Types of microorganisms & their mode of action used for biocontrol

A) Bacteria

Bacterial insecticides are the most common form of microbial biopesticides. They are typically used as insecticides, although they can be used to control unwanted bacteria, fungi or viruses as well. As an insecticide, they are generally specific to individual species of moths and butterflies, as well as species of beetles, flies, and mosquitoes.

Bacillus thuringiensis

The most widely used microbial pesticide is *B. thuringiensis*. Each strain of this bacterium produces a different mix of proteins and specifically kills one or a few related species of insect larvae. When ingested by insect larvae, *Bt* releases endotoxins (proteins) that bind to the intestinal lining of the insect midgut. There are different strains (subspecies) of *Bt*, each with specific toxicity to particular types of insects. *Bacillus thuringiensis* var. *kurstaki* and *Bacillus thuringiensis* var. *aizawai* are used against lepidopteran (moths and butterflies) larvae.

B) Fungi

Fungi are diverse organisms found in every environment, with some species acting as parasitic biopesticides. Their mode of action involves germinating on the insect's cuticle, producing structures that penetrate and infect the insect's body.

- a) ***Beauveria bassiana*:** It is an entomopathogenic fungus that causes a disease known as the "white muscadine disease" in insects. ***B. bassiana*** is applied to the target pest as a spore, which is the reproductive and dispersal structure of the fungus. Once the spores have contact with the insect exoskeleton, they



Lesser grain borer
infected with
fungus

grow hyphae (long, branching vegetative appendages) that secrete enzymes, which in turn dissolve the cuticle (outermost layer of the skeleton).

- b) *Trichoderma harzianum*:** It provides natural, season-long control of diseases because it grows on the root system in a way that benefits the plant (root colonization). It protects roots from diseases caused by *Pythium*, *Rhizoctonia* and *Fusarium* and permits stronger, healthier root systems.



C) Viruses

The most common and effective types are the baculoviruses, a group that includes two types of insect viruses: Nuclear Polyhedrosis Viruses (NPV) and Granulosis Viruses (GV). Insect viruses are obligate disease-causing organisms that can only reproduce within a host insect. Most are so specific in their action that they infect and kill only one or a few species of Lepidoptera larvae (caterpillars), making the viral insecticides good candidates for management of crop pests with minimal off-target effects.

- a) *Cydia Pomonella* Granulosis:** The granulovirus of the codling moth, *Cydia pomonella*, or CpGV, is a good example of a commercially successful viral insecticide. CpGV is highly specific to the codling moth. It is a major pest causing severe economic damage in apple and pear orchards throughout most of the temperate world.



D) Nematodes

Nematodes are microscopic roundworms that lack segments or appendages and may be parasitic, free living, or predaceous. Entomopathogenic nematodes have a symbiotic association with a bacterium (*Xenorhabdus* spp. and *Photorhabdus* spp.) that is lethal to many soil-dwelling insects but does not affect animals or plants. Because they are highly mobile and can locate and destroy new victims in just a few days, entomopathogenic nematodes make outstanding candidates for all kinds of biological control.

Species of nematodes vary in their host range and host-finding behavior. Most failures in efficacy of field applications are related to a poor match between the nematode species and target insect pest. Some nematodes (e.g., *Heterorhabditis* spp.) are very active in the soil and search a relatively large area for a host insect, whereas the widely available nematode, *Steinernema carpocapsae*, is relatively sedentary and tends to sit and wait for a host insect to pass by close.

Table 1: Microbial agents for managing stored product pests

Biocontrol Agent	Target Pests	Mode of Action	Key Considerations
Predators			
<i>Xylocoris flavipes</i>	<i>Callosobruchus maculatus</i> , <i>Tribolium</i> spp.	Attacks and feeds on pests	Host location depends on olfactory stimuli
Parasitoids			
<i>Anisopteromalus calandrae</i>	Rice weevil	Parasitizes and kills insect stages (egg, larvae)	Highly host-specific
<i>Habrobracon hebetor</i>	Almond moth (<i>Cadra cautella</i>), <i>C. cephalonica</i>		
<i>Holepyris sylvanidis</i>	Red flour beetle		

Biocontrol Agent	Target Pests	Mode of Action	Key Considerations
<i>Trichogramma pretiosum</i>	<i>C. cautella</i> , <i>Ephestia</i> spp., <i>Plodia interpunctella</i>		
Entomopathogenic fungi			
<i>B. bassiana</i> and <i>M. anisopliae</i>	<i>Rhizopertha dominica</i> and <i>Sitophilus oryzae</i>	Infects through cuticle, causing lethal infections	Temperature, humidity and grain type affect efficacy
Entomopathogenic nematodes			
<i>Steinernema</i> spp. & <i>Heterorhabditis</i> spp.	Soil-dwelling and stored-product insects	Releases symbiotic bacteria lethal to pests	Sensitive to dry conditions, encapsulation improves survival

Limitations of microbial insecticides

- **Pest-Specific Action:** Most microbial insecticides target specific pests, which means they may not control all insects in storage, requiring complementary pest management strategies.
- **Environmental Sensitivity:** Factors like heat, dryness, and UV radiation can reduce their effectiveness, making proper application timing crucial.
- **Storage and Handling:** Some microbial products need specific storage conditions to maintain potency, though widely used ones come with clear guidelines.
- **Limited Market Scope:** Their specificity limits widespread commercial use, leading to higher research and production costs.



Conclusion

Microbial control methods provide an effective, environmentally safe, and sustainable solution for protecting post-harvest grains from pests and pathogens. Their specificity, minimal chemical residue, and compatibility with IPM strategies make them a viable alternative to synthetic pesticides. However, their successful implementation requires appropriate application techniques, awareness, and continued research to optimize efficacy.

Future Perspectives

1. **Advancement in formulations** – Developing more stable microbial formulations resistant to environmental factors for improved shelf life and effectiveness.
2. **Integration with IoT and AI** – Leveraging smart monitoring systems for precise microbial application in warehouses.
3. **Wider commercial adoption** – Enhancing production scalability and cost-effectiveness to make microbial control more accessible.
4. **Policy and Awareness** – Promoting government incentives and farmer education programs to encourage microbial pest management adoption.

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MINERAL COMPOSITE RATIO MAPPING USING LANDSAT-8 OLI: AN EXPLORATION THROUGH REMOTE SENSING

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Abstract

This article presents a remote sensing and GIS-based approach to mineral composite ratio mapping using Landsat 8 OLI imagery. By leveraging distinct spectral reflectance characteristics of minerals, targeted band ratios were calculated to enhance the visibility of iron oxides, ferrous, and clay minerals. Radiometric and atmospheric corrections ensured data reliability, while spatial modelling in ArcGIS facilitated both individual and composite mineral maps. The resulting composites offer a multidimensional visualization of mineralogical variability, enhancing interpretability and exploration accuracy. This integrative method serves as a cost-effective, non-invasive tool for regional mineral prospecting.

Key words: Composite mapping, band ratio, satellite imagery, raster calculation

Introduction

The diminishing rate of novel mineral deposit discoveries, juxtaposed with the escalating demand for diverse minerals, has propelled exploration geologists to seek more effective and innovative methodologies for processing various data types across all phases of mineral exploration ([Shirmard et al., 2021](#)). Mineral prospectivity modelling, also known as mineral prospectivity mapping, plays a crucial role in delineating and prioritizing prospective areas for the exploration of undiscovered mineral deposits ([Sun et al., 2020](#)). The integration of different data types presents a comprehensive understanding of the geological processes underlying mineral deposit distribution ([Zheng et al., 2023](#)). One such method is mineral composite ratio mapping, a remote sensing technique used to highlight specific minerals by combining and dividing reflectance values from different spectral bands. It enhances mineral signatures by calculating ratios between bands sensitive to minerals. This method helps in identifying and mapping mineral distributions over large areas quickly and effectively.

What is mineral composite mapping?

Satellite remote sensing offers a powerful approach for assessing the mineralogical composition of a region without the need for extensive field-based soil sampling. Each satellite sensor records reflectance across distinct portions of the electromagnetic spectrum, and various minerals exhibit characteristic absorption or reflection patterns based on their chemical and structural properties. By applying band ratio techniques to satellite imagery, specific mineral signatures can be enhanced and identified, facilitating the creation of mineral composite maps (Shirmard et al., 2021). Commonly used satellites for such analyses include Landsat 8 OLI, ASTER, and Sentinel-2 MSI. GIS tools play a vital role in transforming spectral data into spatial outputs by generating individual mineral maps and integrating them into unified composite maps, thus offering a comprehensive understanding of the region's mineral potential.

LANDSAT-8 OLI

Landsat 8, launched by NASA and the USGS in 2013, is equipped with the Operational Land Imager (OLI) sensor, which captures multispectral data across nine spectral bands, covering the visible, near-infrared, and shortwave infrared regions. With a spatial resolution of 30 meters, OLI provides high-quality imagery suitable for geological and mineralogical studies. Its spectral configuration is particularly effective for mineral composite ratio mapping, as different minerals reflect and absorb electromagnetic radiation differently in specific bands. By applying band ratio techniques—such as iron oxide (Band 4/Band 2), clay (Band 6/Band 7), or carbonate (Band 6/Band 5) indices—Landsat 8 OLI enables accurate detection and mapping of surface mineral distributions, supporting efficient exploration and regional-scale mineral assessment. Landsat Thematic Mapper and Enhanced Thematic Mapper, due to their coarse spatial and spectral resolution, are appropriate for regional mapping (Liu et al., 2016). However, the Advanced Spaceborne Thermal Emission and Reflection Radiometer sensor on the Terra satellite and the Advanced Land Imager sensor on EO-1 offer better spatial and spectral resolution, making them ideal for detailed lithological mapping (Sohn & McCoy, 1997). The selection of band ratios for mineral mapping is highly dependent on the spectral characteristics of the target minerals and the sensor capabilities, with careful consideration required to minimize noise and environmental influences.

Table 1. Landsat 8 OLI Bands (Surface Reflectance)

Band	Wavelength (μm)	Name
Band 1	0.43 – 0.45	Coastal/Aerosol
Band 2	0.45 – 0.51	Blue
Band 3	0.53 – 0.59	Green
Band 4	0.64 – 0.67	Red
Band 5	0.85 – 0.88	Near Infrared (NIR)
Band 6	1.57 – 1.65	SWIR 1
Band 7	2.11 – 2.29	SWIR 2

Table 2. Common Mineral Ratios in Landsat 8 OLI

Mineral Indicator	Band Ratio	Targeted Mineral Type
Iron oxides	Band 4 / Band 2	Hematite, limonite
Ferrous minerals	Band 6 / Band 5	Biotite, chlorite
Clay minerals	Band 6 / Band 7	Kaolinite, illite
Carbonates	Band 6 / Band 5	Calcite, dolomite
Alteration zones	Band 7 / Band 6	Hydrothermal alterations

Methodology

The selection of the study area is the foundational step in mineral mapping, guided primarily by geological significance and exploration potential. Once identified, acquiring suitable Landsat 8 OLI imagery becomes essential (Herbei et al., 2015). These datasets can be freely accessed and downloaded from the USGS Earth Explorer platform. It is critical to select images with minimal cloud cover to ensure clarity and accuracy. Prior to analysis, the imagery must undergo preprocessing, including radiometric and atmospheric corrections, to enhance data quality and remove distortions caused by sensor noise or atmospheric interference.

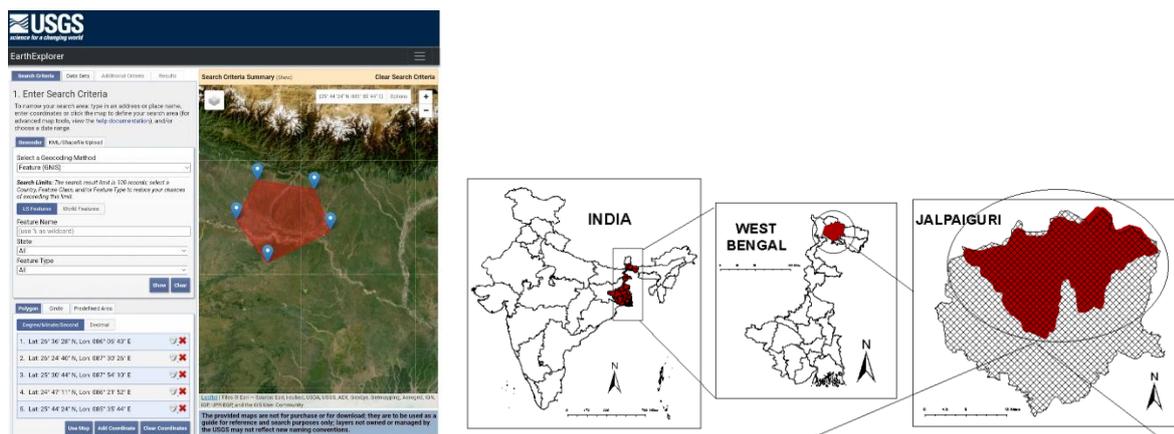
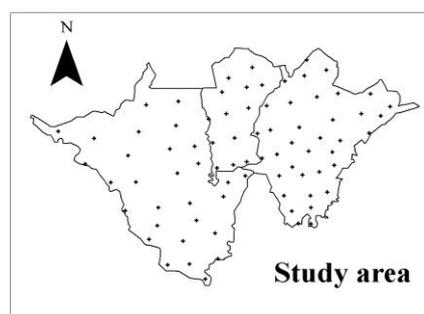


Fig 1. Downloading satellite imagery from USGS Earth Explorer according to the study area.

Following preprocessing, all seven spectral bands of the Landsat 8 OLI image should be imported into ArcGIS software for further processing. To generate a True Color Composite (TCC) image of the study area, bands 4, 3, and 2 are assigned to the red, green, and blue channels, respectively. Within ArcGIS, this can be done by navigating to the Toolbox, then selecting Data Management Tools → Raster → Raster Processing → Composite Bands. Here, all bands are added and combined to form a true color representation of the surface. With the TCC prepared, the next step is the band ratio calculation to identify specific mineral signatures. This process is carried out using the Spatial Analyst Tools. By accessing the Map Algebra → Raster Calculator, users can define mathematical expressions to compute targeted band ratios. For example, Band 4/Band 2 is commonly used to detect iron oxide, Band 6/Band 5 highlights ferrous minerals, and Band 6/Band 7 is effective for mapping clay minerals. Once the individual ratio images are generated, spatial distribution maps for each mineral group can be visualized and interpreted. To create a mineral composite image, the ratio layers are reassembled using the same composite method used for the TCC. However, in this case, the selected bands are replaced by the ratio images: for instance, assigning the ferrous mineral ratio to the red channel, the iron oxide ratio to green, and the clay mineral ratio to blue. This final composite provides an integrated visual representation of the mineralogical variability across the study area (Sovdat et al., 2019), serving as a valuable tool for mineral exploration and geological analysis.

Result

TCC that combines red, green, and blue bands will always show the true colour of the selected experimental study area. This type of composite is useful for identifying vegetation, water bodies, built-up areas, and other land cover features in a way that is intuitive and visually interpretable. In the case of individual spatial maps for each mineral composition, the outputs illustrate the distinct distribution patterns of specific minerals across the study area. These maps typically feature a non-graded legend, where lighter shades indicate higher concentrations of the respective minerals, while darker tones represent lower abundance. Such representations allow for the assessment of spatial variability in mineral distribution on an individual basis, guided by the spectral response captured in satellite imagery. However, when these individual ratio maps are combined to produce a composite image, a single map can effectively communicate the simultaneous distribution of



multiple minerals. This is achieved by assigning selected band ratio layers to the Red, Green, and Blue (RGB) channels. For instance, assigning the ferrous mineral ratio to Red, iron oxide ratio to Green, and clay mineral ratio to Blue allows the composite to visually distinguish mineral concentrations by color intensity. In the resulting image, areas with dominant red hues indicate zones rich in ferrous minerals, while blue-dominant areas reflect higher clay content. This composite approach offers a more integrated and interpretable visualization of mineralogical variation across the landscape.

