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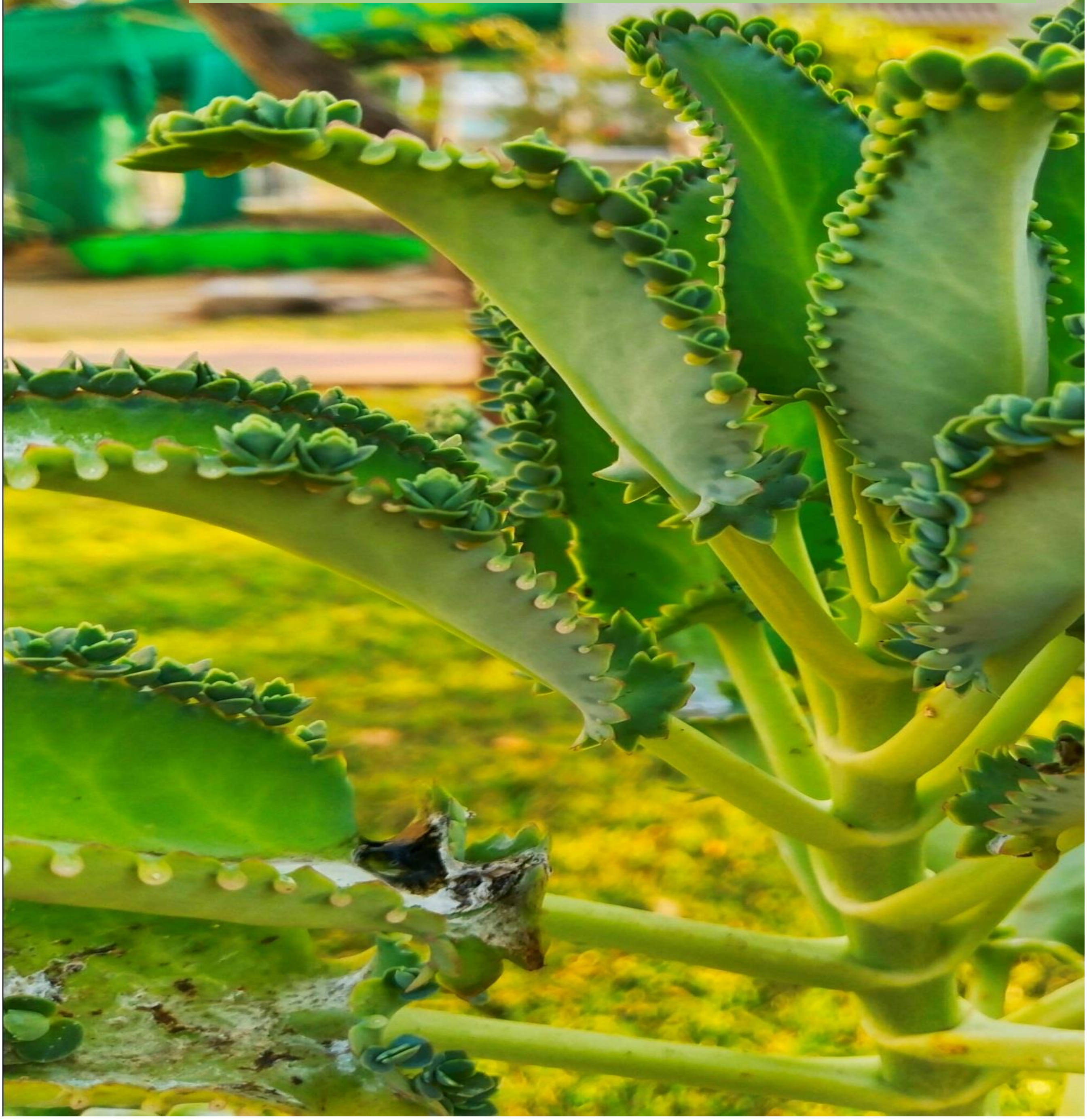

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Impact of Greenhouse Gases in Agriculture and other Ecosystems and Its Mitigation

Sridhara, M R[1]*, Kavyashree, C[1], L. Shravika[1] and Indumathi, P[2]

[1]**Department of Agronomy, University of Agricultural Sciences, Raichur - 584104 (Karnataka), India*

[2]*Department of Soil Science & Agricultural Chemistry, University of Agricultural Sciences, Raichur - 584104 (Karnataka), India*

Corresponding author mail id: agrisridhar72@gmail.com

ABSTRACT

The most significant environmental problem in the entire globe today is global warming, which is brought on by a rise in the concentration of greenhouse gases in the atmosphere. It is anticipated to have a significant influence on agriculture, particularly cattle, fisheries and agricultural production. Given its importance for guaranteeing India's food, nutritional and economic security, Indian agriculture is subject to stressors brought on by climatic variability and climate change. Understanding emission patterns, their causes and how they relate to one another is crucial to understanding why greenhouse gas reduction is necessary. By storing carbon in the soil and lowering methane and nitrous oxide emissions from the soil by changes in land use, enhancing input use efficiency greenhouse gases emissions from agriculture can be mitigated.

Keywords: *Agriculture, Carbon dioxide, Climate change, Global warming, Greenhouse gases*

Introduction

As the world's population increases, agriculture faces the enormous challenge of providing sufficient healthy food and its environmental consequences such as water scarcity and climate change. Global warming, caused by the increase in concentration of greenhouse gases (GHGs) in the atmosphere, has emerged as the most prominent environmental issue all over the world. These GHGs *viz*. carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O) trap the outgoing infrared radiations from the earth's surface and thus raise the atmospheric temperature. Various agricultural activities such as land clearing, cultivation of crops, irrigation, animal husbandry, fisheries and aquaculture have a significant impact on the emission of GHGs and the consequent climate change.

The total geographical area of the country is 328.7 million hectares (2.4% world geographical area), of which 139.4 million hectares is the reported net sown area and 200.2 million hectares is the gross cropped area with a cropping intensity of 143.6 %. Also second largest populous country with the population of 1.3 billion. According to Food and Agriculture Organization (FAO), by 2050 the world population is likely to touch 9.8 billion and 11.2 billion in 2100. As we are seeing huge increasing population over years, thereby requirement of food grains also increases.

The impacts of climate change are also shown in various other forms throughout the world, including the rise of sea level, decrease in glaciers, northward movement of plant habitats, changes in animal habitats, rise of ocean temperature, shortened winter and early arrival of spring. During 1970-2010, the GHGs emissions from Indian agriculture have increased by about 75% (Pathak *et al.* 2014). The increasing use of fertilizers and other agri-inputs and the rising population of livestock are the major drivers for this increase in GHGs emission. Due to the emissions of methane and nitrous oxide from agricultural soils and livestock, agriculture sector will be a major contributor to the enhanced greenhouse effect.

The understanding of trends in emission of greenhouse gases, their drivers and the relation between the two is essential for comprehending the need for GHGs mitigation. India recognizes that for ensuring country's food security in both short and long terms and making the agriculture sustainable and climate-resilient, appropriate adaptation and mitigation strategies will have to be developed.

Greenhouse Gases

Greenhouse gases are the gases present in the atmosphere that absorb the infrared radiations and creates a greenhouse effect.

The major greenhouse gases are:

1) Carbon dioxide (CO_2)

2) Methane (CH_4)

3) Water vapours

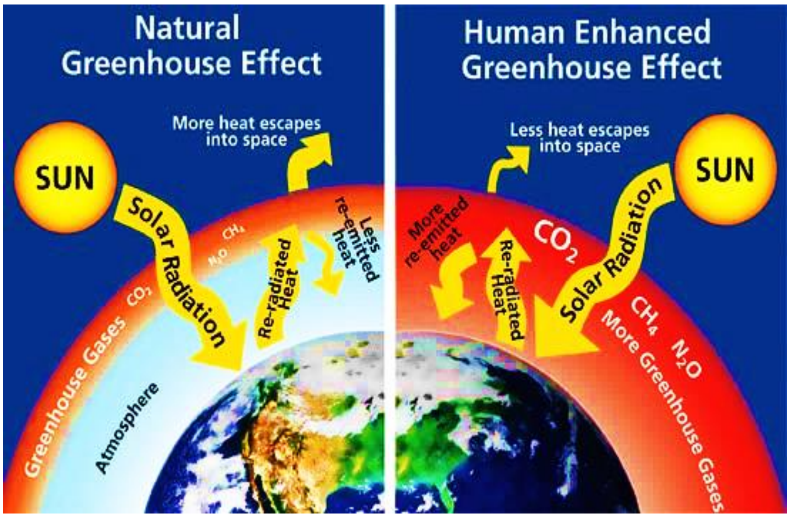
4) Nitrous oxide (N_2O)

5) Ozone (O_3)

6) Chlorofluorocarbons (CFCs) and other halocarbons

Greenhouse effect

The greenhouse effect is a process that occurs when gases in Earth's atmosphere trap the Sun's heat. This process makes Earth much warmer than it would be without an atmosphere. The greenhouse effect is one of the things that makes Earth a comfortable place to live. Percentage contribution of GHGs to the greenhouse effect is higher in carbon dioxide followed by methane, nitrous oxide and halocarbons.



This is a representation of the earth and the atmosphere and the sun. Our atmosphere has greenhouse gases – carbon dioxide, nitrogen, and oxygen just to name a few. Side A has some greenhouse gases. Side B has more greenhouse gases than side A. The sun shines down through the atmosphere to the earth leads to the *reflection, refraction and absorption.* Reflected light bounces off a surface and leaves the surface at the exact same angle it came in. Refracted light goes through a substance and it looks like the light changes angle as it goes through. Absorbed light does not bounce off or pass through a substance and is usually transferred to heat energy.

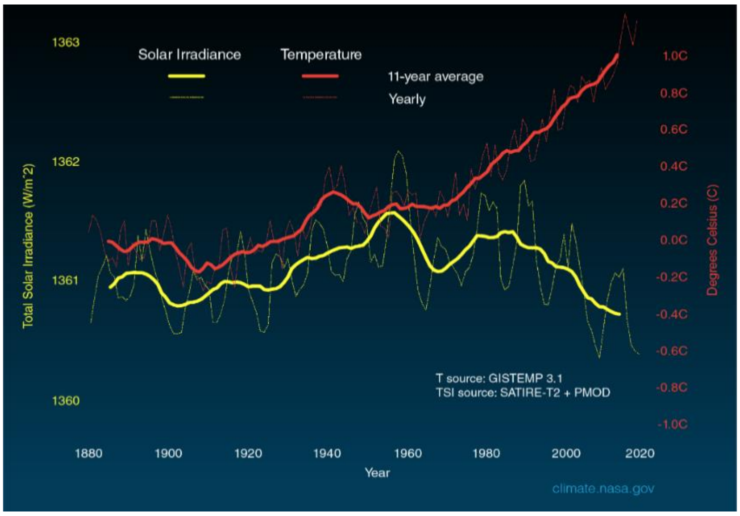


Figure 1. Average solar irradiance and temperature variations from 1880 to 2020

The above graph compares global surface temperature changes (red line) and the Sun's energy received by the Earth (yellow line) in watts (units of energy) per square meter since 1880. The lighter/thinner lines show the yearly levels, while the heavier/thicker lines show the 11-year average trends. Eleven-year averages are used to reduce the year-to-year natural noise in the data, making the underlying trends more obvious.