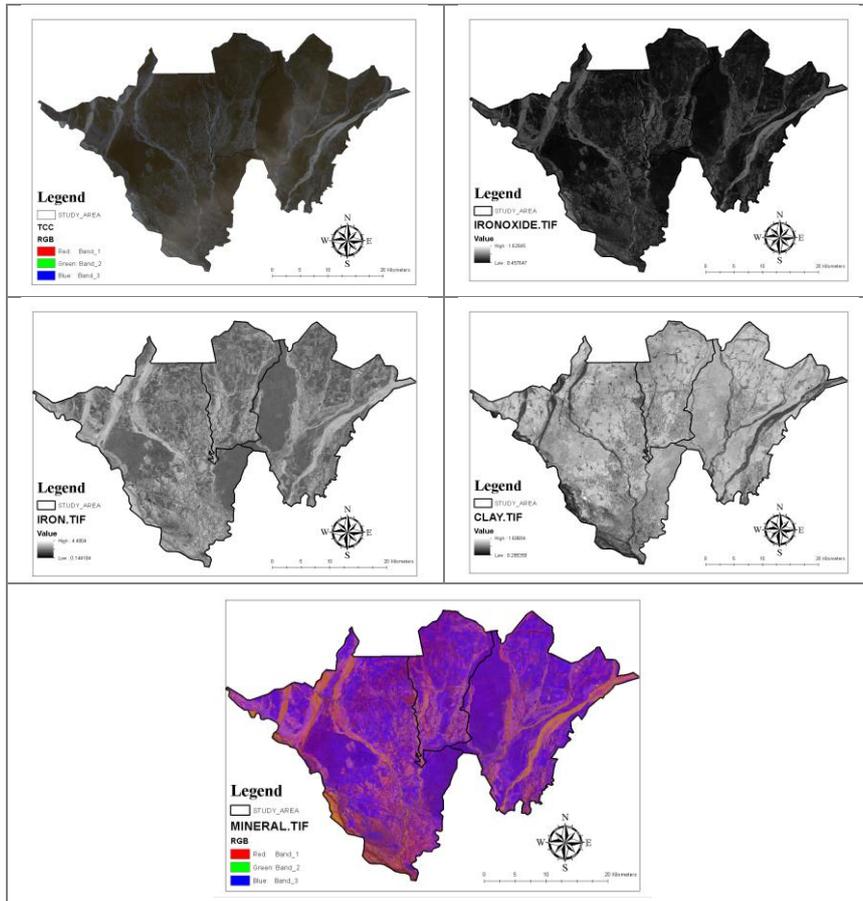


Fig.2. Output spatial map of TCC, Iron oxide, Ferrous minerals, Clay mineral and mineral composite mapping of the study area.

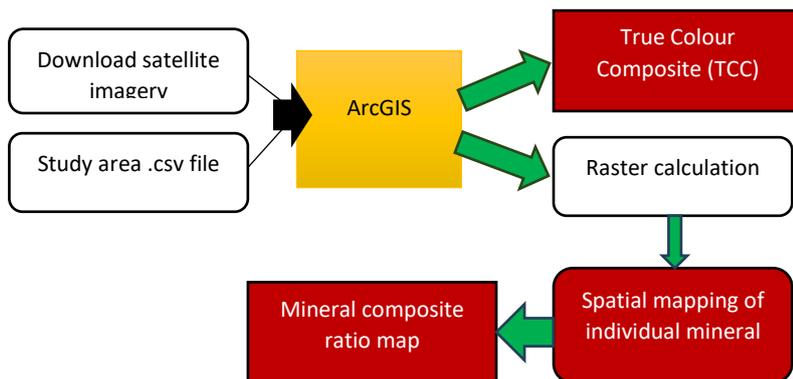


Fig.3. Flow chart of mineral composite ratio mapping process

Conclusion

The integration of Landsat 8 OLI data with GIS techniques offers an efficient and cost-effective method for mineral mapping. Through preprocessing and careful band selection, meaningful spectral information can be extracted to highlight mineral-specific features. True Colour Composites provide a natural view of the landscape, while band ratio calculations enhance the visibility of individual mineral signatures. Spatial maps allow for the identification of specific mineral distributions across the study area. Combining these into a composite image further enhances interpretation by visually representing multiple minerals in a single view. This approach supports better geological understanding and mineral exploration planning. Overall, remote sensing and GIS provide a powerful framework for non-invasive mineral assessment.

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NUTRACEUTICALS: (INNOVATION LEADING TO A HEALTHY FUTURE)

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Abstract

Nutraceuticals are defined as a hybrid category of products that bridge the gap between nutrition and pharmaceuticals. Coined from “nutrition” and “pharmaceuticals” nutraceuticals encompasses foods, dietary supplements, and functional foods with purported health benefits. (Puri V, Nagpal M, 2022). Nowadays, emphasis is given to those herbs which are used as food and medicine due to its greater acceptance. Due to dynamic action, the popularity of nutraceuticals among people as well as healthcare providers has been increased over medicines and health supplements. These herbs could be better options to formulate as nutraceuticals. Several nutraceuticals are described based on their availability as food, chemical nature, and mechanism of action. This review documents herbs with a wide variety of therapeutic values such as immunity booster, antidiabetic, anticancer, antimicrobial, and gastroprotective.

Introduction

Almost 2500 years ago, Hippocrates (460–377 BC), the father of modern medicine, proved the relation of food and its importance for the treatment of various ailments. In recent years scientific community has drawn a great deal of attention on the phrase “Let food be thy medicine and medicine be thy food” coined by Hippocrates. Stephen De Felice, founder and chairman of the Foundation for Innovation in Medicine, Cranford, NJ, invented the phrase "nutraceutical" in 1989 by combining the words "nutrition" and "pharmaceutical." A food or component of food that offers medical or health advantages, such as the prevention and/or treatment of an illness, is referred to as a nutraceutical, in De Felice's definition (Bajaj Manya, 2024). The concept of nutraceuticals emphasizes the preventive and therapeutic roles of certain food components beyond basic nutritional function. There is a vast cornucopia including herbs and foods which stimulate support and nourish our body system. Some have been used by different traditional systems of several countries and are now being evaluated by modern research. Use of pharmaceutical antibiotic would build up tolerances which make it ineffective eventually. It is a better way to choose such herbs in our daily life, which would be not only capable of normalizing our body functions (even in disease condition) but being preventive and nutritive, and also boost our immune system. Herbs may not act as precisely as an antibiotic but can act as antibacterial (even antiviral) by boosting our body's own defence mechanism. To feel as a healthy well-being, one of the prominent approaches is to stay away from stress and other lifestyle diseases. The following are some examples of herbs used as food as well as medicine during infection, to boost the immune system or even in several other illnesses.

- *Astragalus membranaceus* (Fabaceae) is a traditional Chinese herb. It is an extremely versatile and powerful immune enhancer antioxidant and has hepatoprotective activity. It also showed antidiabetic and anticancer activity.

- Triphala is one of the most revered tonics in Indian Ayurveda. It is a combination of three important herbs, namely, *Terminalia bellerica* (Combretaceae), *Terminalia chebula* (Combretaceae), and *Embllica officinalis* (Phyllanthaceae). All these herbs act as a nutritive tonic. Triphala helps all organs/systems of our body, particularly skin, liver, eyes, and digestive and respiratory system. The most well-known therapeutic uses are immunomodulating, antibacterial, antimutagenic, and adaptogenic, etc., which are well established.
- The northeast region of India is extraordinarily rich in flora and fauna. The tribal people of the northeast region follow the principle of Hippocrates. They use their food as medicine. *Paederia foetida* (Rubiaceae) is one of the tribal plants. A research study proved its gastroprotective activity and antioxidant activity (Bajaj Manya, 2024).
- The yellow powder (turmeric) from South Asia, a curry ingredient, is well known for its preventive action. It is very active against various types of bacteria, fungus, virus, and also parasite. It is a potent inhibitor of HIV (Shailaja M, Damodara Gowda KM, 2017).
- Asian ginseng, probably the most westernized herb, is used as a tonic. It has been popular to promote immunity. The most well-known ginseng is *Panax* ginseng, and it has protective effects in neurological disorders (Shailaja M, Damodara Gowda KM, 2017).
- According to Indian Ayurveda, garlic, onion, and ginger are the basis of all healing food recipes. Garlic is one of the most widely used natural health products. These are considered as food, spice, and medicine. It has been the subject of intensive study for its possible effects against heart disease and cancer. It increases the general immune system activity (Makkar R., Behl T., 2020).

The FSSAI guidelines for nutraceuticals are outlined under the Food Safety and Standards (Health Supplements, Nutraceuticals, Food for Special Dietary Use, Food for Special Medical Purpose, Functional Food, and Novel Food) Regulations, 2016. These regulations specify standards for health supplements and nutraceuticals, ensuring safety and efficacy in the Indian market. Additionally, the FSSAI compendium provides detailed information on nutraceuticals and their classifications, which is essential for compliance and regulatory approval. For a comprehensive overview, you can refer to the official FSSAI website.

FSSAI has directed Nutraceutical Regulations to stop using 14 ingredients lacking scientific data for safe usage. The country's apex food regulator ordered FBOs to discontinue the use of raspberry ketone, silica, *angelica sinensis*, *paullinia cupana*, saw palmetto, notoginseng, chlorella growth factor, pine bark extracted to pinus radiate, pine bark extracted from pinus pinaster, Vitamin D3-veg, chaga extract, *oxalobacter formigenes*, *phytavail* iron and tea tree oil. FBOs were also asked to discontinue antichoke, kale powder, *salvia hispanica*, cashewfruit, passion fruit, kiwi fruit extracts, broccoli and enzymes, including pectinase and xylanase, as health supplements. However, their use in products was not prohibited, but FBOs cannot claim that the products are supplement or nutraceuticals. No further manufacturing of products using these ingredients will be allowed until these ingredients are assessed and approved by the authority. Further, FBOs are directed to furnish information and data in respect of these ingredients within one month. (Putta S., 2020 June 8).

Classification of Nutraceuticals: The food components used as nutraceuticals can be categorized as following

- **Nutraceuticals Based on Food Availability (Bioavailability)**

Traditional Nutraceuticals

These classes are generally sourced directly from nature, without any changes in the natural form. Various constituents such as lycopene in tomatoes, omega-3 fatty acids in salmon, or saponins in

soy are available and consumed for different health benefits. Further, various types of traditional nutraceuticals are as follows:

- i. Chemical constituents
 - a. Nutrients
 - b. Herbals
 - c. Phytochemicals
- ii. Probiotic microorganisms
- iii. Nutraceutical enzymes

(I) Chemical Constituents

(a) Nutrients: Primary metabolites such as amino acids, various vitamins, and fatty acids had well-defined functions in various metabolic pathways. Plant and animal products along with vitamins have many health benefits and are helpful in curing diseases related to heart, kidney, lungs, etc.

Natural products obtained from plants are beneficial in treating various disorders such as brittle bones and low haemoglobin count, and they provide strength to bones and muscles, help in neuron transmission, and maintain rhythm of heart muscles. Fatty acids, omega-3 PUFAs present in salmon, had influenced the overall inflammatory response and brain function and reduced cholesterol in the arteries.

(b) Herbals: Nutraceuticals along with herbs had an excellent impact on prevention of various chronic diseases to make life better. Salicin present in the willow bark (*Salix nigra*) had been proved for anti-inflammatory, analgesic, antipyretic, astringent, and antiarthritic response clinically. Flavonoids such as psorelen present in parsley (*Petroselinum crispum*) is useful in diuretic, carminative, and antipyretic. Peppermint (*Mentha pipreta*) contains various terpenoids especially menthol, a bioactive constituent, and cures cold and flu. Tannin contents of lavender (*Lavandula angustifolia*) help releasing stress and blood pressure and are useful for lung disorders such as asthma. (Bhavana Chaudhary, D., & Waris F., 2020).

(c) Phytochemicals: They are mainly classified on the basis of phytochemicals. Carotenoids (*isoprenoids*) are present in vegetables, enhancing immune system, mainly killer cells accounting for an anticancer response. Legumes (chickpeas and soybeans), grains, and palm oil contain noncarotenoids, which remove cholesterol and are anticarcinogenic.

Flavonoids, a class of secondary metabolites, which are present in most of the plants, having more than 4000 varieties had been proven clinically for preventing various diseases such as cancer, diabetes, heart diseases, and kidney problem through its antioxidant properties and their bioactive components.

Phenolic acids are the largest class of secondary metabolites, mainly found in citrus fruits and red wine, and have the antioxidant activity of scavenging the free radicals produced as a result of various metabolic pathways such as protein, carbohydrate, and fat. They also have anticancer and anti-tumour activity. One of the classical examples is *Curcumin* (turmeric), used as phytochemicals in most of the kitchen (Bhavana, Chaudhary, D., & Waris F., 2020).

(ii) Probiotic Microorganisms: Metchnikoff coined the term “probiotic.” Its application is well boosted in modern medicine due to its ability of making the intestine more friendly for processes such as absorption and metabolism. Probiotics are very important to make life smoother by removing the toxic flora of the intestine and maintaining a friendly environment, for example, useful

consumption of *Bacillus bulgaricus*. Currently various probiotic products are available in the market with adequate nutrients to counter various pathogens so that several ailments related to human body can be treated.

The antimicrobial property usually had an altering impact on the microflora, making the epithelial tissues more grounded and making a situation for the supplements for better retention, which is required by the body. Moreover, probiotics are very useful in lactose intolerance by the production of related enzymes (*β-galactosidase*) and hydrolysing lactose into its sugar components. Examples are:

- Lactobacillus acidophilus: Known to improve lactose digestion.
- Bifidobacterium longum: May help in the breakdown of lactose.
- Streptococcus thermophilus: Works in synergy with Lactobacillus bulgaricus to enhance lactose tolerance (Ahmed M. Elazzazy et.al., 2025).

(iii) Nutraceutical Enzymes: Enzymes are proteinous in structure, are produced by the cell, and act as a biocatalyst. It eases the metabolic rate and fastens the life process. The medical problem mainly related to the GIT (gastrointestinal tract) whether GERD (gastroesophageal reflux disease) or constipation or diarrhoea or ulcerative colitis could be treated with enzyme supplements. The enzyme could be a better option for diabetic patients. Nowadays, enzyme therapies are used for several rare diseases such as

Gaucher disease - Gaucher disease results from mutations in the GBA1 gene, leading to deficient glucocerebrosidase activity within lysosomes, in this case GBA1 enzyme (also called *beta-glucosylceramidase* or *beta-glucocerebrosidase*) are induced by enzyme therapy (Shemesh E., et al.,2015).

Hunter syndrome - is a rare X-linked recessive disorder characterized by the deficiency of the lysosomal enzyme *iduronate-2-sulfatase*, which is essential for the breakdown and recycling of sugars. Enzyme replacement therapy with *idursulfase* is induced, (International Journal of Molecular Sciences 2020).

Although enzymes are produced by their own cells, microbial sources are preferred more over plant and animal sources as they are more economic.

Nontraditional Nutraceuticals

They are foods enriched with supplements or biotechnologically designed crops to boost the nutrients. For example, rice and broccoli are rich in beta carotene and vitamins, respectively. Food samples contain bioactive components which are engineered to produce product for human wellness. They are as follows:

(1) Fortified Nutraceuticals: These types of nutraceuticals include breeding at the agriculture level or addition of compatible nutrients to the main ingredients such as minerals added to cereals, flour fortified with calcium, iron, and folic acid, and milk fortified with cholecalciferol commonly used for vitamin D deficiency (Puri V., et al., 2023).

(2) Recombinant Nutraceuticals: Biotechnology tools have been well applied through a fermentation process in various food materials such as cheese and bread to extract the enzyme useful for providing necessary nutrients at an optimum level (Puri V., et al., 2023).

List of nutraceuticals with health benefits

Table 1:

Nutraceuticals/ Dietary Supplements	Nutrients	Health Benefits
Water Soluble Vitamins	Vitamin C	Wound healing, Antioxidant
	Vitamin B1	Carbohydrate metabolism, Neurological function
	Vitamin B2	Energy metabolism, Nerve function
	Vitamin B3	Brain function
	Vitamin B6	Convert proteins to energy
	Vitamin B12	Formation of RBC's, Synthesis of amino acids Metabolism of fat, protein and carbohydrate
	Folic acid	Formation of RBC's, Formation of genetic material of cells
Fat Soluble Vitamins	Pantothenic acid	Intraneuronal synthesis of acetylcholine Synthesis of cholesterol, steroids, and fatty acids
	Vitamin A	Cancer, Skin health, Healthy vision, Powerful Antioxidant
	Vitamin D	Absorption of calcium, Formation of bones and teeth
	Vitamin E	Boost immune system, Antioxidant
Minerals	Vitamin K	Blood clotting
	Calcium	Maintaining bone strength, blood clotting
	Iron	Oxygen transport, Energy production
	Magnesium	Healthy nerve and muscle function and bone function
	Phosphorus	Phosphorylation process, Genetic material
	Copper	Heart functioning, Iron absorption
	Iodine	Functioning of thyroid gland
	Chromium	Diabetes
Herbals	Selenium	Antioxidant
	Zinc	Sperm production, wound healing
	Aloe vera	Anti-inflammatory, Wound healing
	Evening primrose oil	Treatment of atopic eczema
	Garlic	Anti-bacterial, Anti-fungal
	Ginger	Carminative, Anti-emetic
Ginseng	Adaptogen	
Green tea	Cell mediated immunity, Antioxidant (Bhavana, Chaudhary D., & Waris F, 2020).	

Benefits of Nutraceuticals

General Health & Well-being:

- **Supports Daily Nutritional Requirements:**

Nutraceuticals can help bridge nutritional gaps and ensure adequate intake of essential vitamins, minerals, and other beneficial compounds.

- **Antioxidant Benefits:**

Many nutraceuticals, like those found in fruits, vegetables, and herbs, are rich in antioxidants that combat free radicals and oxidative stress, potentially protecting cells from damage and promoting overall health.

- **Immune Support:**

Certain nutraceuticals, such as Vitamin C and Vitamin B, can boost immune function and help the body fight off infections.

- **Cognitive Function:**

Vitamins B and D, omega-3 fatty acids, magnesium, and iron can improve cognitive functioning and reduce the risk of neurodegenerative diseases such as Parkinson's and Alzheimer's disease.

- **Mental Health:**

Some nutraceuticals may help reduce anxiety, stress, and depression. Ex: Omega 3 fatty acids.

Disease Prevention and Management:

- **Cardiovascular Health:**

Nutraceuticals like omega-3 fatty acids and certain antioxidants (Vitamin E, Carotenoids, Polyphenols) may help reduce the risk of heart disease and other cardiovascular problems (Liu Y., Liu L., 2019).

- **Diabetes Management:**

Some nutraceuticals, such as those with anti-inflammatory properties, may help improve blood sugar control and reduce the risk of diabetes-related complications. Ex: *Trigonella foenum-graecum* (fenugreek), *Momordica charantia* (Bitter melon) etc. (Ying Le, et al. 2022)

- **Cancer Prevention:**

Certain phytochemicals and antioxidants found in plant-based nutraceuticals have been linked to a reduced risk of certain cancers. Ex: Omega 3 fatty acids, turmeric, green tea, garlic etc. (Garza-Juárez, et al. 2023).

- **Age-Related Conditions:**

Some nutraceuticals like glucosamine, chondroitin, collagen may help protect against age-related conditions like cataracts and age-related muscular degeneration (Maiuolo J., et al., 2023).

- **Retinal Health:**

Nutraceuticals such as carotenoids, xanthophyll, lutein, and zeaxanthin improve retinal health and function in retinal diseases while also protecting against hyperglycaemia-induced vascular changes in diabetes (Maiuolo J, et al., 2023).

Conclusion

Natural products have been known for their therapeutic values for centuries. In the modern era, these substances have been used as an immunity booster; antidiabetic, anticancer, antimicrobial, and gastroprotective agents; and so on. Therefore, these herbs could be better options to be formulated as nutraceuticals. The future of nutraceuticals is bright and promising, as they continue to revolutionize the healthcare industry by bridging the gap between nutrition and pharmaceuticals. With their preventive health benefits, personalized interventions, integration with conventional medicine, technological advancements, and increased research efforts, nutraceuticals are poised to play a significant role in promoting well-being and managing health conditions. However, achieving their full potential requires collaboration among regulatory authorities, healthcare professionals, and industry

stakeholders to ensure safety, efficacy, and consumer awareness. As we embrace a holistic approach to healthcare, nutraceuticals will undoubtedly become an integral part of our journey towards optimal health and wellness. (Chauhan, Baby, *et al* 2013).

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CULTURAL PRACTICES OF OKRA

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Introduction

Okra [*Abelmoschus esculentus* (L.) Moench] commonly referred to as "Lady's fingers". It belongs to the family Malvaceae and has the chromosome number $2n=130$. There are 38 species in the genus *Abelmoschus*. There is often cross-pollination in the crop. The only edible parts of okra are its delicate fruits and pods. It is a significant vegetable crop that is grown all over India during the summer and rainy seasons. It has a lot of vitamins, minerals, calcium, and potassium.

Most okra is grown in tropical and subtropical climates. With a yield of 6873 thousand MT from an area of 548 thousand hectares, it ranks fifth in the nation's vegetable crop, right behind tomatoes. Okra is rich in vitamins A and C, folate, Fiber and antioxidants, making it an essential component of diets in Africa, Asia and the Americas (Singh *et al.*, 2017). Its mucilaginous nature makes it a useful thickening agent in soups and stews, while its medicinal properties are linked to improving digestion, lowering cholesterol levels, and regulating blood sugar levels (Gupta & Sharma, 2015).

Fruit is useful against genitor-urinary disorders, spermatorrhoea and chronic dysentery. Fruits are also dried or frozen for use during off-season. Dried fruit contain 13-22% edible oil and 20-24% protein and is used for refined edible oil. Dry fruit skin and fibres are used in manufacture of paper, card board and fibres. Root and stem are used for clearing cane juice for preparation of jaggery. Cultivated okra is an annual herb with duration of 90-100 days. Flowers are bisexual and often cross-pollinated. Time of anthesis is 8.00-10.00 a.m. Dehiscence of anthers occurs 15-20 minutes after anthesis and is completed in 5-10 minutes. Pollen fertility is maximum in the period between one hour before and after opening of flower.

Origin and distribution

Okra originated in tropical and subtropical Africa. Existence of a large number of related species with wide variability and dominant characters suggest possible role of India as a secondary centre of origin. India is the largest producer of okra in the world. It is also used as a vegetable in Brazil, West Africa and many other countries. In India, major okra growing states are Uttar Pradesh, Bihar and West Bengal.

Nutritive value (per 100 g of edible portion)

Moisture	89.6g	Carbohydrate	6.4g
Protein	1.9g	Fat	0.2g
Fiber	1.2g	Calories	35kcal
Phosphorus	56mg	Magnesium	43mg
Sodium	6.9mg	Copper	0.19mg
Iron	1.5mg	Vitamin A	88IU
Thiamine	0.07mg	Riboflavin	0.1mg
Nicotinic acid	0.6mg	Vitamin C	13mg
Oxalic acid	8mg	Carbohydrate	6.4g

(Source- Fagaria *et al.*, 2012)

Soil and climate

One deep ploughing during summer followed by 2-3 light ploughings is sufficient to obtain the tilth. Soil should be rich in fertility and well drainage facility the best germination. Okra prefers loose, well drained and rich soil. The ideal pH for growth of plants is 6-8.

Varieties of okra

Varieties	Features
Kashi Mangali, Kashi Satdhari, Kashi Shristi, Pusa makhmali, Punjab no. -13, Arka Anamika, (Selection-1, Harbhajan Okra, Punjab-7, Parbhani karanti,	Resistant to YVMV
Kashi Bhairav, Shitala Uphar, Kashi Chaman,	Resistant to YVMV and OLYC
Kashi Vardan	Resistant to YVMV and OLYC, moderately tolerant to major pests under field condition.
Kashi Lalima	Reddish purple fruit, Tolerant to YVMY and OLYC Rich in anthocyanin, suitable for summer and Kharif.
Pusa Sawani	Resistant to YVMV but now resistant has been break down.
Kashi Vibhuti	Dwarf growth habit
Gujrat okra -3, Gujrat okra Hybrid	Fruits/ Pods green colour
Arka Nikita	(F1) Hybrid –Early flowering 30-40 DAS
Kashi Lalima (VROR-157), Kashi Chaman (VRO-109), Kashi Vardan	These are sowing Summer and rain.
Red burgundy & Alabama	Red pods & Red stems and high yielding varieties
Pusa Sawani and P-4	Resistant to Shoot and Fruit borer

Season : In areas where winter is mild, bhindi is grown throughout the year. Since it cannot tolerate frost and low temperature, only two crops are taken in plains of North India. As kharif crop, seeds are sown from May to July and as a spring summer crop, sowing is done during February-March. In hills of North India bhindi is sown during March-April.

Seed rate and spacing: During summer, vegetative growth is relatively less and seeds are sown at a closer spacing of 45 x 20 cm or even less. Seed rate required is 18-20 kg / ha. During kharif, plant grows vigorously with more branching and seeds are sown at wider spacing of 60 x 30 cm for branching types and 45 x 30 cm for non-branching types. Seed rate recommended for kharif crop is 8-10 kg/ha. For harvesting smaller fruits for export, three rows planting with a spacing of 20-30 cm between rows and 20 cm within a row is advantageous. Distance between two sets is kept as 60 cm. This system has the unique advantage of easiness in inter cultural operations, harvesting, application of plant protection chemicals, etc.

Land preparation and sowing: Field is ploughed thoroughly for 2-3 times for making soil to a fine tilth. Ridges and furrows or raised beds are prepared and dibbling on sides of ridges or on raised beds sows' seeds. Soak seeds for 6-12 hours before sowing to enhance germination during summer.

Training and Pruning : Okra as such does not require training or pruning. Varieties developed so far are upright growing and hence staking is also not practised. Recently, some success has been achieved in raising near normal kharif crop (ratoon) from plants of spring-summer sowing by pruning the plants after summer fruiting and with the onset of the rains, from 20-25 cm above the ground, adding organic and inorganic matter in the soil and providing plant-protection cover. Okra Arka Abhay and Pusa A 4 give quick branching after pruning.

Manuring and fertilizer: Apply 20-30 t of farmyard manure as basal dose at the time of final ploughing. As in general, dose of 100 kg of N, 60 kg of P₂O₅ and 50 kg of K₂O is recommended (Fagaria *et al.*, 2012). NPK recommendation varies from state to state and a lower dose of 50:80:30 kg N is recommended under Kerala condition. One third dose of N, full P and K are to be applied as basal dose. Remaining N has to be applied in two split doses, 4 weeks after sowing and at flowering and fruiting stages. Split application of N in soil at every 3rd picking is advantageous for getting high yield, for increasing number of harvests and to maintain size of fruits towards last harvests.

Irrigation: Water stress at flowering and fruiting stages will drastically influence growth of plants, size of fruits and yield. Immediately after sowing, field is irrigated. Subsequent irrigation is given at fixed intervals depending on texture of soil and climate. In black soils, irrigation is done at 4-5 days but frequency of irrigation in the rainy –season crop depends upon the rains and field moisture (Fagaria *et al.*, 2012).

Weed Management: Weed growth should be under control till crop canopy covers fully. This is achieved by frequent hoeing, weeding and earthing up. Spring-Summer crop may need 2-3 weeding and hoeing but the rainy season crop may need frequent weeding. Used of weedicides like Lasso (2 kg a.i./ha) or fluchloralin (1.5 kg/ha) or Metalachlor (1.0 kg a.i./ha) and one hand weeding at 45 days after sowing was very effective and financially viable under the All-India Co-coordinated trials. Pre planting application of fluchloralin @0.5-1.0kg/ha and alachlor DAS have been recommended to check weeds.

Post-Harvest Handling and Storage

After harvesting, okra is handled carefully to preserve its freshness. The pods are delicate and highly perishable, with a shelf life of only a few days at room temperature. As a result, proper post-harvest handling is crucial, especially in regions where refrigeration and transportation infrastructure are limited.

Preservation Techniques

In many African and Asian cultures, okra is preserved through drying or pickling. Drying is a common preservation method, particularly in areas with limited access to refrigeration. The pods are sliced into pieces and dried under the sun or using dehydrators. Once dried, the okra can be stored for several months and rehydrated before cooking.

In other regions, pickling is a popular method for preserving okra. Pickled okra is often enjoyed as a snack or condiment and is a traditional practice in the southern United States, where it is prepared with vinegar, spices, and salt.

Diseases of Okra and its management

1. Yellow Vein Mosaic Virus

Symptoms : This is the most serious disease of bhendi. Characteristic vein clearing is the typical symptom and yield loss may be up to 100% depending on stage of occurrence of the disease. Fruits of virus affected plants turn to cream or white in colour. Virus is transmitted through a whitefly *Bemisia tabaci*.

Management: Removal of weeds susceptible to mosaic from nearby fields, control of white fly, uprooting and burying of affected plants, adjusting time of sowing and cultivation of resistant varieties like Arka Anamika, Prabhani Kranti, Varsha Uphar, Punjab Padmini, COBhH 1, Arka Abhay, Susthira etc. are recommended for raising a disease-free crop. Control of white fly is done by spraying Malathion (0.1% or Dimethoate (0.05%) or monocrotophos (0.05%) at an interval of the days.

2. Enation leaf curl : Small, pinhead out growth (enations) on the undersurface of leaves appears and leaves curl in an adaxial direction. The most characteristic symptoms of the disease are twisting and bending of leaf petioles. The virus is also transmitted by white fly.

Management: Rouge out of diseased plant and burn them. Spray the crop with Malathion (0.1%) or and Dimethoate (0.5%) or Monocrotophose.

2. Cercospora leaf spot (Causing agent)

Symptoms : This disease is serious when there is high humidity in atmosphere and is common in a seed crop. Sooty, black mouldy growth of pathogen appear as under surface of leaves and finally leaves dry off and fall down. Mature pods are also attacked and show blackish spots.

Management: Spraying with Bavistin (0.1 g /L) or Bordeaux mixture at fortnightly interval will control the disease.

3. Powdery mildew (*Erysiphae chicoracearum*)

Symptoms : This is caused by a fungus under prolonged humid conditions. White powdery pustules appear on lower surface of leaves resulting in yellowing and death of leaves.

Management: Spraying of wettable sulphur (2g/l) at fortnightly interval is recommended for control. Spray Karathane (0.2%) at 15 days interval.

4. Damping off (*Pythium* sp., *Rhizoctonia* sp, and *Fusarium* sp.)

Both pre and post emergence of seedling occur. Affected seedling rot at collar region and topple down on the ground and finally die.

Management: Provide proper drainage. Treats the seeds with Capitan or thiram @3g/kg seed before sowing.

Insect Pests and management

1. Spotted bollworm (*Earias vittela*)

Symptoms- The larvae bore into the growing shoot initially and fruits at later stage. The affected fruits spoil and become unfit for human consumption.

Management: Follow crop rotation excluding cotton and hollyhock. Spary carbaryl (0.2%) or Cypermethrin (0.05%) at fortnightly interval.

2.White fly (*Bemisia tabaci*)

Symptoms: The insect do not cause considerable damage to the crop but act as vector to transmit the yellow vein mosaic virus disease

Management: Spray of Malathion (0.1%) or Dimethoate (0.03%) or Carbaryl (0.2%) controls the attack of the white flies.

2. Jassids (Botanical name)

Symptom : Wedge shaped pale green jassids suck sap from under surfaces of leaves causing marginal yellowing, cupping and drying of leaves. Due to intense hopper burn, defoliation also occurs. Infestation is serious during summer.

Management: Prophylactic spray of neem oil-garlic mixture at fortnightly intervals is advantageous for avoiding pest incidence.

3. Fruit borer (Botanical name)

Symptom : Borer infestation results in toppling and death of young seedlings, withering and drying up of individual leaves and central shoot. Fruits will be damaged severely.

Management: Spray of carbaryl or thiodan or endosulfan or fenvalerate or cypermethrin or deltamethrin is effective for control of borer. Summer ploughing and clean cultivation are also helpful in reducing pest infestation.

4. Spider mite (*Tetranychus cinnabarinus*)

Symptom-The insect sucks the sap from tender parts of the plant. The affected leaves turn pale and family defoliation occur.

Management: Spray of Malathion (0.1%) or Dimethoate (0.03%) or Carbaryl (0.2%) control of the spider mite.

5. Nematodes

Symptom : Root knot nematode (*Meloidogyne incognita*) infects roots causing galls premature leaf fall, wilting and decline in growth and fruit production. Symptoms in the field generally appear as well-defined patches.

Management: Crop rotation with non-host plants like wheat, rice and corn should be practiced as a regular measure. Successive deep ploughing during summer and soil solarisation gives very good control. Treating field with nematicides also can be adopted.

Harvesting and yield: Harvest fruits when they attain maximum size but still tender. Fruits of 6-8 cm long are preferred for export purposes. This is usually attained by 5-6 days after opening of flower. Harvesting is done in alternate days with a knife or by bending pedicel with a jerk. For harvesting, cotton cloth hand gloves should be used to protect fingers from stinging effect. Pre-cooling of fruits before packing maintains turgidity of fruits and will save it from bruises, blemishes and blackening. This is usually done before packing fruits in perforated cartons of 5-8 kg before export market requires tender, dark green straight, short (6-8cm) fruits. Transporting to refrigerated van for export. Yield 6.0 – 8.0 t / ha for spring-summer crop 10 – 12.5 t / ha for kharif crop.

Seed production: For seed production, adjust sowing in such a way that dry weather coincides with maturation and drying of pods and incidence of yellow vein mosaic disease is minimum. Being an often-cross-pollinated crop, provide an isolation distance of 400 m from other varieties. Field inspection and rouging should be conducted at pre-flowering, flowering and fruiting phases. Harvesting of initial two fruits will be helpful in promoting growth of plants. Average seed yield is 1.0-1.5 t/ha.

PHYSIOLOGICAL DISORDERS IN TOMATO

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Introduction

Tomato (*Lycopersicon esculentum* Mill.) is one of the most significant greenhouse crops. Fruit cracking and blossom end rot are two serious physiological conditions that can harm tomatoes. There is still no completely effective way to regulate this illness, which was initially discovered more than a century ago (Saure, 2001). The situation is extremely dangerous since it is unpredictable (Battey, 1990) and there are no control measures in place.