The amount of solar energy Earth receives has followed the Sun's natural 11-year cycle of small ups and downs, with no net increase since the 1950s. Over the same period, global temperature has risen markedly. It is therefore extremely unlikely that the Sun has caused the observed global temperature warming trend over the past half-century.

Greenhouse gases and their sources

GHGs	Natural sources	Anthropogenic sources
CO_2	Respiration and volcanic eruption	Burning of fossil fuel, deforestation, decomposition of soil organic matter
CH_4	Wetlands and ocean	Rice production, livestock, landfills and use of fossil fuels
N_2O	Oceans and soils	Agricultural and other land-use activities

Table 1. Summary of Key Greenhouse Gases

Description	CO_2	CH_4	N_2O
Pre-industrial concentration	280 pmv	700 ppbv	275 ppbv
Concentration in 1992	355 pmv	1714 ppbv	311 ppbv
Concentration in 1994	358 pmv	1720 ppbv	312 ppbv
Concentration in 1997	366.7 ppmv	1800 ppbv	312 ppbv
Rate of Concentration change per year	0.50 %	0.80 %	0.20 %
Atmospheric lifetime (years)	50-200	12	120
2020 global mean abundance	413.2 ± 0.2 ppm	1889 ± 2 ppb	333.2 ± 0.1 ppb
2020 abundance relative to 1750	149 %	262 %	123 %
Mean annual absolute increase over the past 10 years	2.4 ppm/year	8 ppb/year	0.99 ppb/year

IPCC (2017)

Global Warming Potential (GWP)

Global Warming Potential (GWP) has been developed as a metric to compare (relative to another gas) the ability of each greenhouse gas to trap heat in the atmosphere. Carbon dioxide (CO_2) was chosen as the reference gas to be consistent with the guidelines of the Intergovernmental Panel on Climate Change (IPCC). The GWP depends on both the efficiency of the molecule as a greenhouse gas and its atmospheric lifetime.

Evidence for increased GHGs in the atmosphere

1. Global temperature rise: The year 2015 was the first time, the global average temperature was 1°C. The year 1998 was the warmest year.

2. Warming of Oceans: The oceans have absorbed much of this increased heat, with the top 700 meters (about 2,300 feet) of ocean showing warming of 0.302 degrees Fahrenheit since 1969.

3. Shrinking of Ice sheets: The Greenland and Antarctic ice sheets have decreased in mass. Data from NASA's Gravity Recovery and Climate Experiment show Greenland lost 150 to 250 cubic kilometers of ice per year between 2002 and 2006. Antarctica lost about 152 cubic kilometers of ice between 2002 and 2005.

4. Raise in the Sea water level: Addition of water from melting land ice and the expansion of sea water as it warms.

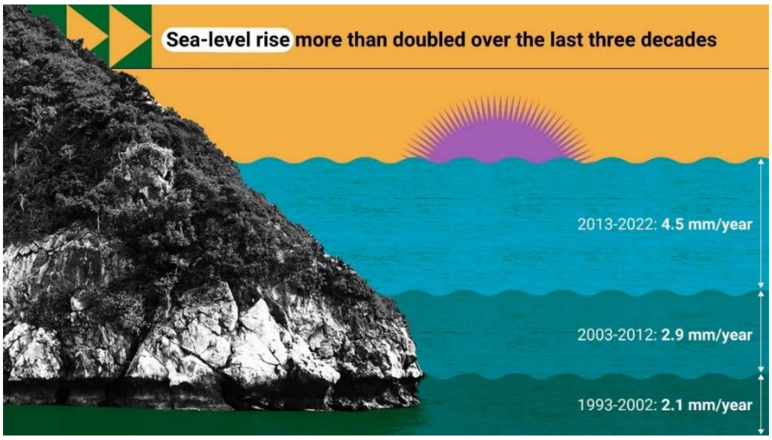


Figure 2. Graphical representation of global sea level rise over decades (NASA, 2021)

Why Is Global Sea Level Rising?

- Thermal expansion: Warmer water is less dense than colder water.
- Melting of glaciers and ice caps: Water released by the melting of ice on land adds to the volume of the oceans.
- Melting and calving of Greenland and Antarctic ice sheets: Depends on ice sheet dynamics (how the ice flows).

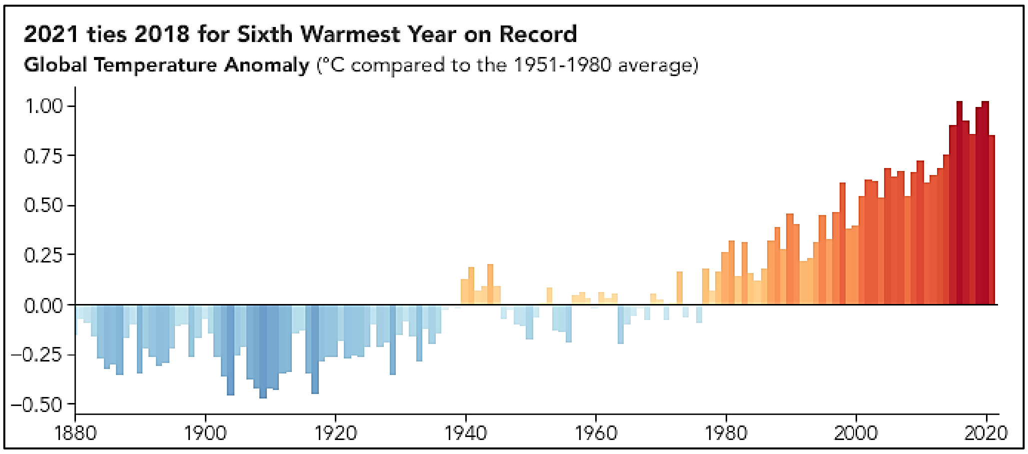


Figure 3. Climate change anomalies (CO_2 & Temp.) from 1880 to 2020 (Source: NASA/GISS, 2021)

Greenhouse gases emission in agriculture

Greenhouse gases emitted from agricultural activities are generally not visible. Agriculture is responsible for about 17% of GHG emission in India, which is almost same as its share in the country's GVA (NABARD, 2022).

The emission results from the following:

Application of organic and inorganic inputs to the soil, decomposition of biomass and dead plant residues, plant respiration, livestock rearing, enteric fermentation in ruminants, manure handling and burning of crop residues.

Impact of climate change in Agriculture

- ✓ Reduction in crop yield
- ✓ Shortage of water
- ✓ Irregularities in onset of monsoon, drought, flood and cyclone
- ✓ Rise in sea level
- ✓ Decline in soil fertility
- ✓ Loss of biodiversity
- ✓ Problems of pests, weeds and diseases

Mitigating GHGs emission from Indian Agriculture

- The managed soils are the major sources of methane and nitrous oxide both having significant global warming potential.
- Agriculture has the potential to mitigate GHGs cost-effectively through the adoption of low carbon in agricultural technologies and management practices.

The three approaches for mitigation of GHGs are:

- Reduction in emissions
- Enhancement of removals
- Avoiding emissions

Conclusion

Identification of soil management practises that are climate change compatible, where soil organic carbon is boosted or at least maintained and GHG emissions are decreased, is necessary for Indian agricultural production systems to remain viable in the future. By storing carbon in the soil and limiting the releases of methane and nitrous oxide from the soil through improvements in land-use management and improving input-use efficiency, the mitigation of GHG emissions from agriculture may be accomplished. Farmers should be encouraged to adopt mitigation strategies, enhance soil health, and utilise water and energy more effectively through the development of policies and incentives.

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From Petri Dish to Plate: Exploring the Future of Lab-Grown Meat

Prasad M. Govindaiah[1*] and Diksha P. Gourkhede[2]

[1]Department of Livestock Products Technology, ICAR - Indian Veterinary Research Institute, Izatnagar, Uttar Pradesh, India; [2]Department of veterinary public health and epidemiology, College of Veterinary and animal sciences, Kishanganj, Bihar, India

Corresponding author: prasadmglpt@gmail.com

Abstract: The emerging realm of lab-grown meat, or cellular agriculture, shows promise in tackling the environmental, health, and animal welfare issues linked with traditional meat production. This technique involves cultivating animal cells in a laboratory to create meat, presenting a sustainable and ethical alternative to conventional livestock farming. However, despite its potential, lab-grown meat confronts challenges like technological limitations, consumer acceptance, and legal recognition. Research and funding are crucial to push forward this technology, ensuring safety and meeting societal needs. The article delves into the production process, its potential as functional food, and ongoing ethical and socioeconomic considerations. It also explores implications for the meat industry, environmental impacts, and regulatory aspects to encourage further economic exploration and public endorsement of this transformative innovation.

Keywords: lab-grown meat, cellular agriculture, consumer acceptability

Introduction

The world's population is projected to reach 9.5 billion by 2050, driving significant social, economic, and demographic shifts, including urbanization and increasing incomes in emerging economies. This trend is set to persist, with global per capita meat consumption forecasted to grow by 1.2% annually, resulting in a 14% overall surge in meat consumption by 2030 (Daszkiewicz, 2022). These changes, accompanied by evolving consumer behaviours, will strain global food resources, necessitating attention to diverse dietary options (Hedrick, 1970; WPP, 2015). A notable outcome of this growth is the substantial rise in meat consumption. Studies by Henchion *et al.* (2014) underscore this increase, driven primarily by rising incomes in Asian, Latin American, and Middle Eastern countries. The mounting demand for meat, especially from animal sources, raises environmental concerns due to increased greenhouse gas emissions, water usage, and land exploitation (FAO, 2019). Recent diet trends like the ketogenic diet further intensify the demand for protein, largely met through meat (Iacovides & Meiring, 2018).

Traditional meat production faces challenges in meeting this demand due to its energy-intensive nature, and ethical and environmental concerns are driving interest in sustainable alternatives (Srutee *et al.* 2022). Plant-based meat (PBM) made from sources like nuts, grains, soybeans, and wheat is an initial response, but nutritional concerns persist (Curtain & Grafenauer, 2019). Lab-based meat, also known as clean meat or cultured meat, emerges as a promising solution, involving in-vitro cell culture to produce meat without animal sacrifice (Ben-Arye & Levenberg, 2019). Lab-grown meat boasts benefits such as customizable nutrition profiles and sterile production, reducing foodborne risks (Sergelidis, 2019). Environmentally, it's eco-friendly, cutting emissions and resource use (George, 2020). This innovation attracts investment and research attention worldwide (GFI, 2020). Despite initial resistance, the lab-grown meat market could reach $25 billion by 2030, driving the need for quality and cost improvements (Brennan *et al.* 2021).

Lab-grown meat challenges include refining appearance, texture, and nutritional value to match conventional meat (Ismail *et al.* 2020). Overcoming these hurdles hinges on addressing ingredient quality, cost, and safety concerns for widespread adoption (Golkar-Narenji *et al.* 2022). As the global population grows, lab-grown meat offers a sustainable solution to meat production challenges, addressing environmental, ethical, and nutritional aspects. Continued research is vital for integrating lab-based meat into the global food supply chain effectively.

Defining Cultured Meat:

Cultured meat is an innovative approach involving the cultivation of individual myo-satellite cells on a substrate within a liquid medium, coupled with mechanical stimulation to ultimately harvest fully differentiated mature muscle cells (Jairath *et al.* 2021). The process of producing cultured meat begins by collecting individual stem cells from animals, which are then cultured within a bioreactor to simulate conditions resembling those found in the animal's body (Vlčko *et al.* 2023). Within this bioreactor environment, an enriched culture medium supplies the necessary nutrients for cellular growth. The interaction between the medium's composition and stimuli from the scaffold structure prompts immature cells to differentiate into skeletal muscles, fat, and connective tissues, ultimately forming edible tissue. Subsequently, the differentiated cells are harvested, processed, and packaged to create the final products (Mike, 2016).

The Genesis of Cultured Meat:

The inception of cultured meat embarks as an idea and eventually materializes in the market. This journey commences with the emergence of the cultured meat concept in the mind of politician Frederick Edwin Smith in 1927 (Brian, 2011). Subsequently, the notion receives attention when French authors reference cultured meat in their works in both 1943 and 1967 (Jairath *et al.* 2021). In the early 1950s, Dutch researcher Willem van Eelen pioneers research using tissue culture as a substrate for in-vitro meat production, culminating in his patent acquisition in 1999 (Bhat *et al.* 2015). Additionally, the prominence of cultured meat technology is highlighted as a research team secures funding from NASA for the Tissue Culture and Art Project in 1997, aimed at producing in vitro meat for space travelers. The team achieves success by cultivating goldfish muscle cells into muscle explants (Benjaminson *et al.* 2002)

Understanding the Science of Lab-Grown Meat

Unveiling the Mechanics of Cultured Meat: The sequential process behind preparing cultured meat is depicted in Figure 1.

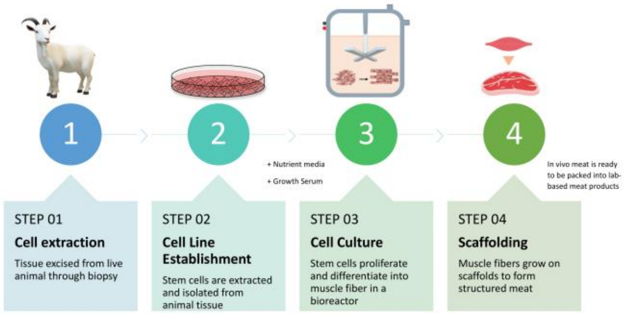

Figure 1: Illustrative diagram outlining the process and structure of lab-based meat production

Step 1 - Cell Extraction: The process commences with the gentle extraction of cells from the animal's body, ensuring no harm or loss of life to the animal. These individual cells are meticulously screened and selected to be cultured in the laboratory, forming a cell repository.

Step 2 - Cell Line Establishment: The chosen cells from the cell repository are placed within a carefully monitored and controlled environment conducive to their growth and proliferation. This environment is supplemented with essential nutrients to facilitate their development.

Step 3 - Cell Cultivation: As the cells multiply, additional elements are introduced, such as protein growth factors and new surfaces for cell attachment. This enables the cells to differentiate into distinct cell types, including muscle, fat, and other connective tissues.

Step 4 - Scaffold Creation: Once the cells have differentiated into the desired cellular materials, they can be harvested from the controlled environment. Subsequently, conventional food processing techniques are employed to refine the material, followed by packaging for consumer consumption.

Consumer Reception and Recognition

Consumer Preferences: While conventional agricultural meat remains favored by many, vegetarians often opt for existing plant-based products or plant-derived proteins (Santo *et al.* 2020). In this landscape, cellular meat emerges as a potential consumer-friendly alternative (Sollee, 2022). However, as a nascent biotechnology, cellular meat faces a multitude of regulatory obstacles. The absence of a firmly established regulatory framework prompts the pivotal query of which regulatory scheme should oversee cellular meat, considering the existing legal backdrop. The approach to regulating cellular meat will play a vital role in garnering consumer acceptance (Sollee, 2022).

Animal-Friendly Approach: Lab-based meats are tailored to be animal-friendly, with every component of the meat analogue designed to be animal-free (Hamdan *et al.* 2021). Yet, the growth of lab-based meat presently necessitates stem cell sources from live animals, relying on culture media containing animal serum as a growth supplement (Stephens *et al.* 2018). This raises concerns about ingredients used in lab-based meat production, particularly in relation to religious dietary practices, vegetarianism, and veganism (Hamdan *et al.* 2021).

Religious Considerations: Religious perspectives have engendered considerable discussion around the acceptability of lab-based meat, entwined with consumption legality. Certain faiths hold specific dietary directives that prohibit consuming particular animals due to safety, ethics, or sanctity reasons (Baral, 2020). Islamic Shari'ah law, for instance, bars carnivores with fangs, taloned birds, reptiles, non-ruminants, pests, frogs, and pigs (Hossain, 2019). In Judaism, Kosher law forbids pigs, hares, hyraxes, and camels (Rohrbacher, 2015). Hindus, Buddhists, and Jains venerate cattle in their religions (Szűcs *et al.* 2012). Generally, lab-based meat, except for cultured beef, aligns with the acceptability of these communities, with Hindus showing the highest acceptance (C. Bryant & Barnett, 2020).

Vegetarian and Vegan Considerations: Consumers adhering to vegetarianism or veganism, driven by principles like ahimsa (nonviolence), often display less enthusiasm for lab-based meat (Mace & McCulloch, 2020). They lean towards plant-based meat substitutes over lab-based alternatives, viewing the latter, derived from real animal cell lines, as technically non-vegetarian or non-vegan, despite its reduced animal suffering (Nezlek *et al.* 2022). Their resistance stems from health, environmental, and ethical concerns, perceiving conventional meat as less healthy and its production as inhumane (C. J. Bryant, 2020). However, advancements that promise healthier, cruelty-free meat might encourage their adoption of lab-based meat (Hopkins, 2015).

Implicit and Explicit Attitudes: Public perception of new technologies is influenced by implicit and explicit attitudes. Implicit attitudes are reflexive evaluations, while explicit attitudes stem from cognitive deliberation, often influenced by implicit attitudes. Diverse methods gauge these attitudes. Time-based measures ascertain implicit attitudes, linked to spontaneous behaviour, while self-report scales assess explicit attitudes, tied to deliberate behaviour. A study on cultured meat found that influencing explicit attitudes through context-relevant information can impact its commercial success (Bekker *et al.* 2017). Positioning cultured meat as a substitute or complement to conventional meat plays a pivotal role in consumer acceptance, as they tend to compare it with existing products (Verbeke *et al.* 2015). Focusing on the benefits of cultured meat can bolster its reception among consumers.

Consumer Habits and Cultured Meat: Consumer eating habits significantly shape the reception of new products and technologies. In Western nations, shifting meat consumption habits, driven by safety and sustainability concerns, are evident. Factors like sustainable production and meat quality also play a role. Cultured meat emerges as a potential response to these evolving preferences. Initial introductions like a cultured meat burger in London aimed to gauge consumer readiness and assess their perceptions (Verbeke *et al.* 2015). Surveys conducted across various countries have revealed varying degrees of acceptance, showcasing potential interest and willingness to try cultured meat (Weinrich *et al.* 2020).

Conclusion

In summary, the imminent surge in global population and subsequent rise in meat consumption necessitate innovative solutions. Lab-grown meat, as a response to environmental, ethical, and nutritional concerns, shows promise. Its advantages, such as tailored nutrition and eco-friendliness, are gaining traction and investments. While challenges persist, continued research will be vital for its seamless integration into the food supply chain. This transformative technology holds the potential to redefine meat production, addressing the complex challenges of a growing world

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Aquatic Invaders: A Deep Dive into Ballast Water Management and its Impacts

Baig Laika Riyaz[1*], Samad Sheikh[2], Jahanzaib Khan[1], Indulata Tekam[3]

[1]Faculty of Fisheries, Rangil, Ganderbal, SKUAST-Kashmir*
[2]ICAR – Central Institute of Fisheries Education, Mumbai, Maharashtra
[3]College of Fishery Science, NDVSU, Jabalpur, Madhya Pradesh
**Corresponding author: laikabaig64@gmail.com*

Abstract:

Ballast water has been recognized as one of the primary vectors for introducing and spreading aquatic invasive species (AIS) around the world. Ballast water is transferred by ships from one location to another but plays vital role to maintain stability and balance of ship during transit. This practice unintentionally introduced non-native species that can have severe ecological, economic, and public health impacts. There are no simple solutions because management of vessels ballast water has been shown to be a difficult task. However, implementation of Ballast Water Management System (BWMS) attempts to control and manage ballast water of vessels and stops the movement of dangerous aquatic species from one area to another. This article provides information related to ballast water, including sources, types of organisms transported, and their impacts in detail.

Keywords: Ballast water, bioinvasive species, commercial vessels, voyage, treatment and management

Introduction

Ballast is referred to as material that provides weight to an object or keeps it stable. Whereas, Ballast water is defined as salt or freshwater with suspended materials that is taken on board in a ship to control trim, stability, tensions of the ship and draught. Ships are constructed and built to transport both cargo and passengers via water. Therefore, ships need to carry water in their ballast tanks primarily to maintain their own safety and proper propulsion, and the water needed is obtained from the surrounding ocean. It means that from an environmental perspective in terms of biodiversity, natural barriers are being easily crossed among all distinct biogeographic regions in the world, which contributes to the homogenization of species, affects the ecological balance of aquatic ecosystems, and makes it easier to disseminate information about biodiversity. The earliest recorded sea trade network took place 5,000 years ago between Mesopotamia, Bahrain and the Indus River in western India to interchange oil and dates for cooper and possibly ivory from the Indus (Stopford, 2009).

Ballast water is used mainly by cruise ships, commercial ships, and bulk cargo carriers since they are invent to transport different cargo and passengers. The water loaded in the ballast tanks and cargo holds of ships is called ballast water. Uneven distribution of weight on the ship, weather conditions and fuel consumption during the voyage, a fully loaded vessel needs to use ballast water operations. Because of these reasons, the design of vessel and structures essentially depend on ballast water for safe navigation. However, it also has some detrimental effects on biodiversity, economy and human health since the uptake and discharge of ballast water into the marine environment by ocean-going ships aids in the global spread of bioinvasive species and pathogens.

Ballasting and de-ballasting process

Ships are built with high capacity ballast pumps and piping systems to operate in ballast tanks. Ballasting or de-ballasting is used to bring seawater on board and remove it when the ship is at sea or in a port.