Blossom end rot

A tiny darker or wet patch surrounding the fruit's blossom end is the first obvious sign of blossom end rot and appears about the time the fruit starts to ripen (Saure, 2001). As the fruit ages, the spot gets darker, bigger, and sunken. Concentric rings may be seen in large lesions. Fruit that has blossom end rot typically ripens too quickly and becomes unfit for consumption. Secondary pathogens, which manifest as a black, felt-like growth on the fruit, frequently infect the afflicted fruit areas. More than half of the fruit may be impacted, or it may only be a small spot. Most often in immature fruit at the start of cell expansion, blossom end rot appears to happen when stress surpasses stress tolerance (Saure, 2001).

Fruit cracking

Fruit cracking is a physiological disorder, which mainly occurs when there is a rapid net influx of solutes and especially water into the fruit, while at the same time ripening or other factors reduce the strength and elasticity of the tomato skin (Leonardi, Guichard, & Blossom end rotting, 2000; Maroto *et al.*, 1995; Peet, 1992). There are three types of fruit cracking in tomatoes: (A) Concentric cracking -which is a splitting of the epidermis in circular patterns around the stem scar (B) radial cracking -which is a splitting of the epidermis from the stem scar towards the blossom end (C) fruit cuticle cracking (Dorais, Demers, Papadopoulus, & Ieperen, 2004), which has several other names including russeting, hair cracking, swell cracking, shrink cracking, rain check, crazing, and cuticle blotch. Peet (1992) reported that anatomical characteristics of crack-susceptible cultivars are large fruit size (Snapp, Huang, & Warncke, 2002), low skin tensile strength and/or low skin extensibility at the turning to pink stage of ripeness, thin skin, thin pericarp, shallow cutin penetration, few fruits per plant, fruit not shaded by foliage.

Goldspot, Goldspeck

Mature fruit frequently has gold flecks or specks around the calyx and shoulders, especially throughout the summer. The flecks are whitish and less common in green fruit. The fruit's shelf life is greatly shortened by these particles, which also make it less appealing (Janse, 1988). Den Outer and van Veenendaal (1988) determined that cells with the distinctive gold look contained a granular aggregate of small calcium salt crystals, most likely calcium oxalate.

Rough Fruit or Catfacing

Fruits with exposed locules are referred to as "rough," while misshapen and abnormally huge fruits might occasionally emerge as numerous linked fruit growing together. Long periods of cold

temperatures cause the development of both illnesses (Gruda, 2005). According to Saito and Ito (1971), a week of air temperatures of 17/10°C is enough to cause aberrant bloom development in the field. The fruit has more locules when it is exposed to low temperatures during the sensitive phase (Wien and Turner, 1994). According to Wien and Zhang (1991), foliar applications of GA3 also cause the disease and increase the frequency of locules. For a single flower, the most sensitive period is long before anthesis.

Edema (Oedema)

It is frequently confused with a fungal or bacterial illness. The blister-like swellings on the leaf in its early stages resemble an undifferentiated growth that resembles a callus. The epidermis splits, most likely due to internal pressure, giving the new blisters their granular look (Grimbly, 1986). The turgid parenchyma cells become visible as a result. Eventually, these enlarged parenchyma cells burst. When these cells rupture over time, the leaves twist and distort, and when the cells dry up, a necrotic region is created.

Summary

Abiotic-derived abnormalities in fruit color or appearance are known as physiological diseases. Such variations are sometimes mistaken for biotic damage, which is harm caused by insects or microorganisms. Physical, chemical, or herbicide injuries, as well as nutrient deficits, are different from physiological illnesses. Genetic predisposition, environmental variables, watering habits, dietary habits, and cultural customs like training and pruning are all contributing causes to physiological diseases. Numerous variables contribute to the majority of physiological problems, with genetics virtually always playing a role. For the majority of illnesses, this intricate interaction of variables is poorly understood, and conflicting findings have occasionally been documented. On top of that, many illnesses have multiple names. For the purposes of this discussion, physiological disorders are categorized into the following groups: watering (cracking, russetting, rain check, shoulder check); temperature extremes (catfacing, boat fruit, rough fruit, puffiness, sunscald); calcium amount or movement into the fruit (gold fleck or speck, blossom-end rot); and nutrient imbalances, particularly between potassium and nitrogen or magnesium (blotchy ripening, greywall).

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RED FRUITS COMPOSITION

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Introduction

Red fruits belonging to the family Rosaceae (strawberry, raspberry, blackberry, and sweet cherry) and Ericaceae (blueberry, cranberry)—have become much more popular due to their high nutritional value, distinctive flavor, taste, and nutraceutical qualities, as well as their well-known health-promoting qualities as dietary sources of bioactive compounds (Skrovankova *et al.*, 2015). Red fruits are known to include a variety of bioactive substances and nutrients, such as antioxidants, dietary fiber, minerals (calcium, phosphorus, iron, magnesium, potassium, sodium, manganese, and copper), vitamins (A, C, and E), and minerals (Skrovankova *et al.*, 2015 and De Souza *et al.*, 2014).

Red fruit composition

Vitamins : A group of berries, including strawberries, cherries, red and black raspberries, blackberries, blueberries, blackcurrants, and grapes, are referred to as red fruits. One of the primary antioxidant compounds found in red fruits is vitamin C, also known as ascorbic acid, which is the most abundant in these fruits. This water-soluble carbohydrate-derived molecule is well-known for having acidic qualities because of the presence of a 2,3-enediol moiety and strong antioxidant activity because it neutralizes free radicals and other reactive oxygen species (Gomes-Rochette *et al.*, 2016).

Minerals : Fruits are typically not considered the main source of minerals consumed. Nevertheless, fruits add an average of 5.8%, 17.3%, 33.0%, and 6.6% to the intakes of calcium, magnesium, potassium, and zinc, respectively, according to the Dietary Approaches to Stop Hypertension (DASH) (Lin *et al.*, 2003). In addition to being high in vitamins (Skrovankova *et al.*, 2015), red fruits are also a great source of minerals, including calcium, iron, potassium, magnesium, manganese, sodium, copper, and phosphorus (De Souza *et al.*, 2014).

Anthocyanins : It is widely acknowledged that the largest and most significant class of phenolics found in red fruits are anthocyanins. Water-soluble substances called anthocyanins give many fruits, notably red fruits, their blue, purple, red, or black hues. The primary dietary source of anthocyanins is grapes. They are viewed as secondary metabolites with potential nutritional benefit because of their varied biological characteristics. The skin of berries is where anthocyanins are mostly found.

Sugar and organic acids : The primary sugars found in red fruits are typically fructose and glucose, whereas the primary organic acids found in this fruit type are citric and malic acids. In their study of the sugar and organic acid content of 25 wild and farmed berry species, (Mikulic-Petkovsek *et al.*, 2012) discovered that the most prevalent sugars in berry fruits were fructose and glucose, while the primary organic acids were malic and citric acid. Rather, (Viljakainen *et al.*, 2010) also demonstrated notable differences in organic acids and sugars among several berry cultivars.

Lipids and fatty acids : The berry fruits (blackberry, blueberry, strawberry, and raspberry) contain a considerable amount of linoleic (C18:2, n-6) and linolenic (C18:3, n-3) fatty acids, making them an exceptionally high source of polyunsaturated fats (Table 6). In addition, red fruits have notable concentrations of stearic acid (C18:0), myristic acid (C14:0), palmitic acid (C16:0), oleic acid (C18:1, n-9), and α -linolenic acid (C18:3, n-3). Punicic acid (C18:3, n-5), a conjugated isomer of α -linolenic acid, makes up the majority of the lipid fraction in pomegranate seeds, in contrast to all other red fruits examined in this research (Pereira de Melo *et al.*, 2014).

Aroma and Flavor Compounds : Ripe strawberries have been shown to contain a wide variety of volatiles of various chemical types, such as alcohols, aldehydes, esters, furanones, ketones, and terpenes (Jetti *et al.*, 2007) In contrast to cultivated cultivars, wild strawberries have a strong flavor and aroma (Negri *et al.*, 2015) For instance, musk strawberries, also known as *Fragaria moschata*, are known for their distinctive scent. Musk strawberries are currently not very common in farm plantings.

Conclusion

The possibility that eating fruit could improve human health is an interesting idea that has been researched globally. As a result, fruits are consistently marketed as healthful. The amount of research suggesting a link between eating fruit and a lower risk of serious chronic illnesses has increased over the last few decades. Dietary fiber, which is found in fruits, is associated with a decreased risk of obesity and cardiovascular disease. In addition to providing vitamins and minerals, fruits also contain phytochemicals that have anti-inflammatory, antioxidant, and phytoestrogen properties, among other beneficial effects. Bioactive substances like vitamins and phenolic compounds, which have been shown to have potential health advantages, are abundant in fruits, particularly tiny fruits. However, our understanding of the variance in these chemicals during fruit growth and the postharvest period is still in its early stages. It is currently mostly unknown how plant performance, output, and fruit quality are impacted by climate change and new agricultural production technologies. The goal of future research should be to create species-specific methods that enhance fruit quality and nutritional qualities without appreciably reducing yield. To produce fruits of superior quality and great market appeal that are well-suited to the various producing zones and future climate change, new fruit species and cultivars with improved features are required.

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RED PALM OIL: A NUTRIENT-RICH SOLUTION FOR CHRONIC DISEASE PREVENTION AND HEALTH PROMOTION

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Abstract

Red palm oil, rich in tocotrienols, tocopherols, and carotenoids, offers numerous health benefits including cardiovascular protection, neuroprotection, and management of hyperglycemia. It has shown efficacy in preventing ischemia/reperfusion damage, protecting against anthracycline-induced cardiotoxicity, improving endothelial function, and alleviating oxidative stress. Red palm oil may also enhance wound healing and exhibit anticancer properties. This review examines its therapeutic potential in managing chronic diseases, emphasizing its bioactive compounds and their mechanisms of action, highlighting its role in health promotion and disease prevention.

Keywords: Red palm oil, Health, Nutrient, Disease prevention

Introduction

Palm oil, derived from the fruit of the oil palm tree (*Elaeis guineensis*), is one of the most consumed vegetable oils worldwide. While it has been criticized for its high saturated fat content, red palm oil, the unrefined form of palm oil, stands out for its remarkable nutritional profile and therapeutic properties. Red palm oil is a potent source of tocotrienols and tocopherols (forms of vitamin E), which possess powerful antioxidant properties. Additionally, it is rich in carotenoids like beta-carotene, essential for the production of vitamin A, a vital nutrient for immune function and eye health. Over the years, red palm oil has garnered attention for its potential in preventing and managing chronic diseases. Research has shown its ability to protect against oxidative stress and inflammation, two key factors in cardiovascular diseases, neurodegenerative conditions, and metabolic disorders. Studies have highlighted its protective effects against ischemia/reperfusion injury, anthracycline-induced cardiotoxicity, and endothelial dysfunction. Furthermore, red palm oil has demonstrated benefits in wound healing, diabetes management, and even cancer prevention, suggesting that its bioactive components play a crucial role in enhancing health and preventing disease. This article explores the diverse health benefits of red palm oil and its potential applications in disease prevention and therapeutic strategies.

- 1. Prevention of Ischemia/Reperfusion Damage:** Ischemia/reperfusion injury is a significant cause of heart damage following a myocardial infarction. Red palm oil supplementation has been shown to enhance functional recovery in rat hearts after such injury. By reducing the myocardial infarct size, red palm oil aids in the recovery process through the activation of PKB/Akt phosphorylation, a pathway crucial for cell survival and repair. Bester et al. (2010) demonstrated that red palm oil supplementation significantly reduces heart tissue damage, providing promising potential for its use in heart disease management.
- 2. Protection Against Anthracycline's Cytotoxicity:** Anthracycline drugs, such as daunorubicin (DNR), are commonly used in chemotherapy for treating systemic neoplasms and solid tumors. However, their use is associated with chronic cardiotoxicity, which can result in congestive heart

failure. Research by Wergeland et al. (2011) revealed that supplementing DNR chemotherapy with red palm oil helps protect the heart. The tocotrienol-rich fraction of palm oil stabilizes crucial enzymes, including superoxide dismutase 1 (SOD1) and nitric oxide synthase 1 (NOS1), and inhibits stress-induced mitogen-activated protein kinase (MAPK) activation, thereby safeguarding the heart from DNR-induced damage.

3. **Endothelial Dysfunction and Hypertension:** Endothelial dysfunction is a hallmark of many cardiovascular diseases, including hypertension and diabetes. It is often characterized by the decreased bioavailability of endothelium-derived nitric oxide (EDNO), leading to vascular damage. Supplementation with palm oil vitamin E has been shown to improve endothelial function in rats with streptozotocin (STZ)-induced diabetes and hypertension. Muharis et al. (2010) demonstrated that palm oil vitamin E increases the availability of EDNO, reducing blood pressure and improving vascular health in these rats. This effect highlights the potential of palm oil in managing hypertension and vascular diseases.
4. **Antihyperglycemic and Anti-lipemic Effects:** Palm fruit juice (PFJ) contains bioactive phenolic compounds that have demonstrated significant antihyperglycemic and anti-lipemic effects in rats. PFJ supplementation delayed the onset of type 2 diabetes mellitus and potentially reversed advanced diabetes by lowering blood glucose levels and improving lipid profiles. Bolsinger et al. (2014) reported that PFJ reduced lipid accumulation and enhanced insulin sensitivity in male Nile rats, offering promising results for the management of diabetes and obesity.
5. **Neuroprotection and Memory Enhancement:** Neurodegenerative diseases such as vascular dementia (VaD) can lead to significant cognitive impairment. The tocotrienol-rich fraction (TRF) of palm oil has demonstrated potential in preventing cognitive decline associated with VaD. Shaikh et al. (2022) showed that TRF supplementation attenuated decreased memory, elevated plasma homocysteine levels, and reduced acetylcholinesterase (AChE) activity in VaD rats. TRF also decreased oxidative damage markers, including glutathione (GSH) and superoxide dismutase (SOD) levels, thus supporting its role in protecting against cognitive decline.
6. **Wound Healing and Burn Injury:** The role of palm oil in wound healing has been observed in both diabetic and non-diabetic animal models. Supplementing diabetic rats with palm vitamin E (PVE) has been shown to improve wound healing by enhancing antioxidant enzyme activity and increasing the production of platelet-derived growth factor-BB (PDGF-BB), a key mediator in wound repair (Musalmah et al., 2005). Additionally, virgin red palm oil (VRPO) accelerated burn wound healing in rats by promoting fibroblast density, neovascularization, and epithelialization, highlighting its potential for improving recovery from burns (Nadia et al., 2020).
7. **Protection Against Oxidative Stress:** Oxidative stress is a common feature in many chronic diseases, including diabetes, cardiovascular disease, and neurodegenerative disorders. Supplementing with TRF from palm oil has been shown to reduce oxidative stress markers and enhance the antioxidant defense system in diabetic rats. Matough et al. (2014) demonstrated that daily TRF supplementation for four weeks resulted in a significant reduction in lipid peroxidation and an increase in antioxidant enzyme activities, offering potential benefits in managing oxidative stress-related conditions.
8. **Cancer Prevention:** TRF has shown promise in cancer prevention, particularly in prostate cancer. Srivastava and Gupta (2006) found that TRF selectively slowed cell growth and induced cell death in prostate cancer cells. The compound caused cell cycle arrest and accumulation of sub-G1 cells, demonstrating its potential as a chemopreventive agent against prostate cancer. These

findings suggest that TRF may be an effective adjunct therapy in the prevention and treatment of prostate cancer.

Conclusion

Red palm oil, particularly its tocotrienol-rich fraction, offers a wide range of health benefits, including cardiovascular protection, neuroprotection, antihyperglycemic effects, and wound healing. The bioactive compounds present in red palm oil, such as tocopherols and carotenoids, play a crucial role in mitigating oxidative stress, inflammation, and cellular damage associated with various diseases. Additionally, red palm oil's effects on lipid profiles and its potential to prevent cancer further highlight its therapeutic promise. While the current research on red palm oil is promising, further clinical trials are necessary to confirm its therapeutic efficacy in humans and establish guidelines for its use in disease prevention and treatment.

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FISHERIES SUBSIDIES AND THE WTO: BALANCING SUSTAINABILITY AND LIVELIHOODS IN INDIA

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Introduction

The global fishing industry faces a pivotal moment. With nearly 90% of marine fish stocks fully exploited or overfished, adopting sustainable practices has become an urgent priority. One of the primary drivers of overfishing has been government subsidies, which fuel industrial fleets to fish beyond ecological boundaries. After two decades of negotiations, the World Trade Organization (WTO) achieved a historic breakthrough in June 2022 with its Agreement on Fisheries Subsidies, aiming to restrict these harmful financial incentives.