The ancient ships carried solid ballast to provide stability because the cargo was light or there was no cargo to carry. But as time passed, problems emerged with the loading and unloading of these solid items. Therefore, solid ballast was replaced by water ballast due to time-consuming procedure of moving solid cargo. Sea water was utilized for ballasting and de-ballasting because it was abundantly available and consumed in large quantities. Thus, ships become a vehicle for the transfer and spread of dangerous foreign species from one region of the world's oceans to another during the loading and unloading of untreated ballast water, which poses a serious risk to the environment, human health, and the economy. Sediment and microscopic organisms are carried into the ballast tanks together with the ballast water when a ship's ballast pumps are turned on. These organisms include several species of larvae as well as germs, microorganisms, eggs, tiny invertebrates, cysts, and other small objects. Several of these creatures can survive for long periods in hostile settings, such as a ship's ballast tanks. The creatures are dispersed into the nearby marine environment by releasing the ballast water. These alien species will not only survive but can thrive under the appropriate circumstances and become invasive, dangerous, and even obliterate local populations without the help of their

natural predators.

Figure-1: Ballasting and de-ballasting process (Source: http://globallast.imo.org)

Invasion of foreign species:

The introduction of foreign species, along with overexploitation of marine resources, environmental alteration and demolition of aquatic biodiversity as well as onshore sources of contamination, is regarded as the fourth greatest threat to the world's oceans, causing severe effects on social, environmental, economical, and public health factors. The consequences of these alien species introduction and dissemination are increasingly being examined due to their importance, irreversibility and magnitude; they are now considered as a type of pollution and a major threat to the biodiversity (Castro, 2012). As transit times have decreased and ballast water levels have increased, these introductions have become increasingly visible in recent decades (Carlton and Geller, 1993). Scientists initially detected the warning signs of an alien species invasion in 1903, when the Asian phytoplankton algae Odontella (*Biddulphia sinensis*) was common in the North Sea (Leppäkoski, 2002). Other countries having specific problems with invasive species raised their concerns to the attention of the International Maritime Organization (IMO) and Marine Environment Protection Committee (MEPC) in the late 1980s (Lakshmi *et al.* 2021).

International Maritime Organization and World Health Organization (WHO) both recognize the potential for spilled ballast water to cause harm. Approximately 15% of non-native species are known to pose problems with significant ecological and economic consequences, according to IMO data (OTA, 1993; Ruiz *et al.* 1997) and also spreading bacteria that may cause pandemic diseases (ICS and INTERTANKO, 2000).

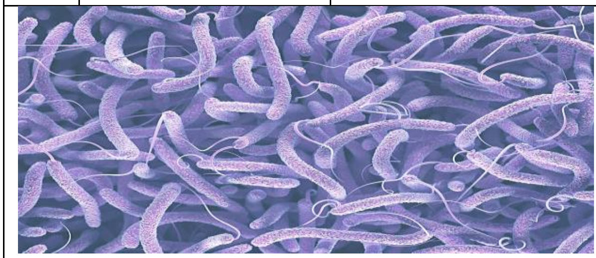
There are five ways to assess the impact of an invader in a new environment (Parker *et al.* 1999):

1. Effects on organisms (such as growth and mortality);
2. Effects on population dynamics (such as abundance and population growth);
3. Effects on genetics (such as hybridization);
4. Effects on communities (such as trophic structure, species richness and diversity);
5. Effects on environmental processes (primary productivity as well as nutrient availability, etc).

Table 1: Distribution of taxon of different invasive species around the world

Sl. No.	**Taxon**	**Distribution In world (Water body name)**	**From which country**	**Affected species**	**Source**
1.	Cholera (*Vibrio cholera*)	South America, the Gulf of Mexico, and other regions	Nations with inadequate sanitation	Bacterium strains O139 and O1 can cause cholera in humans	
2.	Asian Kelp (*Undaria pinnatifida)*	New Zealand, the United Kingdom, Spain, France, Italy, Australia, Argentina, the United States and Mexico.	Indigenous to cold-water coastal regions of Japan, China and Korea	Tends to occupy vacant (disturbed) habitats, without threatening the extant canopy-forming seaweeds	(South *et al.* 2017)
3.	Cladoceran Water Flea (*Cercopagis pengoi)*	Baltic Sea	Black and Capsian seas	Block trawls and fishing nets	(Hassaan and El, 2021).
4.	Chinese mitten crab (*Eriocheir sinensis)*	Baltic Sea, West Coast of North America as well as Western Europe	North America	Destroy fish habitat by significantly eroding river banks through their burrowing activities.	

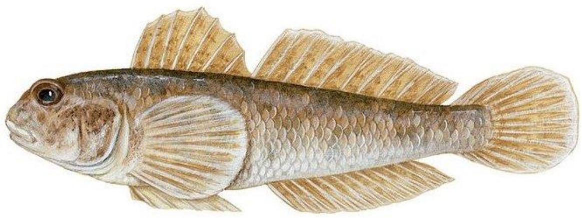
5.	North American comb jelly (*Mnemiopsis leidyi)*	Azov, Caspian and Black Sea	Eastern Seaboard of the Americas.	Negative impacts on fish population	(David and Gollasch, 2015)
6.	Round goby (*Neogobius melanostomus*)	North America and Baltic Sea	Black Sea, Caspian Seas and Asov Sea	elimination of benthic prey species such as mussels, shrimps and commercially important fish species	
7.	North Pacific Seastar (*Asterias amurensis)*	Southern Australia	Japan, Korea, far Eastern Russia and North China	consume the handfish's endangered eggs.	
8.	Zebra mussel (*Dreissena polymorpha*)	northern and western Europe, including Baltic Sea, Ireland and the eastern part of North America	Black Sea	Cause serious infrastructure and vessel fouling issues.	(David and Gollasch, 2015a).
9.	European green crab (*Carcinus maenas)*	Southern Australia, the United States, South Africa and Japan	European Atlantic coast	eats gastropods like clams, mussels, oysters, and mussels.	
10.	Toxic algae (red/green and brown tides) various species			Filter-feeding shellfish and fish	Castro *et al.* 2010).



Cholera (*Vibrio cholera*)

Asian Kelp (*Undaria pinnatifida*)

Cladoceran Water Flea (*Cercopagis pengoi)*



Round goby (*Neogobius melanostomus)*

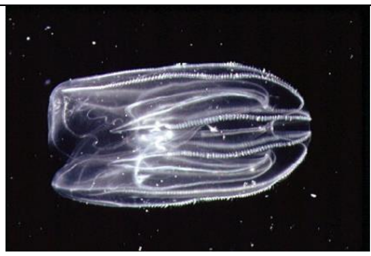
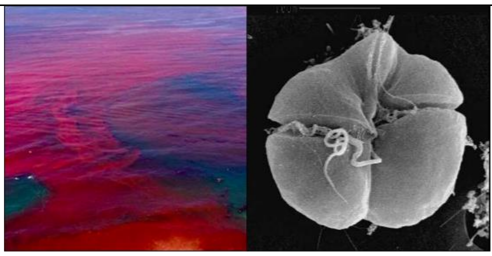
		
Chinese mitten crab (*Eriocheir sinensis)*		North American comb jelly (*Mnemiopsis leidyi)*
		
North Pacific Seastar (*Asterias amurensis)*		Zebra mussel (*Dreissena polymorpha)*
		
European green crab (*Carcinus maenas)*		Toxic algae (*Karenia brevis*)

Figure-2: Examples of invasive species (Source: The Internet)

Conclusion:

Ballast water is a significant vector for the introduction and spread of AIS around the world. The impacts of AIS can be severe, leading to ecological, economic, and public health impacts. The BWM Convention and other regulations and guidelines provide a framework for handling ballast water. However, effective ballast water management requires a coordinated and collaborative effort between stakeholders, including governments, shipping industries, and scientific communities. By implementing effective management strategies, we can minimize the risks associated with ballast water and protect the health and integrity of aquatic environments worldwide.

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Nanobionics: A novel approach to harvest solar energy

P. C. Pradhan[1], M. P. Chaudhari[1], Ashish Khandelwal[2]

[1]*College of Agriculture, S. D. Agricultural Universty, Tharad, Gujarat*
[2]*ICAR-Indian Agricultural Research Institute, New Delhi*

Introduction

Bionics is the application of biological methods and systems found in nature to the study and design of engineering systems and modern technology. Nanobionics is the interface of nanotechnology and biology.

Chloroplasts are the ultimate source of chemical energy in food supplies and carbon-based fuels on the planet. By capturing atmospheric CO_2, these plant organelles convert light energy into three major forms of sugars that fuel plant growth: maltose, triose phosphate, and glucose. The interface between plant organelles and non-biological nanostructures has the potential to impart organelles with new and enhanced functions. Photosystems interfaced with nanomaterials are extensively studied, but nanoengineering chloroplast photosynthesis for enhancing solar energy harnessing remains unexplored.

Nanobionics has the potential to enable new and enhanced functional properties in photosynthetic organelles and organisms for the enhancement of solar energy harnessing and biochemical sensing. The chloroplast contains densely stacked arrays of light- harvesting proteins that harness solar energy with maximum glucose conversion efficiency. The high stability and unique chemical and physical traits of nanomaterials have great potential. It enables chloroplast-based single-walled carbon nanotubes (SWNTs) to absorb light over a broad range of wavelengths in the ultraviolet, visible and near-infrared spectra which is not captured by the chloroplast antenna pigments. The electronic bandgap of semiconducting SWNTs allows them to convert this absorbed solar energy into excitons[1] which transfer electrons to the photosynthetic machinery.

The high stability and unique chemical and physical traits of nanomaterials have the potential to enable chloroplast-based photocatalytic complexes both ex vivo and in vivo with enhanced and new functional properties. Single-walled carbon nanotubes (SWNTs) embedded within chloroplasts have the potential to enhance the light reactions of photosynthesis with their distinctive optical and electronic properties. Under bright sunlight, chloroplast photosystems capture more photons than they can convert into electron flow. However, under non-saturating light conditions, maximizing solar energy capture is crucial. SWNTs absorb light over a broad range of wavelengths in the ultraviolet, visible and near-infrared spectra not captured by the chloroplast antenna pigments. The electronic bandgap of semiconducting SWNTs allows them to convert this absorbed solar energy into excitons that could transfer electrons to the photosynthetic machinery. Also, SWNT-based nanosensors can monitor single-molecule dynamics of free radicals within chloroplasts for optimizing photosynthetic environmental conditions.

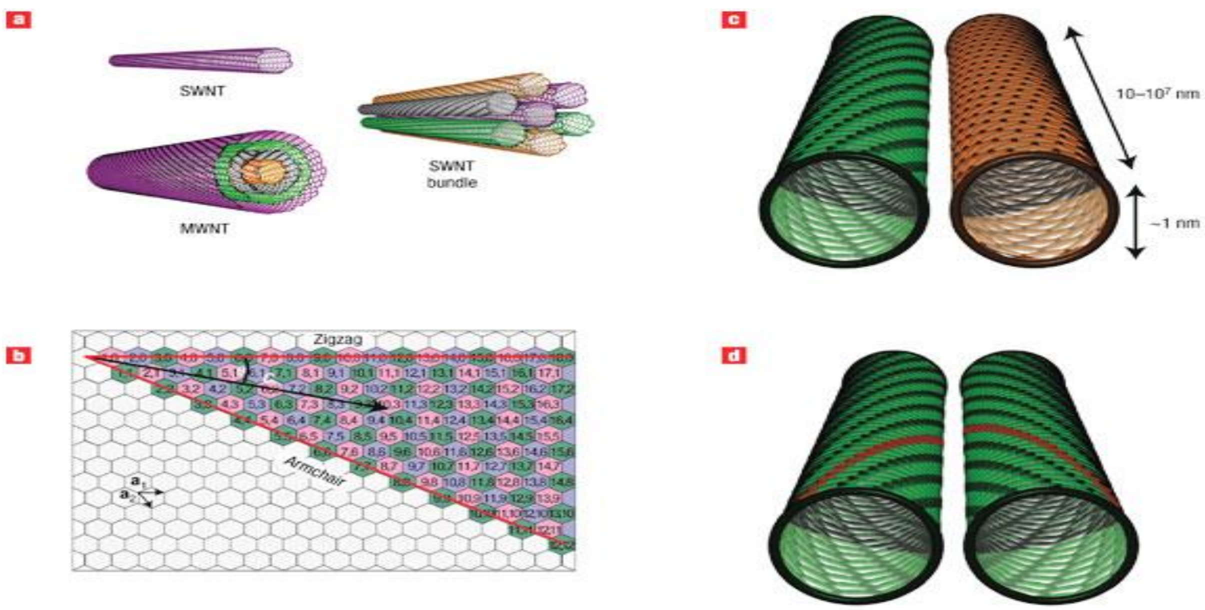

Figure 1. Various type of single and multiwalled carbon nanotubes

Chloroplasts have natural biochemical pathways to scavenge reactive oxygen species and mechanisms for photosystem proteins to self repair[2]as per the need. Cerium leakage, from dextran nanoceria particles which are not able to penetrate the chloroplast outer envelope, promotes only minor scavenging of photogenerated reactive oxygen species (ROS)[3]. SWNT-based nanosensors can monitor single-molecule dynamics[3] of free radicals within chloroplasts for optimizing photosynthetic environmental conditions. SWNT real-time sensing of nitric oxide (NO) in extracted chloroplasts and leaves could also be extended to detect a wide range of plant signalling molecules and exogenous compounds such as pesticides, herbicides and environmental pollutants.

Nanobionic Products

Nanobionic Products are intelligent, dirt free, ultrafine and breathing coatings. The nanobionic coatings are durable and only be destroyed by mechanical means. Nanobionic coatings are not visible and at the same time UV-stable, scratch proof, temperature resistant and retain their gloss.

Conclusion

Nanotechnology has the potential to enable new and enhanced functional properties in photosynthetic organelles and organisms for the enhancement of solar energy harnessing and biochemical sensing.The development of nanobionic plant are facilitated by the passive assembly of high-zeta-potential nanomaterials within the chloroplast photosynthetic machinery via kinetic trapping by lipid exchange.Semiconducting SWNTs delivered by this spontaneous mechanism have the potential for increasing chloroplast carbon capture by promoting chloroplast solar energy harnessing and electron-transport rates. Future studies will explore the effect of nanoparticle assemblies on the carbon reactions of photosynthesis and chloroplast sugar export.

Nanomaterial enhancement of isolated chloroplast stability to free radicals and higher photosynthetic efficiencies opens the possibility of creating hyperstable synthetic materials that grow and repair themselves using sunlight, water and carbon dioxide. SWNT real-time sensing of NO in extracted chloroplasts and leaves could also be extended to detect a wide range of plant signalling molecules and exogenous compounds such as pesticides, herbicides and environmental pollutants.

Nanomaterials offer a promising way to engineer plant function, but the absorption, transport and distribution of nanoparticles within photosynthetic organisms remain poorly understood. This nanobionics approach to engineer plant function will lead to a new research field at the interface of nanotechnology and plant biology.

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Bio fortification for zinc in rice

Kasiammal T, Ibrahim S M, Jeyaprakash SP, Deepika C and Nagalakshmi RM*

*Coresponding author: rmnagalakshmi@gmail.com

Introduction

Rice is one of the staple food crops across the world particularly in Asia. Nutritional enhancement in such widely consumed crop will have a significant impact on the health of the public. Several high yielding varieties have been released in rice, but nutritional enhancement is less concentrated. Most of the high yielding varieties lack micronutrients such as iron and zinc. So there is urgent need to develop biofortified rice varieties. India is the second largest producer of rice. About 46 million hectares of land in India is cultivated with rice with production of 104.99 million tonnes in the year 2021-2022. Domestic consumption of milled rice is about 109 million tonnes in 2022 in India. Iron and zinc content in rice is 0.2-2.8 mg/kg and 0.6-2.3 mg/kg respectively. The high yielding varieties developed after 1966 has low micronutrients. Research in rice biofortification is aimed at high iron rice, low phytate rice, high zinc rice, and high carotenoid rice (golden rice) varieties. Rice itself has low micronutrients but the processing of rice into polished rice further reduces nutrient content. Rice processing means removal of hull and husk to get white rice. The milling process of rice destroys 67% of vitamin B3 , 80% of vitamin B1, 90% of vitamin B6 and 50% of magnesium and phosphorous and 60% of iron[1]. Brown rice is highly nutritious and contains low calorie and low fibre but polishing of brown rice into white rice removes all those nutrients and vitamins.

Zn Deficiency

Zinc deficiency is a major problem that is increasing globally. Average human needs daily intake of 15 mg zinc content .about 17% of the world population is affected by zinc deficiency. In India, about 50 million population is affected by zinc deficiency and it is responsible for 2.1 million deaths among Indian children (< 5 years).[2] Zinc deficiency causes weight loss, hair loss, loss of appetite, eye disorders and poor skin health. According to world health organization, zinc deficiency is the fifth most important factor for illness. According to study conducted by Harvard TH Chan school of public health, India will have 50 million zinc deficient people in the world in 2050.

The process of improving the nutritional quality of food crops is known as bio fortification. Biofortification increases nutrient content through conventional breeding and modern bio technological approaches. Agronomic biofortification is done by supplying mineral fertilizers to the standing crop. Biofortification for rice with iron is started in 1992 and that with zinc is started in 1995.[3]

Consultative Group on International Agricultural Research (CGIAR) in 1991 started developing biofortified micronutrient dense crops because of globally increased micronutrient deficiency given by international nutrient community. CGIAR launched harvest plus challenge program to develop biofortified crops which includes wheat, rice, maize and cassava.[4]

During 2007, harvest plus program was initiated in India. Zinc content of more than 28mg/kg is set as target by harvest plus program.[5] Zinc content is estimated through x–ray fluorescence spectroscopy (XRF) equipment. Germplasm and mapping population zinc content is estimated through X- ray fluorescense spectroscopy leads to the successful development of zinc biofortified rice varieties. In 2017 and 2018 four zinc biofortified rice varieties were released. They are DRR Dhan 45, DRR Dhan 48, DRR Dhan 49 and Surabhi with zinc concentrations of 22.30, 20.91, 26.13 and 22.84 mg/kg.[6]

Apart from developing Zinc biofortified rice varieties, the zinc content of rice grains can be improved by agronomical practices too, which is called agronomical biofortification. Foliar application of zinc increases 65% bioavailability of zinc in rice. Foliar application of zinc increases the grain zinc content to 5 mg/kg.

Challenges in Biofortication

Agronomic biofortification causes toxicity if the mineral fertilizers are applied in large amounts. Poor rural populations have limited access and resources to purchase biofortified rice and increases the production cost. Developing biofortified varieties without affecting yield is a difficult breeding task.

Bio fortification of rice with zinc is needed for countries which have rice as a staple food crop. India coordinated with IRRI and developed biofortified zinc varieties to lower zinc malnutrition among Indians. However there is lot of challenge in bring biofortified varieties under cultivation but it is believed that bio fortified varieties bring huge impact on nutritional security throughout the world.

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Melatonin: A green biomolecule for postharvest management of fruits and vegetables

Sajeel Ahamad*[1], Vivek Saurabh[1], Vinod B R[1], Menaka M[1], Ganesh Kumar Choupdar[1] and Maneesh Kumar[2]

[1]Division of Food Science and Postharvest Technology, ICAR-Indian Agricultural Research Institute, New Delhi 110012, India

[2]Ph.D. Research Scholar, Department of Horticulture, G.B. Pant University of Agriculture & Technology Pant Nagar, U.S. Nagar, Uttarakhand, India

Coresponding author: sajeelahamad04@gmail.com

Abstract

The postharvest management of fruits and vegetables is a critical challenge due to their inherent susceptibility to various biotic and abiotic stresses, as well as the rapid onset of senescence. Melatonin, a naturally occurring biomolecule, has emerged as a promising solution in this domain. This article explores the multifaceted role of melatonin in postharvest fruit and vegetable management. Melatonin, with its potent antioxidant properties, effectively combats oxidative stress, decay-causing microbes, and mechanical damage. It extends the shelf life of produce by curbing ethylene production and respiration rates, thus delaying senescence. Furthermore, melatonin positively influences fruit ripening processes, enhancing factors such as carotenoid accumulation, cell wall degradation, and volatile biosynthesis. The diverse applications of melatonin in alleviating chilling injury, enhancing fruit quality, and bolstering resistance to biotic and abiotic stresses are elucidated. While much progress has been made, further research is warranted to fully unravel the mechanisms underlying melatonin's efficacy and its potential to revolutionize sustainable postharvest management practices for fruits and vegetables.

Keywords: Shelf life, Fruit quality, Chilling injury, Decay control and Delay senescence

Introduction

Melatonin stands as a pervasive biomolecule, wielding diverse effects within the realm of the living world. Its ubiquity spans across a multitude of living systems, ranging expansively from the minute realm of microbes, such as bacteria, to the intricate tapestry of complex entities like humans, animals, and plants. In terms of its chemical constitution, melatonin emerges as N-acetyl-5-methoxytryptamine (Fig. 1), an indoleamine that bears structural resemblance to other indole amine compounds, including tryptophan, auxin, and serotonin, among others. Beyond its structural affinity with fellow indoleamine compounds, melatonin follows a comparable biosynthetic pathway to auxins, sharing a common precursor in the form of tryptophan. This pathway intertwines through various segments of plants, encompassing elements such as seeds, roots, bulbs, and fruits. Even the fruits, esteemed as a vital source of sustenance by humanity, have undergone scrutiny with regard to their melatonin content (Wang *et al.* 2020). Melatonin was first identified in dicotyledonous plants, where it serves as a potent radical scavenger

(Dubbels *et al.* 1995). As a safer alternative to harmful chemicals commonly used in commercial fruit postharvest management, melatonin effectively tackles significant challenges like chilling injury and fruit decay. By retarding ripening and senescence, melatonin also extends the shelf life of fruits and vegetables while preserving their quality.