For India—home to one of the world's largest fishing communities—the agreement brings both promise and peril. While it supports India's long-term sustainability objectives, it also threatens the livelihoods of millions of small-scale fishers reliant on government aid. This article examines India's stance on fisheries subsidies, the far-reaching consequences of the WTO deal, and the way forward for a sector vital to food security and employment.

The Significance of Fisheries for India

Fisheries are a critical economic and social backbone of India. The sector serves as a vital pillar of the country's blue economy, contributing approximately 1% to India's GDP and sustaining the livelihoods of over 28 million people, including fishers, processors, and traders. In 2022–23, fisheries generated ₹57,586 crore (USD 7 billion) in export earnings. Additionally, a vast number of people rely on small-scale fisheries for their subsistence, further underscoring the sector's importance.

Unlike developed nations with industrial fleets, India's fishing sector is dominated by small-scale, artisanal fishers who rely on traditional boats and minimal mechanization. These fishers, often from marginalized coastal communities, depend on government subsidies for fuel, nets, and boats to sustain their livelihoods.

The Problem with Harmful Fisheries Subsidies

Globally, harmful fisheries subsidies—estimated at USD 22 billion per year—distort markets and accelerate overfishing.

The key concerns include:

- Overcapacity & Overfishing
- Subsidies for fuel, vessel modernization, and fishing infrastructure encourage excessive fishing effort, depleting stocks.
- Illegal, Unreported, and Unregulated (IUU) Fishing
- Subsidized fleets sometimes engage in IUU fishing, harming both ecosystems and legal fishers.
- Unfair Competition: Wealthy nations (China, EU, Japan) provide five times more subsidies than developing countries, giving their industrial fleets an unfair advantage.

India's Stand at the WTO Negotiations

India played a pivotal role in shaping the WTO agreement, advocating for:

1. **Special Protections for Developing Nations:** Argued that small-scale fishers should not bear the burden of subsidy cuts meant for industrial fleets. Secured transition periods and exemptions for artisanal fishing communities.
2. **Stronger Discipline for Industrial Fishing Nations:** Pushed for stricter limits on subsidies by developed countries, particularly for distant-water fishing. The final agreement bans subsidies for IUU fishing and overfished stocks, but gaps remain.
3. **Fuel Subsidies – A Red Line for India:** Fuel subsidies are a lifeline for Indian small-scale fishers, reducing operational costs by 30-40%. India resisted a complete ban, ensuring subsidies for small fishers remain permissible.

Impact of the WTO Agreement on India: Opportunities and Challenges

Opportunities:

1. **Sustainable Fisheries & Long-Term Resource Protection:** The agreement helps prevent overfishing, ensuring long-term sustainability of India's marine resources. It aligns with India's Pradhan Mantri Matsya Sampada Yojana (PMMSY), which promotes sustainable aquaculture.
2. **Potential Boost to Legal & Small-Scale Fisheries:** Since subsidies for IUU fishing are banned, legal and small-scale fishers may benefit from better enforcement and reduced competition from illegal operators. India can redirect subsidies towards sustainable fishing, modernization, and infrastructure.
3. **Market Access & Export Benefits:** Countries like the EU and US impose strict regulations on seafood imports. Compliance with WTO rules could improve India's shrimp, tuna, and seafood exports. It also helps avoid trade sanctions linked to unsustainable fishing practices.
4. **Leveraging Special & Differential Treatment (SDT):** India has a transition period to adjust its subsidy policies without immediate penalties. India can negotiate for extended flexibility in future WTO talks.

Challenges

1. **Impact on Small & Artisanal Fishers:** India has over 4 million fishers, many of whom rely on government support (fuel subsidies, boat upgrades). The ban on certain subsidies could hurt livelihoods if alternative support is not provided.
2. **Need for Strong Monitoring & Enforcement:** India must strengthen surveillance systems to track IUU fishing, requiring investment in satellite tracking, vessel monitoring, and port controls. There is risk of non-compliance penalties if enforcement is weak.
3. **Conflict Between Development & Sustainability:** India's fishing industry is still developing, and sudden subsidy cuts could slow economic growth. In this condition, balancing food security, employment, and conservation will be difficult.
4. **Future Negotiations on Unresolved Issues:** The current agreement does not fully discipline all harmful subsidies (e.g., fuel subsidies). Future talks may impose stricter rules, reducing India's policy space.

The Way Forward for India:

To safeguard both marine resources and fishing communities, India should:

- **Redirect Subsidies Towards Sustainability:** India should shift the support from fuel to eco-friendly fishing gear, aquaculture, and deep-sea fishing.

- **Strengthen Enforcement Against IUU Fishing:** India should expand satellite tracking, vessel monitoring systems (VMS), and coastal patrols and also collaborate with neighboring countries to curb foreign illegal fishing in Indian waters.
- **Invest in Alternative Livelihoods:** India should develop coastal tourism, seaweed farming, fish processing and other fisheries related activities to reduce fishing pressure in coastal region.
- **Lead Global Advocacy for Equity:** India should ensure developed nations also comply with subsidy cuts before stricter rules apply to India.

Conclusion

The WTO's Fisheries Subsidies Agreement represents a historic milestone in the global effort to promote ocean sustainability. However, its long-term success hinges on equitable and consistent implementation across member nations. For India, the primary challenge is balancing the livelihoods of its small-scale fishers—who rely heavily on traditional fishing methods—with the urgent need to adopt more sustainable practices. By implementing strategic policy reforms, investing in technology for better fisheries management, and strengthening international partnerships, India can safeguard marine ecosystems while ensuring the economic resilience of its fisheries sector.

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REVOLUTIONIZING BREEDING WITH AI BASED DECISION SYSTEMS

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Background

The amount of data with the breeders are increasing at bottleneck speed. All thanks to the integration of artificial intelligence into agriculture (genotyping tools, sensors, satellite images, precision tools, IoT and weather forecasts). But they are unable to get 100% value of it, as most of the data are either in raw, unstructured or semi-structured formats. We have the data but what to do with such a vast amount of data? The solution is Decision support system. A Decision Support System (DSS) in Plant Breeding is a computer-based tool that assist plant breeders in making informed decisions by analyzing vast and complex data using AI, big data analytics, and predictive models. It processes complex breeding data, such as genotyping, phenotyping and environmental factors leading to more accurate and timely decisions in crop management and improvement. A Combination of AI and DSS in plant breeding enhances data analysis capabilities, allowing for more precise selection, better choice of parents and breeding strategies. AI algorithms can process and interpret complex genotypic and phenotypic data, thereby improving the efficiency of breeding programs.

Need of AI driven DSS

AI-powered DSS play a crucial role in modern plant breeding by enhancing precision, efficiency, and sustainability. They analyse vast datasets, predict optimal breeding strategies, and improve trait selection, ultimately accelerating crop improvement. AI-powered DSS minimizes trial-and-error, reduces costs, and ensures sustainable agricultural advancements.

Key necessity include:

1. Accelerating the Breeding Cycle- Conventional breeding can take 8–12 years to develop a new crop variety. AI can rapidly analyze genotypic, phenotypic, and environmental data to identify superior traits early. Reducing the time required to select promising genotypes, speeding up variety development.
2. Handling Large and Complex Datasets- Breeders deal with vast amounts of data from DNA sequencing, field trials, and climate records. AI-driven systems can process, filter, and extract key insights from this data efficiently.
3. Enhancing Prediction Accuracy- AI models, such as Machine Learning (ML) and Deep Learning (DL), can accurately predict yield potential, stress tolerance, and disease resistance. Provides data-driven recommendations, reducing human bias and improving selection decisions.
4. Optimizing Resource Use- AI can recommend optimal breeding strategies, reducing costs, labor, and land use. Helps breeders prioritize trials for the most promising varieties, minimizing resource wastage.
5. Adapting to Climate Change & Environmental Variability- Climate change is making crop breeding more unpredictable. AI-powered DSS can analyze historical and real-time weather data to suggest climate-resilient genotypes.

6. Improving Decision-Making for Breeders- AI-driven systems provide real-time insights via visual dashboards, predictive models, and interactive tools. Breeders can make informed, faster, and more reliable decisions about which varieties to advance.
7. Integration with Precision Agriculture- AI DSS can be linked with IoT sensors, drones, and remote sensing for real-time field monitoring. Enables automated trait measurement and precision breeding strategies.

How to use AI based DSS in plant breeding- the various steps include:

1. Data Collection

- Genotypic Data: DNA sequencing, molecular markers, genome-wide association studies (GWAS).
- Phenotypic Data: Field trial results, growth parameters, yield data, stress responses.
- Environmental Data: Climate conditions, soil properties, satellite imagery.

2. Data Preprocessing

- Cleaning and normalizing raw data.
- Handling missing values and removing redundant features.
- Using feature engineering to select key predictors for breeding success.

3. AI Model Development

- Machine Learning (ML) & Deep Learning (DL) Models:
- Random Forest, Support Vector Machines (SVM), XGBoost.
- Neural networks (e.g., CNNs for image-based trait analysis).
- Bayesian models for probabilistic trait prediction.

4. Decision Support System (DSS) Development

- User-friendly interface for breeders.
- Data visualization dashboards (heatmaps, scatter plots, AI-generated recommendations).
- Integration with breeding programs through cloud-based platforms or mobile applications.

5. Validation & Field Trials

- AI-predicted selections vs. manually selected genotypes.
- Performance of AI-recommended varieties in multi-location trials.
- Comparing AI-driven breeding cycle duration with traditional approaches.

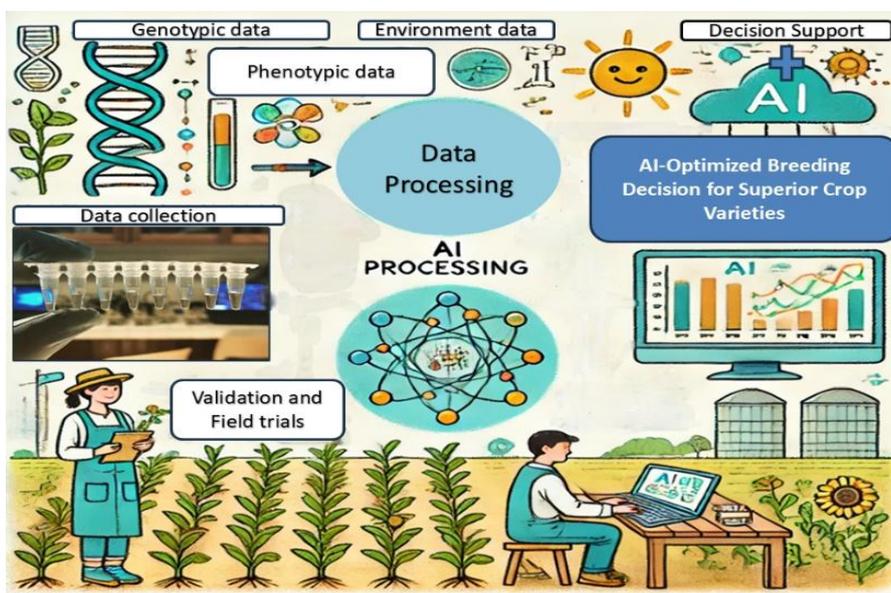


Figure: - Pictorial representation of AI driven DSS that can lead to optimized breeding decisions for development of superior crop varieties.

List of decision support system (DSS) software used in plant breeding

1. General DSS for Plant Breeding:

- DSSAT (Decision Support System for Agrotechnology Transfer) – Crop simulation model for evaluating breeding strategies.
- R (With Breeding Packages like ASReml-R, rrBLUP, BGLR, sommer, etc.) – Used for genomic selection, mixed model analysis, and breeding data interpretation.
- Plant Breeding Decision Support System (PBDSS) – Helps breeders in variety selection and crossing strategies.

2. Genomic and Genetic Data Management:

- TASSEL (Trait Analysis by aSSociation, Evolution, and Linkage) – Used for genetic analysis and association mapping.
- Field Book App – Digital phenotyping and data collection for breeders.
- GOBii (Genomic Open-Source Breeding Informatics Initiative) – Supports genomic selection and large-scale breeding programs.
- Breeding Management System (BMS) – Manages breeding programs, data collection, and analysis.

3. Experimental Design & Data Analysis:

- PBTools (Plant Breeding Tools) – Provides statistical support for breeding experiments.
- META-R – Multi-environment trial analysis.
- AGD-R (Analysis of Genetic Designs in R) – Analyzes different genetic designs in plant breeding

Key Applications of AI-Based DSS in Plant Breeding:

- Genomic Selection and Trait Prediction: AI models analyze genetic data to predict desirable traits, accelerating the selection process and reducing the time required to develop new crop varieties.
- Image-Based Phenotyping and Disease Detection: Utilizing computer vision and deep learning, AI systems can assess plant characteristics and detect diseases from images, enabling early intervention and management.
- Big Data Management in Breeding Trials: AI assists in managing and analyzing extensive datasets from breeding experiments, identifying patterns and insights that inform breeding decisions.

Challenges and Limitations- Major challenges that affect the proper adoption of this technique are:

- Data Quality and Availability: The effectiveness of AI models depends on the quality and availability of data. Inaccurate or incomplete data can lead to erroneous predictions.
- Technical and Financial Barriers: Implementing AI technologies requires technical expertise and financial investment, which may be challenging for resource-limited breeding programs.
- Ethical Considerations: The use of AI raises ethical concerns related to data privacy and the potential socioeconomic impacts on farming communities.

Future Prospects and Innovations

Emerging trends in AI, such as advanced machine learning algorithms and improved data integration techniques, hold promise for further enhancing DSS in plant breeding. These innovations could lead to more resilient and high-yielding crop varieties, contributing to global food security.

Conclusion

The integration of AI-based Decision Support Systems in plant breeding represents a significant advancement in agricultural practices. By addressing current challenges and leveraging technological innovations, these systems have the potential to transform plant breeding, leading to sustainable and efficient crop production.

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REVOLUTIONIZING DAIRY: CRAFTING CHHANA FROM BUFFALO AND SOY MILK

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Introduction

The nation that produces the most milk worldwide is India. India is the world's top producer of milk, accounting for 24% of the total milk production. (According to "Basic Animal Husbandry Statistics 2023") The nation's milk production increased from 146.31 million tonnes in 2014–15 to 230.58 million tonnes in 2022–23 at a compound annual growth rate of roughly 5.85%. The top five milk-producing states in India are Uttar Pradesh (15.7%), Rajasthan (14.44%), Madhya Pradesh (8.73%), and Gujarat (7.49%) Andhra Pradesh (6.70%). As per the NDDB and DAHD (2022–23), the per capita availability of milk in India is 459 grams per day. The significance of milk and milk products in India has been acknowledged since the Vedic era, which is five thousand years ago.



Milk is processed into a variety of products such as cream, butter, yogurt, kefir, ice cream, Cheese and Chhana. Modern industrial processes use milk to produce casein, whey protein, lactose, condensed milk, powdered milk, and many other food-additives and industrial products. Chhana, regarded as the Indian counter part of soft cottage cheese is a heat acid coagulated milk product that serves as the base for a variety of milk products such as Rasogolla, Sandesh, paneer, Cham-Cham, Chhana poddo, Chhana kheer, kheer Mohan etc (V Ammu 2020). It is a coagulated product obtained by the acid coagulation of whole or standardized milk of cow, buffalo or their admixtures. The coagulant used can be sour Chhana whey, lactic acid or citric acid. Chhana shall not contain any ingredients foreign to milk. According to Prevention of Food Adulteration (PFA) rules (1976), the Chhana product shall not have more than 70% moisture and not less than 50% fat on dry matter basis. If skim milk is used, moisture should not exceed 70% and milk fat should not exceed 13% on dry matter basis. According to FSSAI Rules, (2006). Chhana serves as a base material and filler for a large variety of Indian sweet-meats like Rosogolla, Sandesh, Chum-Chum, and Chhana Murki, etc. For several different types of Indian sweetmeats, such as Rossogolla, Sandesh, Chum-Chum, and Chena Murki, among others, Chhana acts as a foundation material and filter. The majority of the country's Chhana production is limited to the eastern regions of West Bengal, Bihar, and Orissa. This is mainly owing to enhanced shelf life, population flow around the globe, better buying capability and diversified food choices etc. Here we are going to make Chhana from a mixture of buffalo and soy milk, hence the different properties of buffalo and soy milk are given below.

Buffalo Milk:

Buffalo milk texture Buffalo milk is used to make Chhana because it produces a velvety body with a delicate, compact, close-knit that is highly sought-after for various Chhana-based goods. The increased calcium level, distinct protein composition, elevated total solids, and higher curd tension in Buffalo Milk, relative to Cow Milk, yield a more robust and coarser Chhana. Thus, a study was

conducted to determine the ideal concentration of several coagulants to produce the highest-quality buffalo milk Chhana (Kulkarni et al., 1984).