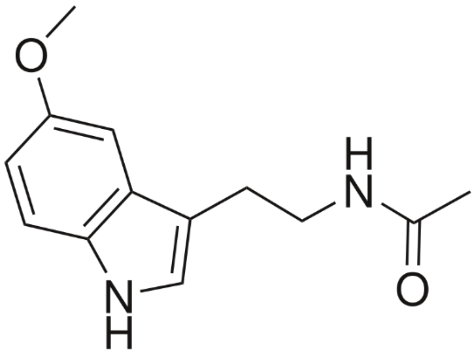

Figure 1. Chemical composition of melatonin

Biosynthesis of melatonin in plants

Within plants, the synthesis of melatonin occurs within both chloroplasts and mitochondria, with a predominant occurrence in the chloroplasts. This biosynthesis journey initiates from tryptophan, a key amino acid (Fig. 2). The first step involves the decarboxylation of tryptophan, leading to the formation of tryptamine. The subsequent stage witnesses the hydroxylation of tryptamine at the indole ring's 5th position, yielding 5-hydroxytryptamine, commonly known as serotonin. Moving forward, serotonin undergoes transformation into N-acetyl serotonin through the action of N-acetyl transferase in the third step. Ultimately, the culmination of this biosynthetic process results in the production of melatonin, facilitated by the participation of N-acetyl serotonin methyl transferase (Tan *et al.* 2020). Recent research has unveiled the potential existence of various pathways for melatonin biosynthesis, particularly in the conversion of serotonin to melatonin. There is ongoing discussion about how this conversion occurs in different ways. In the first proposed process, serotonin undergoes an initial acetylation, followed by O-methylation to generate melatonin (referred to as the NM pathway). Conversely, in the second scenario, serotonin is first O-methylated and subsequently acetylated to give rise to melatonin (known as the MN pathway). These emerging pathways highlight the intricacies of melatonin synthesis and underscore the need for further exploration in this domain.

Modes of action

Melatonin's potential mechanism of action likely involves its capacity to neutralize hydrogen peroxide and stimulate the production of antioxidant enzymes. This effect becomes instrumental in aiding plants' recovery from abiotic stresses. The antioxidative prowess of melatonin has been linked to its role in mitigating both biotic and abiotic stressors in plants. In response to biotic stress, melatonin is believed to trigger the activation of nitric oxide (NO) and salicylic acid (SA) mediated defense signaling pathways. This activation is achieved by prompting the immediate expression of pathogenesis-related proteins (PR-proteins), serving as a crucial component of the defense mechanism (Shi *et al.* 2015). Treatment with melatonin has been found to effectively reduce reactive oxygen species (ROS) activity. This reduction, in turn, leads to an increase in the production of antioxidant enzymes. This orchestrated response contributes to safeguarding fruit plants against a spectrum of both biotic and abiotic stresses (Xu *et al.* 2019). Research suggests that melatonin exerts regulatory control over salicylic acid, jasmonic acid, nitric oxide, and ethylene pathways. This intricate regulation collectively bestows plants with enhanced resistance against diseases. Intriguingly, the interplay between ethylene and jasmonate functions as a protective mechanism, effectively fortifying the plants' defense mechanisms or immunity.

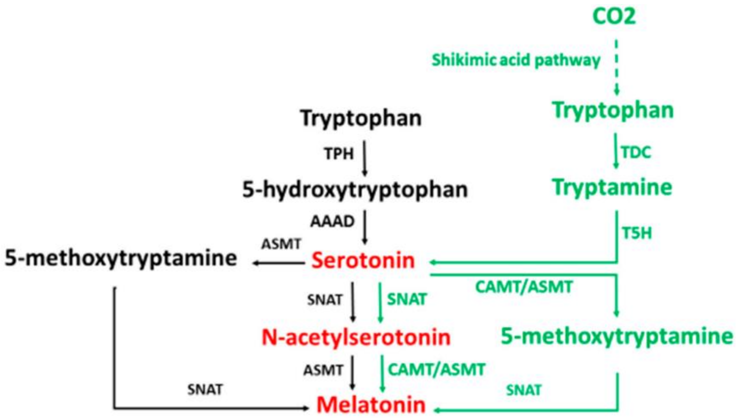

Figure 2. Biosynthesis of melatonin through tryptophan pathway

Functions of melatonin in fruit and vegetable crops

Melatonin boasts a widespread presence, showcasing diverse effects in both plant and animal realms. Within the plant domain, its functions span a broad spectrum, encompassing activities from seed germination and propagation to the eventual senescence phase (Tiwari *et al.* 2020). With a notable antioxidant potency, melatonin operates effectively in both aqueous and lipid environments, seamlessly traversing the plant system. Melatonin's significance is particularly pronounced in fruit and vegetable plants, where it plays pivotal roles in propagation, growth, and overall development (Wang *et al.* 2013).

Figure 3. Effect of melatonin treatment on capsicum (a: melatonin; b: control) and guava (c: melatonin; d: control) after 20 days of storage.

Its impact extends to fostering an extensive range of tolerance against various biotic and abiotic stresses, spanning not only standing crops but also carrying forward into the postharvest stage (Moustafa-Farag *et al.* 2020). The utilization of melatonin as a postharvest treatment to address diverse biotic and abiotic stresses remains relatively nascent. Currently, its application primarily centers around mitigating challenges like chilling injury, managing decay, and retarding senescence. These interventions play a crucial role in extending the postharvest lifespan of fruits and vegetables, consequently contributing to reduced losses within the produce industry.

Role of melatonin in postharvest management of fruits and vegetables

The postharvest losses in perishable commodities like fruits and vegetables are as high as 20–40 %, which occurs at various stages of postharvest handling such as harvesting, transportation, storage, and marketing. Hence, effective and efficient postharvest management strategies are inevitable during handling of fresh produce, which includes proper pre-cooling, sorting, grading, packaging and storage. Several postharvest treatments have been recommended for alleviating chilling injury, and reducing decay and ripening process which ultimately led to good shelf or storage life of the produce. During the recent years, some novel molecules such as 1-methylcyclopropene (1-MCP), nitric oxide (NO), salicylic acid (SA), brassinosteroids (BRs) have shown their potential in postharvest management of several fruits and vegetables (Jayarajan & Sharma, 2018).

Alleviation of chilling injury

Chilling injury (CI) stands out as a significant challenge encountered by tropical and sub-tropical fruits when stored at temperatures above freezing but still considered low. The occurrence of CI spans a wide range of low temperatures, contingent on the susceptibility of different crops and their solute concentration. This phenomenon leads to notable issues like severe pitting, textural deterioration, and mealiness in stored fruits, rendering them unsuitable for consumption. The postharvest application of melatonin has emerged as an effective strategy to mitigate CI without compromising the overall quality of the harvested fruits. This positive outcome has been observed in various fruits such as guava, capsicum, peaches (100 µM) (Cao *et al.* 2016), sapota (90 µM) (Mirshekari *et al.* 2020), and tomatoes (100 µM) (Agdham *et al.* 2019). Melatonin's ability to reduce CI can be attributed to its promotion of polyamine synthesis within treated produce. This effect is achieved by up-regulating key enzymes involved in polyamine synthesis, such as ornithine decarboxylase and arginine decarboxylase, and corresponding genes, a response brought about by melatonin treatment.

Decay control

Fruits, due to their high moisture content, are prone to microbial attacks, leading to decay post-harvest. Safeguarding them against microbial invasion, as well as physical damage like bruises, is essential. The application of melatonin, known for its potent antioxidant properties, has emerged as a promising solution. Melatonin effectively curbs decay by hindering the activities of various fungi, bacteria, and microbes. In addressing fungal pathogens, melatonin's impact was particularly examined against the soft rot (*Ervinia carotovora*) affecting capsicum (Fig. 3 a & b). The application of exogenous melatonin was found to mitigate green mold disease by quelling the activity of defense-related reactive oxygen species (ROS) in the infected fruits. This intervention showcased promising results in reducing the impact of the disease, as evidenced by research conducted by Lin *et al.* in 2019.

Extension in shelf life and delay in senescence

The limited shelf life of many fruits results from elevated rates of ethylene production and respiration, both of which hasten the onset of senescence post-harvest. These processes collectively diminish the market viability of fruits. While various techniques are employed to extend fruit shelf life, recent research highlights the significant role of melatonin in achieving this objective, all while preserving the sensory attributes (Fig. 3). For instance, in the case of broccoli heads treated with melatonin (100 μL/L), a pronounced enhancement in antioxidant activity was observed. This treatment also provided a protective effect on vitamin C and total carotenoid content. Notably, melatonin treatment delayed the yellowing of broccoli by an impressive 4 days compared to the control samples. This delay is of immense significance in the marketing of broccoli. Furthermore, melatonin-treated fruits exhibited elevated levels of bioactive components and displayed superior sensory quality in comparison to their untreated counterparts. Melatonin's positive impact was similarly demonstrated in pear fruits. Melatonin-treated pears exhibited delayed senescence, reduced ethylene production, and maintained superior firmness throughout storage when compared to control fruits (Zhai *et al.* 2018).

Fruit ripening and quality

Fruit ripening stands as a multifaceted process involving intricate physiological and biochemical transformations that render previously unappealing fruits palatable. This process encompasses various shifts such as softening of tissues, alteration in peel color, heightened respiration and ethylene emission rates, and modifications in sugar and organic acid metabolism. In the context of tomatoes, the regulation of ripening hinges on ethylene, with discernible changes encompassing the synthesis of carotenoids and lycopene, the conversion of starch into sugars, and the augmentation of enzymes responsible for degrading cell walls (Sun *et al.* 2015). The application of exogenous melatonin has exhibited a positive influence on controlling ethylene production and its signaling pathways. Consequently, this melatonin treatment facilitated postharvest ripening of tomato fruits. The outcomes included notable biochemical shifts such as the accumulation of lycopene and carotenoids, the degradation of cell walls, and the synthesis of volatile compounds. These changes collectively contributed to the desirable transformation associated with fruit ripening.

Conclusion

Melatonin is an incredible signaling molecule, involved in plethora of biochemical mechanism in plants. The quantification of melatonin in various crops revealed that its level varies from place-to-place, species-to-species, time-to-time and even within the same plant grown at different agroclimatic conditions. Being an antioxidant, it plays an inevitable role in mitigation of both biotic and abiotic stresses in plants. In the lights of the reviewed literature, it clearly elucidates that exogenous application of melatonin addresses the major postharvest-related issues such as chilling injury and fruit decay. It also delays senescence in various horticultural crops, and thereby helps in extending the shelf life without adversely affecting nutritional quality.

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Prospects and challenges of processing potato in India

Neeraj Kumar[1], Brijesh Kumar Yadav[2], Bhupendra Sagore[3]

[1]*MSc. Scholar, Division of Vegetable Science, OUAT, Bhubaneswar*
[2]*Ph.D. Scholars, Division of Post Harvest Technology, ICAR-IARI, New Delhi-110012*
[3]*Ph.D. Scholars, Division of Fruit and Horticulture Technology, ICAR-IARI, New* Delhi-110012

Mail id: nk49660@gmail.com, bkybhu98@gmail.com, sagorebhupen@gmail.com

Abstract:

Due to rapid urbanisation, industrialisation, and economic liberalisation, there are greater prospects for expanding the commercialization of indigenous varieties of potatoes with potential for contributing to food security. Being a significant component of diets, potatoes are used as a fundamental ingredient in ready-to-eat vegetables, which is seeing rising demand and market success. In order for India to become self-sufficient in food and nutrition, processing potatoes shows to be a crucial alternative. This could aid farmers and producers in choosing and cultivating the precise potato varieties needed to meet consumer demand. In order to promote the sustainable development of processed goods with improved nutritional and organoleptic properties, the current study was designed to raise awareness for the cultivation of improved processing potato varieties rather than table varieties. The goal of the present study was to take into account the importance of potato cultivation in relation to producer, processor, and consumer demand, which should be a major focus of future marketing research. Potato processing accounts for a significant portion of production costs and has an impact on productivity.

Introduction:

Potatoes are an inexpensive staple food that is a source of energy, modest amounts of high-quality protein, dietary fiber and, are good source of vitamin C, potassium, and other key micronutrients (FAO, 2008). Demand of fresh potatoes in the year 2010 was 19.78 kg per capita and 23.94 million tonnes was the national demand which is expected to increase to 48.47 kg and 78.47 million tonnes, respectively by the year 2050. Potatoes are processed into number of products including potato starch, fermented into alcoholic beverages, pharmaceutical, textile, paper, protein, fuel, alcohol, bioactive polyphenols, micronutrients and fiber. The demand for processing quality potato is expected to rise to 25 million tonnes by the year 2050. Demand for raw material for potato processing was 2.45 million tonnes for chips, 0.29 million tonnes for potato flakes/powder and 0.06 million tonnes for frozen potato products in the year 2010, which is expected to increase to 14.22, 5.44 and 5.40 million tonnes respectively, in the year 2050 (CPRI, Shimla).

Health Benefits of Potato & Potato Products:

- Potato products can provide protection against acute liver injury and oxidative damage to erythrocytes (Singh *et al.* 2008).
- Potatoes with lower GI are good for diabetic patients and may even decrease the risk of type II diabetes.
- Chlorogenic acid has strong antioxidant activity and potatoes are an excellent source of this.
- Anthocyanidins, delphinidin, pelargonidin, petunidin and malvidin inhibited MCF-7 breast cancer cell cultures.
- Folate deficiency is associated with the increased risk of some cancers and cardiovascular diseases (Bailey *et al.* 2003).
- Coloured potato extracts and an anthocyanin rich fraction have been reported to suppress lymph-node carcinoma of the prostate and prostate cancer-3 prostate cancer cell proliferation (Reddivari *et al.* 2010).
- Because of high carotenoids content potatoes are particularly beneficial for eye health (Tan *et al.* 2008).
- Anthocyanins function as antioxidants and are known to prevent diseases such as cardiovascular diseases, cancer and diabetes (Konczak and Zhang, 2004).
- Several other health promoting (longevity, heart and eye health) and therapeutic (antibacterial, anti-inflammatory, antiallergic, antimutagenic, antiviral, antineoplastic, antithrombotic, and vasodilatory activity) of phenolics has been reported (Manach *et al.* 2004).

Need for processing of potato:

The glut years are followed by a reduction in potato area in the following year and the boom-and-bust cycle continues. Therefore, it is essential that potato consumption is increased to sustain this increase in production and to ensure remunerative prices to the farmers. Under the existing circumstances, processing of the bulky perishable potato into various processed products is a viable option which can help to extend the shelf-life, save the wastage of precious food during gluts, solve the problem of storage, cater to consumer preferences belonging to different age groups and social strata and serve as a means to increase the supply in off seasons thus maximizing the potato utilization (Marwaha *et al.* 2006). The demand for processed potato products like chips, French fries, flakes, etc is increasing continuously in the present liberalized economy mainly due to improved living standard, increased urbanization, preference for fast foods, rise in per capita income, increase in the number of working women preferring ready cooked food and expanding tourist trade. To meet this demand potato processing industry is emerging as a fast-growing industry with more entrepreneurs joining and existing ones increasing their capacity of processing units. In spite of this recent spurt, both organized and unorganized Indian processing industries presently consume about 4% of the total potato produce in the country as compared to about 30–67% in developed European countries and North America (Rana and Pandey 2007). Need for processing of potato are as follows:

- Year-round supply of potato products
- Reduction of post-harvest losses

- Food and nutritional security
- Improving the standard of living
- High amount of dry matter, edible energy and low amount of edible protein
- Ensure lucrative returns
- Hunger and malnutrition free India

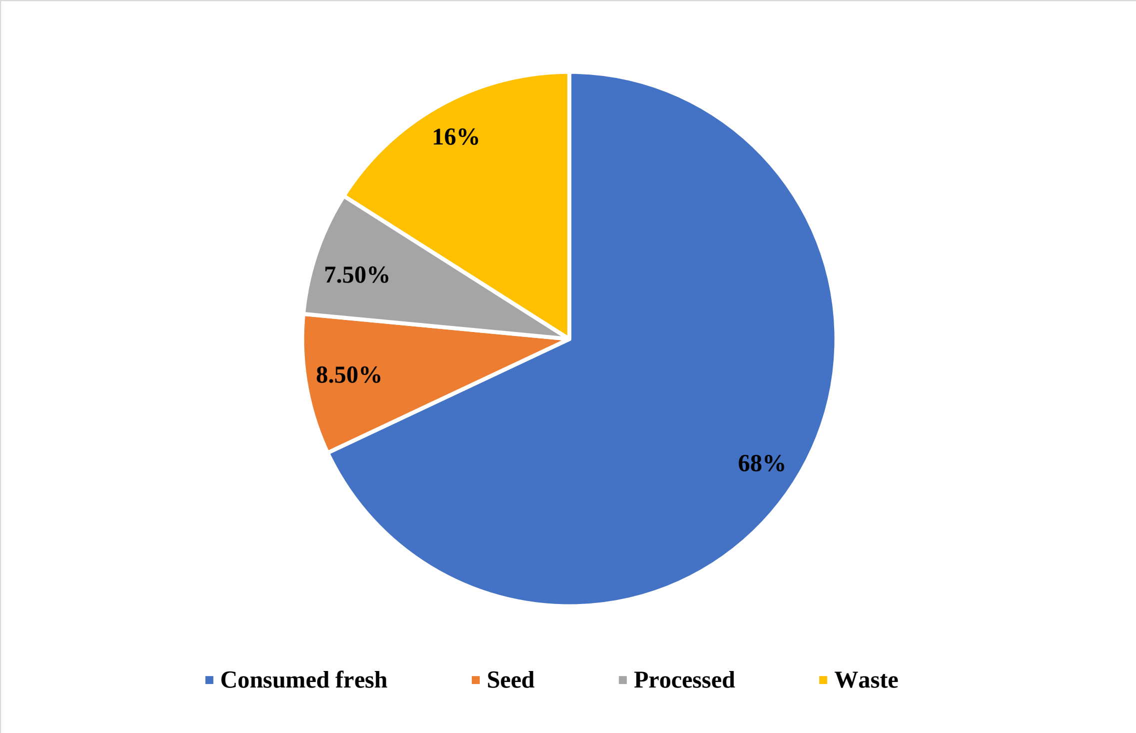

Figure 1. Consumption pattern of potato produced in the country (Source: CPRI, Shimla)

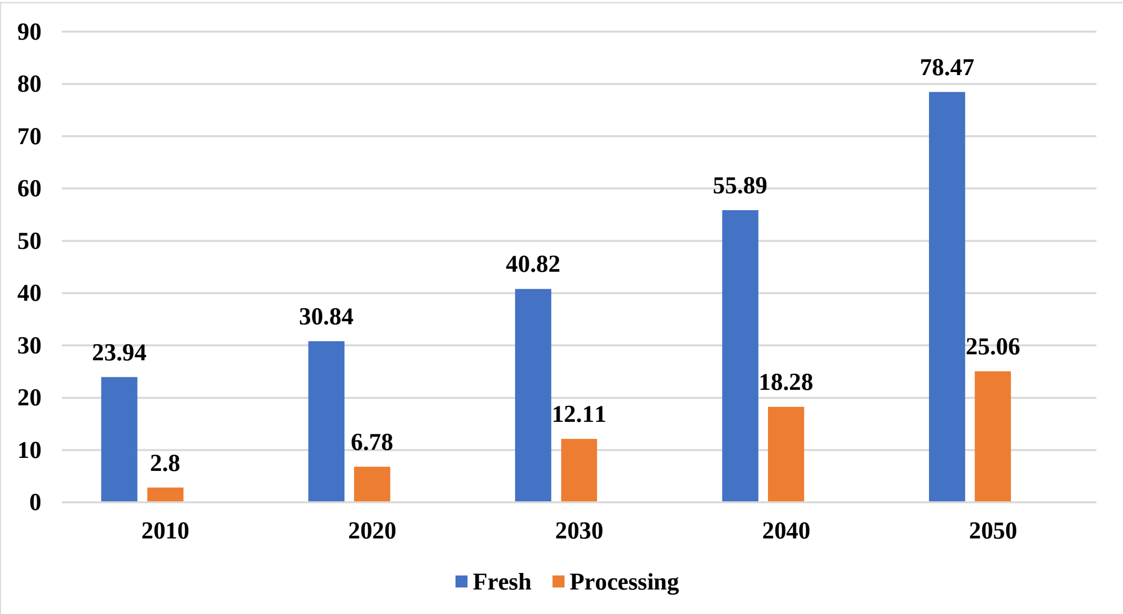

Figure 2. Demand for fresh and processed product over the year potatoes (in million Tonnes) (Source: CPRI, Shimla)