Table 01: Buffalo milk composition (According to PFA)

water	82-83 %
fat	6-7 %
protein	4-5 %
lactose	4-5.2 %
ash	0.8 %

Soy milk:

Soybeans are soaked, then ground with water to make soy milk. Soy milk is the liquid that remains after filtering. Simple household appliances or a soy milk maker can be used to manufacture soy milk at home. Generally, 1 liter of soy milk produces from 100g of soybean. The most typical form of soy milk is found in aseptic cartons. The majority of soy milk on the market is flavored and enhanced with additional calcium or vitamins. Soymilk is a great source of B vitamins and high-quality protein. Since soymilk isn't a particularly high source of calcium, the majority of commercial soymilk products are calcium fortified. The demand for milk is increasing day by day and fulfilling the future need will be a big challenge. About 55- 58 percent of the human population has little or no ability to digest lactose after infancy. That's why there is need of a substitute which can replace the bovine milk. Soy milk has been considered as an excellent economic dairy substitute. All of the essential amino acids are present in soy protein, which is also highly digestible (92 to 100%). Products made from soy protein have a high concentration of isoflavones, up to 1 g/kg, which have protective effects against breast, prostate, colon and lung cancers.

Table 02: Soy milk composition (According to PFA)

water	90 - 92 %
fat	1.5 - 2.0 %
protein	3.6 - 4.0 %
ash	0.25 - 0.5 %
carbohydrates	4.0 - 5.2 %

Health Benefits of soy milk:

- Improves Heart Health by Lowering Blood Pressure and Cholesterol.
- Builds Muscle and Helps Lose Fat.
- Great source of magnesium.
- Moisturizer and treatment of sunburns.
- Provides Electrolytes and Prevents Fatigue.
- Helps Lose Weight.
- Improves Digestion and Relieves Constipation.
- Improve Lipid Profile.
- Strengthen Blood Vessel Integrity.
- Promote Weight Loss.
- Prevent Prostate Cancer.
- Prevent Postmenopausal Syndromes.

- Prevent Osteoporosis.

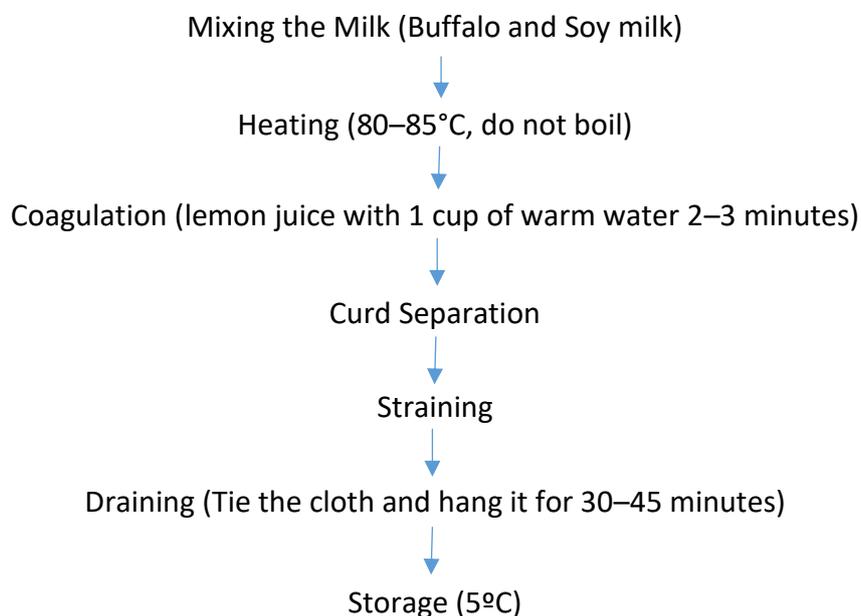
Soy milk can have many benefits when used in Chhana preparation, including:

Soy milk is low in saturated fat and high in unsaturated fats, which can help improve heart health. The protein in soy milk can also help lower blood cholesterol levels. Soy milk is a good source of calcium and iron, which can help strengthen bones and reduce the risk of osteoporosis. Soy milk contains isoflavones, which may help prevent certain types of cancer. Soy milk is a complete source of high-quality protein, containing all the essential amino acids the body needs. This makes it a popular choice for vegetarians and people who can't tolerate animal protein. The present research entitled, "Studies on preparation of Chhana from blend of buffalo milk and soy milk and assessment of shelf life", has been undertaken with the following objectives-

Ingredients

- Buffalo Milk – 1 litre (preferably full cream)
- Soy Milk – 1 litre (freshly prepared or unsweetened commercial soy milk)
- Coagulant – 2 tablespoons lemon juice or vinegar (or food-grade citric acid solution)
- Water – 1 cup (for diluting coagulant)

Fig.1. Flow Diagram of Manufacture of Chhana from blend of soy milk and buffalo milk



Manufacturing Process:

In a stainless-steel pan, combine 1 liter of buffalo milk with 1 liter of soy milk. Stir gently to form a uniform blend. Heat the milk mixture slowly over medium flame. Stir occasionally to prevent scorching. Bring the blend to a temperature of 80–85°C (do not boil). Dilute the lemon juice or vinegar with 1 cup of warm water. Gradually add the coagulant to the hot milk blend while stirring gently in a circular motion. Coagulation should occur within 2–3 minutes. You'll see the whey separate clearly. Once the curds and whey have fully separated, stop stirring. Let it rest for 5 minutes to complete the coagulation process. Pour the curdled mixture through a muslin cloth or fine strainer. Rinse the chhana under cold water to remove acidic taste and stop further cooking. Tie the cloth and hang it for 30–45 minutes to drain excess whey. For firmer chhana, press it under a weight for another 20–30 minutes.

Final Product:

The resulting chhana will have, A soft and smooth texture, Slight nutty flavour from soy, Richness and good binding from buffalo milk fat and some other which are given as follows:

- The development of an effective method to achieve a desirable yield and quality of chhana which will be maintain the optimal texture without affecting the nutritional benefits.
- The blend of buffalo milk and soy milk is expected to improve the nutritional composition of the chhana.
- The addition of soymilk might alter the microbial profile, potentially improving shelf life due to the antimicrobial properties of soy compounds (like isoflavones).
- The shelf life of chhana prepared from the buffalo and Soy milk blend will likely be influenced by factors such as the microbial load, moisture content and the Fat to Protein ratio.
- Combining soymilk with buffalo milk will reduce production costs and make the product more affordable.

Conclusion

For make in use fresh soy milk to avoid off-Flavors. A creative and wholesome substitute for conventional paneer is provided by the production of chhana, which is made using a mixture of soy and buffalo milk. The typical blend ratio can vary (50:50, 60:40) based on desired texture and cost. This blend creates a soft, smooth, and tasty chhana by fusing the rich fat and creamy texture of buffalo milk with the high protein content and cholesterol-free advantages of soy. In addition to improving the nutritional profile, it offers dairy-based sweet and savory items, ideal for making sweets like rasogulla, Sandesh, or as a protein-rich alternative to traditional paneer, an affordable alternative. This approach can be particularly helpful for customers looking for plant-dairy hybrid alternatives as well as for the development of functional foods.

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STEVIA AND CARDIOVASCULAR HEALTH: A FRIEND OR FOE?

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Abstract

Stevia (*Stevia rebaudiana* Bertoni) is a natural sweetener that has gained significant attention due for its high sweetness intensity and zero calories. Steviol glycosides, the primary sweet compounds in stevia, exhibit high sweetness with minimal caloric content, making them suitable for diabetic and calorie-conscious consumers. Furthermore, stevia possesses antioxidant, antimicrobial, and antihypertensive properties, and others beneficial effects contributing to its functional food potential. The incorporation of stevia in diverse food products demonstrates its effectiveness as a sugar substitute without compromising sensory attributes. This article explores the bioactive properties, beneficial effects and impact of stevia in cardiovascular health.

Keywords: Stevia, sweetener, beneficial effect, cardiovascular health.

Introduction

The increasing prevalence of obesity, metabolic disorders, and cardiovascular diseases (CVDs) has heightened concerns over excessive sugar consumption. Excessive sugar consumption, particularly added sugars found in processed foods and beverages, has been substantially associated with adverse cardiovascular health outcomes. The relationship between sugar intake and cardiovascular disease (CVD) involves multiple metabolic pathways, including increased blood pressure, insulin resistance, inflammation, and dyslipidemia.

Cardiovascular disease (CVD) is the leading cause of death worldwide, taking an estimated 17.9 million people each year. CVDs are a category of illnesses of the heart and blood arteries that include coronary heart disease, cerebrovascular disease, and rheumatic heart disease, among others (WHO, 2025). In India, key risk factors for CVDs include high cholesterol, hypertension, obesity, poor diet, diabetes, and sedentary lifestyle (Kundu & Kundu, 2022).

Substituting sugar consumption with non-nutritive sweeteners is a trend that is currently being widely discussed. Non-nutritive sweeteners (NNS) are also known as non-calorific sweeteners because they provide no calories to the body. Among these alternatives, Stevia, a plant-derived sweetener has received considerable attention due to its potential health benefits and regulatory approval in multiple countries.

Stevia (*Stevia rebaudiana* Bertoni) is a natural, zero-calorie sweetener derived from the leaves of the Stevia plant. The sweetness is attributed to steviol glycosides, primarily stevioside and rebaudioside A. Research finding that processed forms of Stevia leaves are generally 250-300 times sweeter than sugar (Peteliuk, *et al.* 2021). European Union certified steviol glycosides (SGs) as a food additive, whereas the FDA (U.S. Food and Drug Administration) conferred the 'Generally Recognized as Safe' (GRAS) status to stevia leaf extract (Orellana-Paucar, 2023). In India, steviol

glycosides (SGs), in particular stevioside and rebaudioside categorised as sweeteners under the rules established by FSSAI (Food Safety and Standards Authority of India) and given the INS number 960. FSSAI carefully regulates stevia glycosides, they ensure public with standard and upper limit to be consumed to ensure their purity and safety. This article aims to provide a review of the current evidence regarding the impact of use of Stevia as a sweetener on cardiovascular health.

Stevia as a Natural Sweetener

Stevia Rebaudiana. Bertoni are members of the Asteraceae family, which is a tiny perennial herb native to South America, specifically the subtropical region of North Eastern Paraguay. Dry stevia leaves are used to sweeten traditional bitter drinks like mate tea (Kinghorn & Soejarto, 2022 & Madan *et al.*, 2010).



Figure 1. *Stevia rebaudiana* Bertoni plant and leaf

The sweetness of stevia (250-300 times sweeter than sugar) is primarily attributed to its bioactive compounds known as steviol glycosides, which are present in the plant's leaves. The most common composition of steviol glycoside in the wild variety of *Stevia rebaudiana* includes stevioside (5–10%); rebaudiosides A (2–5%) and C (1%); dulcoside A (0.5%); rebaudiosides D, E, and F (0.2%); and steviolbioside (0.1%) (Ceunen *et al.*, 2012). Stevioside and rebaudioside A are the most abundant and well-studied glycosides, accounting for the plant's distinct sweetness. In recent years, a diverse range of stevia products has been widely available in commercial marketplaces. These sweeteners come in a variety of forms, including powder (extract), liquid, and dry leaves. Stevia's strong heat stability attribute makes it particularly desirable in the food business (Nunes *et al.*, 2021). Its adaptability extends to a variety of food products, such as drinks, baked foods, and dietary supplements.



Figure 2. Common forms of stevia product in the market (extract/powder, liquid, dry leaf)

Safety and Regulatory Status

The safety and regulatory approval of stevia-derived sweeteners have been extensively reviewed by global health and food authorities. High purity steviol glycosides ($\geq 95\%$) have been recognized

as safe for human consumption by several leading food regulatory agencies. The application of rebaudioside A in food and beverages has been approved as generally recognized as safe (GRAS) by the U.S. Food and Drug Administration (FDA) since 2008. A minimum of 75% of stevioside or rebaudioside A (in stevia's leaf extract) is permitted as food additives in European Union since 2011. However, in 2016 up to 95% of 11 type of steviol glycosides were accepted as combination or ration in the extract (Ilias, *et al.* 2021). The European Food Safety Authority (EFSA), Australia, and New Zealand, setting an Acceptable Daily Intake (ADI) of 4 mg/kg body weight per day for steviol glycoside (Younes, *et al.* 2023). The World Health Organization (WHO) & Joint FAO/WHO Expert Committee on Food Additives (JECFA) reviewed stevia's safety and established the same ADI as EFSA, confirming that stevia consumption within recommended limits poses no toxicological risks (WHO, 2023). In 2015, FSSAI approved the use of steviol glycosides as a sweetener in food and beverages in India, aligning with global regulatory standards (FSSAI, 2015). Meanwhile, some restriction is applied in some food products to a steviol glycoside (INS 960) as an additive is not permitted for use in cocoa and chocolate products (FCS 5.1.3) and imitation chocolate, chocolate substitute products' (FCS 5.1.4) (FSSAI, 2023).

Beneficial Effect of Stevia

Stevia (*Stevia rebaudiana* Bertoni) is becoming increasingly popular as a natural sweetener with possible health benefits beyond its usage as a table sugar substitute. Aside from its sweetening qualities, stevia has been scientifically proven to have medicinal effects such as antioxidant, wound healing activity, antiviral, anti-inflammatory, anti-diabetic, and renal protection. It is worth noting that stevia-derived glycosides are neither carcinogenic, mutagenic, or teratogenic, and they cause no acute or subacute toxicity. More importantly, research has shown that stevia and its glycoside components can help control cholesterol levels. As a result, stevia extracts could offer potential benefits in the treatment of atherosclerosis (Ilias *et al.*, 2021).

Effect of Stevia on Cardiovascular Health

Stevia has been widely studied for its potential cardiovascular benefits, particularly in relation to blood pressure regulation, lipid profile improvement, and endothelial function. Stevia has been shown to enhance glucose homeostasis by increasing glucose-mediated insulin secretion and decreasing gluconeogenesis, all without causing hypoglycemia. Steviosides have been linked to weight loss, reduced inflammation indicators like IL-6 and TNF- α , lower oxidized-LDL, and reduced atherosclerosis. This is accompanied by a positive effect on blood pressure in hypertensive people without inducing hypotension (Ray *et al.*, 2020).

Stevia's antihypertensive properties are among its most well-documented effects; one study found that steviosides have a significant hypotensive effect in different strains of hypertensive rats, are relatively non-toxic, and could be developed into a complementary therapy for hypertension (Hsu *et al.*, 2002).

Beyond blood pressure regulation, Stevia has been found to have lipid-lowering effects, which can help reduce the risk of cardiovascular diseases such as atherosclerosis and coronary artery disease. These findings suggest that stevia may contribute to better lipid metabolism and overall heart health. In a study on the effects of stevia on body weight and other biochemical parameters, compared to sucralose, stevia was reported to decrease body weight and blood TG, LDL and TC levels but increase HDL levels in rats (Elnaga, *et al.*, 2016). Evidently, stevia plays important roles in

improvement of glycemic response and lipid profile in contrast to artificial sweeteners (e.g. sucralose) (Talevi, 2017).

Another significant cardiovascular benefit of stevia is its antioxidant properties. Stevia could help improve antioxidant consumption in human meals by adhering to its ADI (4 mg/kg body weight) as per international guidelines. The antioxidant profile of stevia includes flavonoids, condensed tannins, anthocyanins, phenolic acids, and chlorophyll. Stevia leaf extract's antioxidant activity may reduce the incidence of harm caused by lipid peroxidation, as well as significantly reduce the formation of ROS (reactive oxygen species) and RNS (reactive nitrogen species) moieties in cells (Ameer *et al.*, 2020).

These combined effects highlight stevia's potential role as a natural cardio-protective agent, making it a valuable addition to a heart-healthy diet. Adverse events may occur due to overdosage consumption and impurity of stevia's extract. Overdose consumption of stevia above the recommended acceptable daily limit (4 mg/kg of body weight) may be associated with gastrointestinal adverse events. Meanwhile, *S. rebaudiana* whole-leaf extracts (unpurified) or partially purified extracts containing low-purity SGs are not considered safe for use as food ingredients, and the FDA has given an import alert to these products due to adverse effects on the fertility, renal, and cardiovascular systems of tested rats (Abdel-Rahman *et al.*, 2012). Therefore, excessive consumption of unpurified stevia extract should be discouraged.

Another limitations of stevia are that it cannot replace some of the qualities found in table sugar. It is deficient in the bulk and structural qualities that sugar gives in baked goods, confections, and sauces, which are necessary for texture, mouthfeel, and volume. Furthermore, its inability to engage in browning or caramelization reactions during the baking process results in pale, flavorless baked items. Furthermore, stevia's slightly bitter or metallic aftertaste might detract from the overall flavor profile, especially in chocolate or dairy-based items. Stevia also lack of fermentability properties, hinder its use in items that require yeast fermentation, such as bread (Schiatti-Sisó *et al.*, 2023). To mimic the functioning of sugar, stevia is frequently blended with bulking agents such as polydextrose, maltodextrin, and inulin for ice cream product (Wan *et al.*, 2021) or other sweeteners such as sucralose, xylitol, and sorbitol, resulting in complicating formulas and increasing production costs.

Conclusion

Stevia offers significant potential as a natural sweetener with beneficial effects on cardiovascular health. Its antioxidant, antihypertensive, and others properties make it a valuable functional ingredient, particularly for individuals at risk of CVDs. However, its use should be carefully regulated to avoid potential side effects associated with excessive consumption. Proper guidelines and further research on its long-term safety and formulation improvements are essential to maximize its health benefits while ensuring consumer safety.

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THE USE OF STINK BEANS IN NAGALAND: A CULINARY AND CULTURAL PERSPECTIVE

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Abstract

This article explores the culinary, cultural, and medicinal significance of stink beans (*Parkia speciosa*), locally known as Yongchak, in the northeastern Indian state of Nagaland. Despite their strong and pervasive odor, stink beans are a valued ingredient in Naga cuisine, appreciated for their unique flavor and rich nutritional profile. The article discusses the botanical characteristics of the plant, which bears long, twisted pods filled with bright green seeds, and highlights its high protein, fiber, and antioxidant content. Various traditional culinary uses are examined, including their incorporation into smoked meat dishes, stews, chutneys, stir-fries, and pickles. Beyond their gastronomic value, stink beans are celebrated for their health benefits, such as detoxification, blood sugar regulation, and heart and digestive health. The article also delves into the cultural importance of stink beans among Naga tribes, emphasizing traditional foraging practices and community bonding through food. Despite modern challenges such as urbanization and the bean's pungent aroma, there is a renewed interest in promoting indigenous foods. Efforts by local chefs and food enthusiasts to incorporate stink beans into contemporary dishes reflect a broader movement to preserve and celebrate Nagaland's culinary heritage.

Introduction

Nagaland, a state in Northeast India, is known for its rich biodiversity, diverse tribal culture and unique culinary traditions. One such ingredient that holds a special place in Naga cuisine is the stink bean, scientifically known as *Parkia speciosa*. Also referred to as the bitter bean or twisted cluster bean locally known as Yongchak, this plant belongs to the Fabaceae family and is widely valued for its nutritional benefits and distinctive aroma. While the strong smell of the bean may deter some, it remains a cherished ingredient among the Naga people, who incorporate it into a variety of traditional dishes. This article explores the significance of stink beans in Nagaland's cuisine, their health benefits and their cultural relevance.

Botanical and Nutritional Profile

Stink beans are characterized by long, flat pods containing bright green seeds that resemble plump almonds. They have a strong aroma, often compared to shiitake mushrooms or natural gas, which becomes more pronounced when cooked or chewed. Despite their pungency, stink beans are highly nutritious, rich in proteins, carbohydrates, fiber, vitamins, and essential minerals. They also contain antioxidants and plant compounds that contribute to their medicinal properties, including anti-inflammatory and antimicrobial effects. The high content of sulfur-containing compounds is responsible for their distinct odor but also provides detoxifying benefits to the body.



Fresh Stink Bean Pods and Seeds: A Nutrient-Rich Ingredient with a Distinct Aroma



Stink Bean Pods Growing on the Tree: Nature's Pungent Delicacy

Culinary Use in Nagaland

In Nagaland, where indigenous food traditions emphasize fresh, organic and locally sourced ingredients, stink beans are a valued component of various dishes. They are often used in the following ways:

1. **Fermented and Smoked Dishes:** Stink beans are frequently combined with smoked meats, such as pork or beef, to enhance the umami flavors. The smoky aroma of the meat complements the strong scent of the beans, creating a unique and savory dish.
2. **Curries and Stews:** The beans are commonly cooked with local spices, bamboo shoots and dried fish to make hearty stews. The combination of tangy bamboo shoots and the distinct bitterness of stink beans results in a robust and flavorful meal.

3. **Chutneys and Condiments:** Stink beans are also ground into chutneys along with chili peppers, garlic and tomatoes. This spicy accompaniment is eaten with rice, adding depth and pungency to an everyday meal.
4. **Stir-Fries:** A simple yet popular preparation involves stir-frying stink beans with wild herbs, garlic and ginger. This quick dish retains the natural crunch and flavor of the beans while blending well with the aromatic herbs.
5. **Pickles:** Some communities in Nagaland preserve stink beans by pickling them with mustard oil, chilies and local spices. These pickles serve as a side dish that can be enjoyed year-round.



Stink Bean Chutney (Left) and Pickle (Right): Authentic Flavors of Nagaland's Cuisine



Spicy Stink Bean Curry with Chili Powder and Dry Meat: A Traditional Naga Delight

Cultural and Traditional Importance

For the Naga people, food is more than sustenance; it is an expression of identity and heritage. The use of stink beans reflects the deep-rooted culinary practices passed down through generations. Many Naga tribes believe that eating local and naturally grown foods contributes to overall well-being. Stink beans are often prepared during family gatherings, festivals and celebrations, signifying their integral role in community bonding.

Additionally, the consumption of traditional ingredients like stink beans aligns with the indigenous practice of sustainable foraging. The beans are typically harvested from wild trees in the forests, ensuring minimal environmental impact while preserving the region's biodiversity.

Medicinal and Health Benefits

Beyond their culinary appeal, stink beans are valued for their medicinal properties. Some of their health benefits include:

- **Detoxification:** The sulfur compounds present in stink beans help cleanse the kidneys and improve urinary health.
- **Anti-Diabetic Properties:** The beans contain natural compounds that help regulate blood sugar levels, making them beneficial for people with diabetes.
- **Digestive Health:** The fiber content aids in digestion and promotes gut health, reducing issues like constipation and bloating.
- **Anti-Inflammatory Effects:** The antioxidants in stink beans contribute to reducing inflammation and oxidative stress in the body.
- **Heart Health:** Regular consumption is linked to improved circulation and reduced risk of cardiovascular diseases.

Challenges and Modern Adaptations

Despite their benefits, stink beans face certain challenges in modern consumption. The strong odor can be off-putting to those unfamiliar with the ingredient, limiting its acceptance outside of traditional communities. Additionally, as urbanization increases, there is a decline in foraging and traditional cooking practices, leading to a reduced reliance on indigenous ingredients like stink beans.

However, there is a growing interest in reviving and promoting local foods, with younger generations and culinary enthusiasts experimenting with innovative ways to incorporate stink beans into contemporary dishes. Some Naga chefs and food entrepreneurs are exploring fusion cuisines that blend traditional elements with modern cooking techniques, making these ingredients more accessible to a wider audience.

Conclusion

The stink bean, despite its pungent aroma, remains a cherished ingredient in Nagaland's culinary and cultural landscape. Its rich nutritional value, versatility in cooking, and deep-rooted significance in traditional food practices make it an important part of the Naga diet. While modernization poses challenges to its widespread use, efforts to preserve indigenous food traditions continue to highlight the importance of stink beans. As interest in local and organic foods grows, stink beans may gain renewed recognition not just in Nagaland but beyond, as a unique and healthful ingredient worth embracing.

TURNING FISH WASTE INTO WEALTH: INNOVATIVE SOLUTION FOR A SUSTAINABLE FUTURE

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Abstract

Transforming fish waste into marketplace valued commodities provides a new way of addressing environmental pollution in an inventive and sustainable manner as well as providing socio-economic benefits. This strategy not only alleviates environmental burdens but also creates new business opportunities for agriculture, aquaculture, energy, cosmetics, pharmaceuticals and others. Fish origin wastes are used primarily in the production of fishmeal, fish oil, biofuels, fertilizer, collagen & Gelatin, chitosan, bio-plastics, enzymes and proteins.

Key Words: Sustainable, Fish oil, Biofuel, Bio-plastic, Fish waste

Introduction

Turning fish wastes into wealth is a fantastic idea with multiple applications. It is an innovative and sustainable approach that helps to reduce environmental pollution and creates economic opportunities. This not only addresses environmental challenges but also creates new revenue streams in industries like agriculture, aquaculture, energy, cosmetics and pharmaceuticals.

Here are some ways to harness the value of fish wastes:

1. Fish meal
2. Fish oil
3. Biofuel
4. Fertilizer
5. Collagen and Gelatin products
6. Chitosan
7. Bio-plastic
8. Enzyme and Protein

1. Fishmeal:

Fish wastes (such as heads, bones, gut) can be processed into fishmeal and fish oil. These products are valuable in the aquaculture industry as animal feed and nutritional supplements.

Fish meal is a high protein source ingredient used in animal feed, particularly in aquaculture and livestock.

Use:

i. Animal feed:

- Fish meal is widely used in aquaculture as a high protein feed for farmed fish and shrimp.
- It's also used in feed for livestock such as poultry, pigs and cattle.

- Fishmeal enhances the nutritional quality of the feed, improving the overall health and productivity of the animals.
- ii. **Fertilizer:**
 - Fish meal can be used as an organic fertilizer. Its nutrient content can help to improve soil fertility and provides essential nutrients to plants, promoting healthy growth.
- iii. **Bioactive Compounds:**
 - Fish meal contains bioactive compounds such as peptides and fatty acids that have potential health benefits. These compounds can be extracted and used in various applications, including functional foods and pharmaceuticals.
- iv. **Bait:**
 - Fishmeal is used in the production of bait for fishing both in recreational and commercial contexts.

2. Fish oil:

Fish oil is a versatile and valuable product derived from the tissues of fatty fish. It is known for its high content of omega-3 fatty acids, which have various health benefits.

Here's a comprehensive overview of fish oil, including its production, uses, benefits and considerations.

Use:

- i. **Dietary Supplements:**
 - Fish oil is rich in omega-3 fatty acids (EPA and DHA), which are beneficial for cardiovascular health, brain function and reducing inflammation.
 - Regular consumption of fish oil supplements is associated with improved heart health, cognitive function and joint health.
- ii. **Cosmetics and Personal care products:**
 - Fish oil is used in skincare products for its moisturizing and anti-inflammatory properties.
 - It can be found in cream, lotion and serums, where it helps to nourish and repair the skin.
- iii. **Industrial application:**
 - Fish oil is used in various industrial processes, including the production of lubricants and coatings. Its properties can enhance the performance of these products.

3. Biofuel:

Biofuel production from fish waste is a promising area with several potential benefits. Fish waste, including the bodies, heads and bones of fishes, contains lipids, protein and other organic materials that can be converted into biofuel.

Process:

- i. **Collection and preparation:** Collect fish wastes from fisheries or market. Clean the wastes and may be ground to increase surface area.
- ii. **Extraction:**
Lipid Extraction: Fish waste contains significant amounts of lipid (fat and oils) that can be extracted using methods like solvent extraction or mechanical processing.

Protein Hydrolysis: Protein in fish waste can be broken down into simpler compounds, which can be used in other processes or converted into biofuel.

iii. **Conversion to Biofuel:**

Transesterification: The extracted fish oil can be converted into biodiesel through transesterification. This biodiesel through transesterification. This process involves reacting the oil with an alcohol (typically methanol) in the presence of a catalyst to produce biodiesel and glycerol.

Hydrothermal Liquefaction: This process involves subjecting fish waste to high pressure and temperature in the presence of water to produce a liquid bio-crude that can be refined into various type of biofuel.

Use:

- i. **Biodiesel:** Can be used in diesel engines and blended with conventional diesel fuel.
- ii. **Biogas:** Used for electricity generation, heating or as a vehicle fuel.
- iii. **Bio-crude:** Can be refined into various types of transportation fuel and chemicals.

4. **Fertilizer:**

Using fish waste as fertilizer is an excellent way to recycle nutrients and improve soil health.

Benefits:

- i. **Rich Nutrient:** Fish waste is rich in essential nutrients that plants need to grow, including nitrogen, phosphorus and potassium. These are key components of most fertilizers and using fish waste can provide a natural, organic alternative.
- ii. **Microbial Activity:** The decomposition of fish waste can enhance soil microbial activity. These microbes help break down organic matter in the soil, making nutrients more available to plants.
- iii. **Improved Soil Structure:** Fish waste can improve soil texture and structure. It helps to increase the soil, which can improve water retention and aeration, making it easier for plant root to grow.
- iv. **Sustainable and Eco-friendly:** Using fish waste as fertilizer helps recycle nutrients and reduces waste. It's an eco-friendly option that minimizes the need for synthetic fertilizers, which can have environmental drawbacks.

5. **Collagen and Gelatin products:**

Collagen and gelatin are valuable products that can be derived from waste, particularly from fish skin scale bones and fins. Collagen is a protein, found in the connective tissue of fish, including the skin, scale and bones. Gelatin is also derived from collagen, and fish waste can be a good source. It is typically extracted from fish skin and bones.

Application:

- i. **Cosmetics:** Collagen is used in skincare products for its moisturizing and anti-aging properties.
- ii. **Pharmaceuticals:** Collagen and Gelatin used in the production of capsules and as a stabilizer in some medications. It's often included in dietary supplements for joint and skin health.

6. **Chitosan:**

Chitosan is a biopolymer derived from chitin, which is found in the shells of crustaceans, such as shrimp and crabs. However, there's growing interest in extracting chitosan from fish scales & skin. Which are often declare during processing. Utilizing fish waste reduces environmental impact by

minimizing waste and promoting circular economy practices. Chitosan is biodegradable, that make it eco-friendly alternative to synthetic polymers.

Applications:

- i. **Biochemical:** Drug delivery systems, wound dressing and tissue engineering.
- ii. **Agriculture:** Natural pesticide and fertilizer.
- iii. **Food Industry:** Food preservation and packaging.
- iv. **Water Treatment:** Adsorption of heavy metals and pollutants.

7. Bio-plastic:

Bio-plastic in made from fish waste represent an innovative and sustainable alternative to conventional plastics. Fish waste, particularly from the fishing and seafood processing industries, can be utilized to create, biopolymers, which are the key ingredients producing biodegradable plastics.

Source:

- **Collagen and Gelatin:** Collagen and Gelatin are extracted from fish skins, bones and scales that can be used to produce biodegradable films. These materials are natural proteins that can be transformed into bio-plastic sheet.
- **Chitosan:** Derived from chitin, a component found in the exoskeletons of shellfish like shrimp and crabs, chitosan is a biopolymer that can be used packaging materials and biomedical applications. It's biodegradable, antibacterial and has a wide range of applications.

Applications:

- **Packaging:** Bio-plastics from fish waste can be used in food packaging, especially where biodegradable materials are desired.
- **Medical use:** Due to their biocompatibility materials like chitosan can be used in wound dressing, drug delivery systems and tissue engineering.
- **Agriculture:** Biodegradable films and coating for crop protection and soil improvement.

8. Enzyme and Protein:

Fish waste, which includes parts like skin, bones and viscera, is a valuable resource for extracting enzymes and proteins. Enzymes and proteins derived from waste are valuable resources in various industries, offering numerous application in food, pharmaceuticals and biotechnology. By utilizing techniques such as homogenization, solvent extraction and chromatography fish waste can be transformed into functional ingredients for food processing, nutraceuticals, cosmetics and biotechnology. This not only helps to reduction but also contributes to environmental sustainability, making it an ultimate opportunity for innovation and resource efficiency.

Enzymes from fish waste:

- I. **Proteases:** Break down proteins into peptides and amino acids. Used in feed processing (e.g., tenderizing meat, producing fish sources) and in detergents for stain removal.
- II. **Lipases:** Main function is catalyzed the breakdown of fats and lipids. Used in the production of biodiesel, flavor development in food and in pharmaceutical.
- III. **Amylases:** Its helps to breakdown starches into sugars. Important in brewing, baking and other food industries.

Proteins from fish waste:

Proteins derived from fish wastes, are valuable resources with diverse applications. Proteins break down by enzymes for easier absorption. Proteins broke down into smaller peptides and amino acids through enzymatic or chemical hydrolysis. The extraction of proteins from fish waste not only

supports sustainability but also opens up opportunities for innovation in food, health and cosmetic industries.

Conclusion

Turning fish waste into wealth, often associated with aquaculture or aquaponic, demonstrates the potential of sustainable practices to generate economic and environmental benefits. By affectively managing fish waste and nutrient cycling, it's possible to create symbiotic system that yield both fish and plants productions.

This approach not only provides a source of food and income but also promotes resource conservation and minimizes environmental impact. As consumers increasingly seek sustainable and locally sourced product. These systems can tap into a growing market.

In conclusion, the innovative use of fish water exemplifies how ecological principles can lead to profitable ventures, supporting food security and sustainable livelihoods while fostering a deeper connection to our ecosystems. Embracing such practices can pave the way for a more sustainable future.

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ADVANCES IN FISH HARVESTING TECHNOLOGY FOR SUSTAINABLE FISHERIES MANAGEMENT

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Abstract

Advancements in fish harvesting technology are transforming sustainable fisheries management by enhancing efficiency, reducing environmental impacts, and minimizing bycatch. Innovations like mechanized fishing gear, synthetic materials, acoustic fish detection, GPS, and satellite-based remote sensing enable precise, resource-efficient operations across scales, from artisanal to commercial fisheries. Technologies improve selectivity in methods such as gill nets, traps, and longlines, targeting specific species while avoiding ecological disruptions. Advanced systems for baiting, deployment, and retrieval further enhance sustainability, supported by ecosystem-based management and regulatory measures that protect biodiversity and ensure responsible utilization. Together, these developments promote environmental conservation and economic growth.

Keywords: sustainable fisheries management, gear technology, stock management, biodiversity conservation, environmental impact.

Introduction

Fish harvesting technology employs a diverse array of methods for capturing aquatic organisms, spanning from manual collection to advanced systems like midwater trawling and purse seining. Target species vary widely, from small invertebrates to large marine creatures like tunas and whales. Due to the diversity in fisheries and species distribution, an assortment of fishing gears and techniques has developed globally, influenced by innovations in materials, vessel design, hydrodynamics, acoustics, and electronics. Traditional methods such as water filtering, prey luring, and hunting still form the basis of many modern approaches (Summerfelt *et al.*, 2009).

Currently, three primary categories of fish harvesting exist: (a) capturing fish individually or in schools using nets or spears, (b) trapping fish with stationary gear like traps or set nets, and (c) attracting fish to bait, lures, or light. Small-scale fishermen, utilizing millions of fishing vessels, contribute to nearly half of the global seafood catch. Traditional fishing has evolved with advancements in efficient tools like trawls, seines, lines, gill nets, and traps. Over the past 50 years, the fishing industry has undergone rapid transformation, with advancements in vessel modernization and equipment enhancing productivity and efficiency. Innovations in propulsion systems, gear mechanisms, synthetic materials, acoustic fish detection, and satellite-based remote sensing have significantly improved fish tracking and operational precision (Kumolu *et al.*, 2011).

Alongside these technological advancements, there is an increasing focus on sustainable fishing practices to protect biodiversity, maintain resource sustainability, and ensure energy efficiency. Today's fishing vessels often feature onboard fish-finding tools, catch processing facilities, and advanced navigation systems. Even small-scale operations in developed nations benefit from enhanced boat designs, propulsion systems, and catch preservation methods. Satellite-based technologies, such as GPS, have revolutionized fishing precision, while safety systems like the Global Maritime Distress Safety System (GMDSS) provide robust rescue mechanisms. Mechanized gear handling has expanded the scale of operations, transforming the fishing landscape. In conclusion, the integration of technology, sustainability awareness, and safety considerations has profoundly shaped the fishing industry, promoting efficiency and adaptability (Smith and Basurto, 2019).

Advances in Fish Harvesting Technology

Advances in fish harvesting technology have significantly impacted sustainable fisheries management. Over the past five decades, key innovations in fishing vessels, gear, and techniques have enhanced productivity and operational efficiency. Mechanization, synthetic materials (such as PA, PET, PE, and PP), and acoustic fish detection have improved gear durability, catch handling, and fish tracking. Technologies like GPS, satellite-based remote sensing, and the Global Maritime Distress Safety System (GMDSS) have optimized navigation, safety, and fishing precision. Additionally, advancements in fishing methods, from small-scale to large-scale operations, support sustainability by minimizing bycatch and ensuring responsible resource management. Increased awareness of environmental integrity, biodiversity protection, and energy efficiency now drives fishing practices. Modern vessels equipped with onboard fish-finding tools, communication systems, and improved propulsion contribute to the sector's sustainability, even in small-scale operations. The industry's adaptability and commitment to sustainable practices are vital for maintaining aquatic resources while improving safety and livelihoods (Kumolu *et al.*, 2011; Smith and Basurto, 2019).

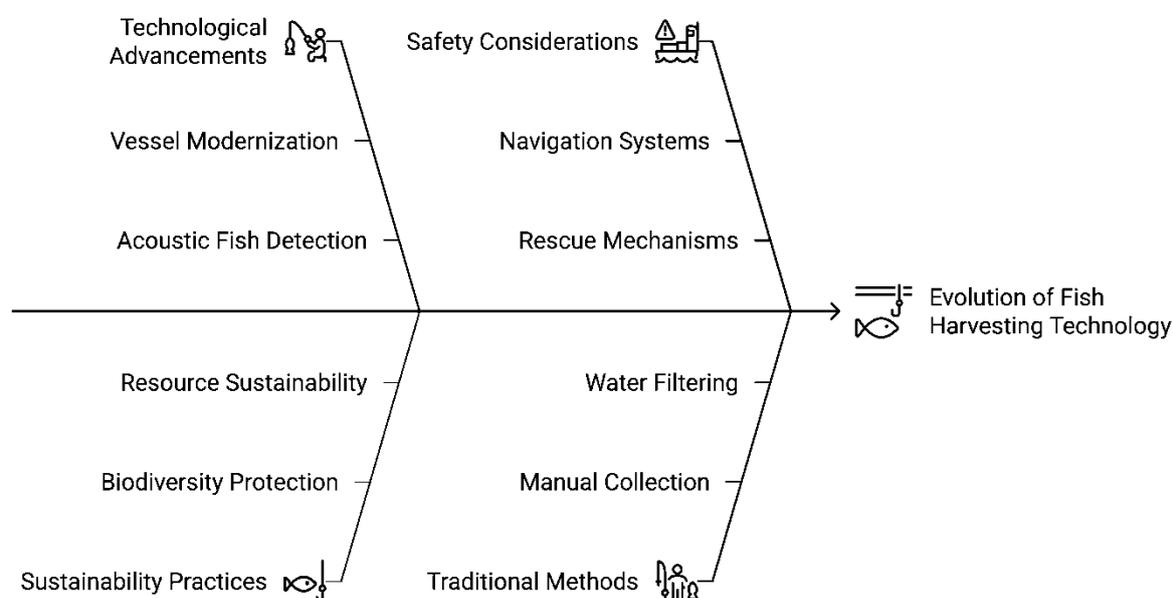


Figure 1: Factors Shaping Fish Harvesting Technology

Improved Sustainability in Fisheries Management

Sustainability refers to the ability to meet present needs without compromising the ability of future generations to meet their own. It involves maintaining a balance between environmental health, economic growth, and social well-being. The concept emphasizes responsible resource management, minimizing ecological damage, and fostering long-term viability across various systems—whether ecological, economic, or societal. Advancements in fish harvesting technology have significantly improved sustainability in fisheries management. Fishing gears are classified into passive and active systems, with active systems like trawling and purse seining being more energy-intensive but yielding higher productivity. Selectivity of gears ranges from more selective methods (e.g., gill nets, hooks, traps) to less selective ones (e.g., trawls, seines). This classification impacts environmental conservation, with selectivity reducing bycatch and enhancing sustainability. Fishing gears are also categorized based on aquatic environments and operational zones, from inland waters to deep-sea regions. Modern fishing technologies, including GPS, acoustic fish detection, and satellite-based systems, allow for more precise targeting, reducing overfishing and bycatch. Trawlers, especially factory and freezer trawlers, now feature improved on-board processing facilities, enhancing catch preservation and reducing waste. Moreover, innovative trawl designs and purse-seining techniques, such as one-boat systems, are developed to optimize efficiency while minimizing environmental impacts. These technological advancements, supported by organizations like the Central Institute of Fisheries Technology (CIFT), improve the sustainability and efficiency of fisheries, promoting responsible resource management and long-term fish stock health. As a result, sustainable fish harvesting technologies contribute to both economic growth and environmental conservation (Boopendranath, 2012; Gillett, 2011).

Optimizing Fish Harvesting with Specialized Equipment

Advancements in fish harvesting technologies are pivotal to ensuring sustainable fisheries management. Tuna purse seiners, for example, have evolved with specialized equipment to manage large, robust tuna purse seines, often utilizing helicopters for efficient school detection. These vessels are equipped with advanced winches and three-drum systems, improving catch efficiency and reducing environmental impact (Lopez *et al.*, 2014). Similarly, the development of seine netting, particularly the Danish seine, has optimized fish capture while minimizing habitat disturbance. By using extended ropes and a precise method of herding fish, it enhances selectivity, reducing bycatch (Crona and Bodin, 2006). Additionally, mini-purse seines, or ring seines, used in small-scale coastal fisheries, allow for efficient fish harvesting in inshore waters with reduced ecological disruption (Tenningen *et al.*, 2012).

Technological Innovations for Sustainable Fishing Practices

In gill netting, advancements such as the shift from nylon multifilament to nylon monofilament nets have improved durability and selectivity, leading to more sustainable fishing practices (Vander *et al.*, 2004). Moreover, trap fishing technologies, including mechanized pot haulers and derricks, have streamlined the capture of species like lobsters and crabs, enhancing operational efficiency and promoting sustainable practices by reducing labor and operational costs (Stevens, 2021). These technological improvements enhance fishing precision, reduce waste, and support sustainable practices by improving selectivity, minimizing bycatch, and optimizing resource use across various fishing methods.

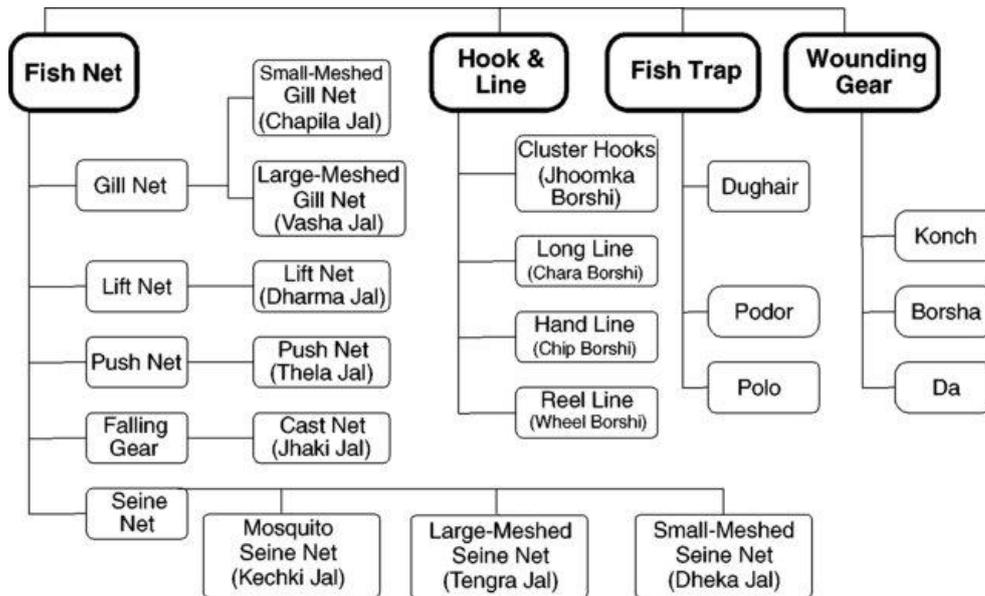


Figure: 1 Classification of the fishing gears (Ahmed *et al.*, 2006)

Enhancing Sustainability Through Selectivity and Reduced Impact

Recent advancements in fish harvesting technologies contribute significantly to sustainable fisheries management by enhancing efficiency and reducing environmental impacts. Traps, such as lobster traps and crab pots, have been redesigned for durability and minimal ecological disruption. For example, the Central Institute of Fisheries Technology (CIFT) developed a robust lobster trap with a plastic-coated steel mesh, addressing corrosion issues and improving longevity (Konigson *et al.*, 2022). Additionally, fyke nets and stow nets have evolved with design improvements to capture fish in shallow and estuarine waters while minimizing bycatch. These nets feature cone-shaped bags and strategically placed wings to guide fish into capture areas, further optimizing their functionality in diverse environments (Pander *et al.*, 2018). The stationary uncovered pound net, also known as set nets, utilizes a leader net to direct migrating fish into enclosures, reducing the likelihood of escape. This method, when combined with optimal positioning, enhances fish capture efficiency without negatively impacting surrounding ecosystems (Colakoglu, 2021).

High-Efficiency Fishing Gear	Low-Efficiency Fishing Gear
1. Pair trawl	9. Squid falling net
2. Otter board trawl	10. Pomfret lift net
3. Beam trawl	11. Gillnet
4. Purse seine	12. Krill push net
5. Anchovy purse seine	13. Baby clam dredge
6. Anchovy falling net	14. Blood clam dredge
7. Anchovy lift net	15. Other shell dredges
8. Light luring vessel	16. Fish trap
	17. Crab trap
	18. Squid trap
	19. Octopus trap
	20. Longline
	21. Red frog crab lift net
	22. Handline

Figure 2: Classification of fishing gears according to their catching efficiency. (Kulanujaree *et al.*, 2020)

Longline Innovations and Improved Sustainability

In line fishing, innovations in long lines, including drifting, bottom-set, and vertical variations, allow for more selective and controlled fishing. These advancements contribute to a reduction in non-target species capture, further promoting sustainability in fishing practices (Mytilineou *et al.*, 2014). Recent advancements in fish harvesting technologies have significantly enhanced the sustainability of fisheries management. Longliners have evolved with automated and semi-automated systems to deploy baited hooks and retrieve lines, improving efficiency and minimizing bycatch. These systems are particularly useful for catching species like sharks and tuna while reducing the environmental impact (Flaaten and Anh, 2008). Pole and line vessels have also seen innovations, particularly for capturing tuna. These vessels now feature live bait tanks and water-spraying systems to attract fish, enhancing their efficiency in selective fishing. This technique is prevalent in areas like the Lakshadweep Islands, where sustainability is a key focus (Gillett, 2016).

Refining Fishing Methods for Eco-Friendly Practices

The trolling method, using hooks and lures to target predatory fish, has become more refined with the use of artificial lures and controlled speeds to optimize catches while minimizing non-target species capture (Tampubolon *et al.*, 2015). Jigging, which involves the jerking of baited hooks to lure fish, has also improved, making it an effective method for catching squid and cod (Awbros, 2020). Inland fisheries in India have benefited from lightweight, shallow-draft vessels like coracles and catamarans, and tools such as gill nets, bag nets, and traps, which are tailored for specific environments and species. These innovations allow for efficient, low-impact harvesting while preserving aquatic ecosystems (Gunasekara *et al.*, 2023; Vander *et al.*, 2004).

Optimizing Fish Harvesting for Ecosystem Management

Recent advancements in fish harvesting technologies have focused on improving selectivity and minimizing environmental impact, aligning with sustainable fisheries management goals. Mechanized trawling, tested in reservoirs like Hirakud and Ukai, aims to eliminate unwanted species, such as predatory fish and aquatic weeds, helping manage aquatic ecosystems more effectively (Thierry *et al.*, 2020). Seine nets and drive-in nets have also been optimized for use in rivers and reservoirs, providing efficient means for capturing fish without overexploitation. Lift nets and falling gear, such as cover pots and plunge baskets, have evolved to enhance selectivity, capturing fish only when they are concentrated, reducing bycatch (Morales, 2021). Clap nets, notably used in West Bengal for hilsa fishing, employ a unique design that targets migratory fish, ensuring a more focused harvest.

Ensuring Sustainable Fisheries Through Responsible Systems

Sustainability in fishing practices is now emphasized through responsible systems that promote scientifically informed stock management, precautionary approaches, and bycatch minimization. Efforts also include the ban on destructive methods and stock restoration initiatives. International cooperation and recognition of artisanal and small-scale fisheries further ensure a holistic, long-term strategy for resource preservation (Boopendranath, 2012). These technological advancements, combined with strict regulations and research into energy-efficient systems, are crucial for maintaining biodiversity, preventing overfishing, and supporting sustainable fishery practices.

Conclusion

Advances in fish harvesting technologies play a crucial role in ensuring the sustainability of fisheries management by enhancing efficiency, improving selectivity, and reducing environmental impacts.

Over the past few decades, technological innovations in fishing vessels, gears, and techniques have significantly improved the sustainability of fish harvesting practices. From specialized equipment like tuna purse seiners and longline systems to innovations in trap fishing, gill netting, and seine netting, each advancement contributes to responsible resource management, minimizing bycatch, and promoting biodiversity conservation. Technologies such as GPS, acoustic fish detection, and satellite-based systems have enhanced precision and reduced the risk of overfishing. Furthermore, these innovations have empowered the industry to operate more efficiently while maintaining ecological balance and reducing operational costs. As a result, these advancements not only benefit the fishing sector but also play a vital role in safeguarding marine and aquatic ecosystems for future generations. The continued adoption of these technologies, supported by strong regulations and international cooperation, will be critical for the long-term sustainability of fisheries. By combining modern technology with responsible management practices, the fishing industry can contribute to a balanced, healthy marine environment while supporting economic growth and the livelihoods of communities dependent on fisheries.

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