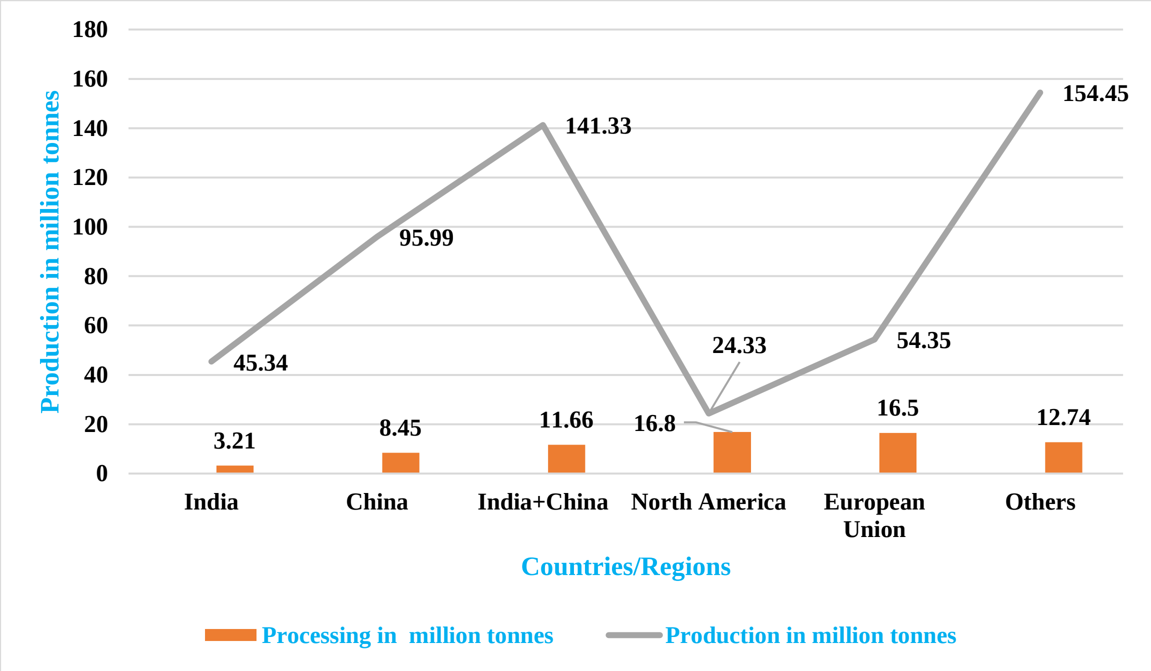

Figure 3. Total production and Total processed product in different countries (Sources: CPRI, Shimla)

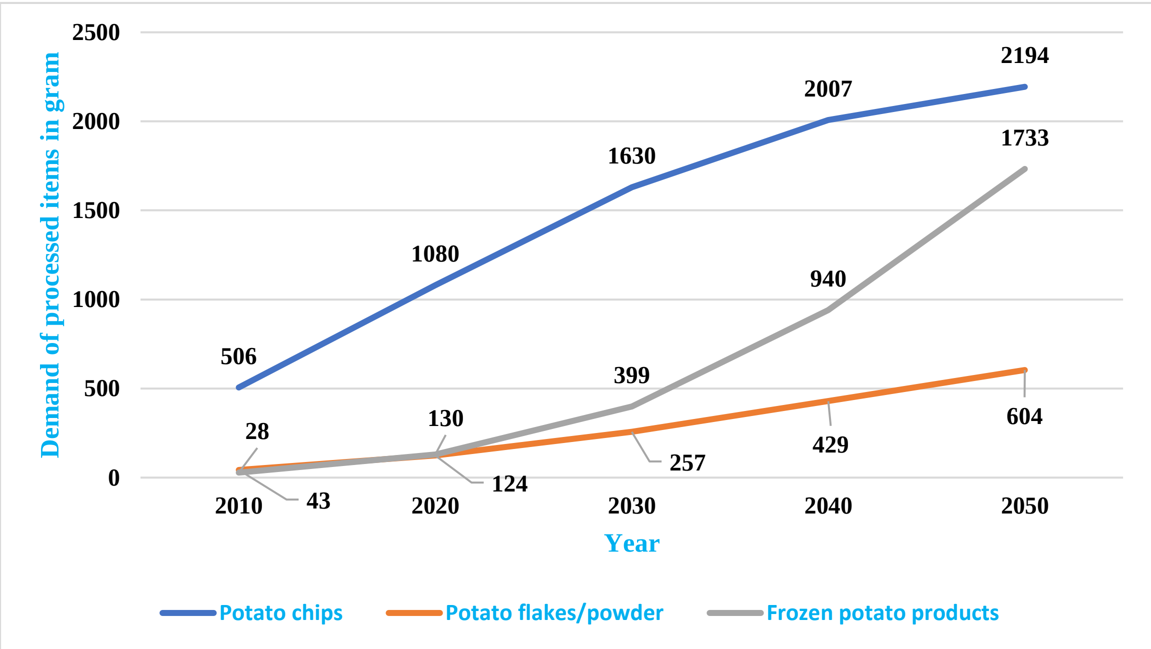

Figure 4. Demand trend for different processed items (Sources: CPRI, Shimla)

Table 1. Desirable quality characteristics for processing:

S.No.	Characters	Dehydrated	French fries	Chips	Canned
1	**Tuber shape**	Round to oval	Oblong	Round to oval	Round to Oval
2	**Tuber size (mm)**	>30	>75	45-80	20-35
3	**Eyes**	Shallow	Shallow	Shallow	Shallow
4	**Specific gravity**	1.080	1.080	>1.080	<1.070
5	**Dry matter (%)**	>20	>20	>20	<18
6	**Reducing sugar (% fresh weight)**	0.25	0.15	<0.1	0.5
7	**After cooking discoloration**	Slight	Slight	-	Nil
8	**Texture**	Fairly firm to mealy	Fairly firm	Fairly firm to mealy	Waxy

(Marwaha *et al.* 2010)

Quality of Indian processing varieties and suitability for different processed products:

All the indigenous processing varieties viz., 'Kufri Chipsona-1', 'Kufri Chipsona-2', 'Kufri Chipsona-3' and 'Kufri Himsona' contain 21–24% dry matter, <0.1% reducing sugars on fresh tuber weight basis, low phenols and glycoalloids and produce high yields of light-coloured chips. Large tubers of these varieties produce high yield of French fries having mealy texture and are highly acceptable. Besides fried products, these processing varieties also produce higher yield of dehydrated products such as dehydrated chips, flour, flakes, and starch in comparison to table varieties. Indigenous processing varieties yields 30-40 t/ha and are resistant to late blight, while kufri chipsona-2 and Kufri Himsona also have tolerance to frost. Among processing varieties Kufri Chipsona 3 produces 11-15 % more total and processing grade tuber yields when compared to other processing and table varieties. This attribute will enhance the profit of farmers and give them greater freedom in selling the produce to the processor or to the ware market, depending upon the prices.

Based on tuber morphological and biochemical characters and quality evaluation tests, varieties and advanced processing hybrids suitable for making different processed products were identified:

Challenges of processing potato in India:

The challenges of processing potato in India are as follows:

- Arranging round the year supply of processing varieties to the industries
- Developing suitable varieties for French fries
- Developing early maturing processing varieties
- Developing inexpensive technologies for the production of diverse potato products
- Developing temperature insensitive processing varieties
- Breeding varieties resistant to cold sweetening
- Zone specific breeding for processing varieties.

- Providing low calories, antioxidant rich fried products to the consumers at affordable price.
- Developing yield and quality enhancing technologies in processing varieties.
- Finding low-cost alternative storage technology for processing potatoes.
- Improving infra-structure facilities for frozen fried potato products.

Table 2. Biochemical traits and suitability of Indian processing varieties:

Varieties	Dry matter (%)	Reducing sugars (mg/100 g FW)	Suitablity for products
Kufri Chipsona-1	21-24	45-100	Chips, French fries, Flakes, Flour, Dehydrated products
Kufri Chipsona-2	21-25	45-95	Chips, Flakes, Flour, Dehydrated products
Kufri Chipsona-3	21-24	50-70	Chips, Flakes, Flour, Dehydrated products
Kufri Himsoan	22-26	45-65	Chips, Flakes, Flour, Dehydrated products
Kufri Frysoan	21-23	80-100	French Fries

(Source: CPRI, Shimla)

Conclusion:

There is a huge scope of processing in potato crop. Some health-related problems associated with the processed products these can be overcome by the food safety standards. Processed value-added products have the huge market demand with enhanced market value as compared to fresh potatoes used for table purpose which can improve the income of the farmer and uplift the living standard and can definitely be the important milestone in the endeavour of doubling the farmer's income. Situation can be improved by increased investment in the food processing industry. There is huge potential for the development of the processing industry at the farm level as these do not require expertise and sophisticated machinery. Apart from these, Thus, value addition in potatoes is definitely going to occupy a larger share in the Indian GDP in the days to come and there is a huge potential considering the present international trade scenario. If these items can be produced at the village level, then import can be reduced substantially.

Future thrust:

Potato is mostly recognized as a starch rich vegetable and are less recognized for their contribution to overall dietary fiber or micronutrients including Ca, K, Mg, Fe, and Mn as well as vitamin C. Information on the availability of potato nutrients and phytochemical remains limited mainly to preclinical models and limited clinical studies. There is still a misconception about the health-related issues like obesity, diabetes which is hampering the processing sector and peoples' choice for these products, which requires improved awareness about lies related to potato nutrition. There is an immediate need for the development of those varieties that are processing friendly suitable in Indian climatic condition.

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Pulsed Light - A Novel Technology in Fruit and Vegetable Preservation

Vinod B. R*, Menaka M and Gouthami Shivaswamy

PhD Scholar, Division of Food Science & Postharvest Technology, ICAR- IARI, New Delhi

**Corresponding author: vinodbr0026@gmail.com*

Abstract

Pulsed light emerges as a promising novel approach for postharvest preservation due to its non-thermal nature, which minimizes nutrient loss and maintains product quality. This technology harnesses intense, short bursts of light to inactivate spoilage microorganisms and pathogens, thus extending shelf life and reducing the need for chemical treatments. Pulsed light treatment affects microbial cells by inducing damage to cell membranes, proteins, and DNA, enhancing food safety. Moreover, its non-chemical and eco-friendly nature aligns with the growing consumer demand for sustainable food preservation methods.

Keywords: Ultraviolet radiation, Non-thermal technology, Microbial inhibition, Preservation

Introduction

Food consumption and its priorities have evolved in tandem with human evolution. The consumption of processed foods is increasing as a result of lifestyle changes, particularly in urban areas. Traditional thermal-based food-processing techniques like appertization, pasteurisation, and canning processes are effective for microbial inactivation but, they also cause undesirable changes in the food matrix, such as structural changes in proteins and polysaccharides, affecting food functionality, flavour, textural softening, and the breakdown of colours and vitamins. Consumers' desire for fresh, natural, and minimally processed fruits and vegetables of higher quality have been increased in recent years. To solve this, scientists are working on many novel non-thermal alternative procedures. Pulsed light processing is one such emerging technology.

Pulsed light (PL) is a non-thermal technology that uses high-intensity light pulses for a brief period of time to decontaminate foods like fruits, vegetables, juices, milk and meat products (Figure 1). The PL covers a range of wavelengths from 200 to1100 nm, including ultraviolet (200–400 nm), visible (400–700 nm), and near-infrared region (700–1100 nm).

Working principle

The non-thermal approach enables the development of pulsed light with gradually rising energy from low to high and then discharging the concentrated form of energy as intense broad-spectrum pulses (light) to assure microbiological decontamination on fruit surfaces and packaging material. The electromagnetic energy is held in the capacitor for a fraction of a second before being released as light (pulses) in a hundred-millionths of a second, resulting in power amplification with minimal additional energy usage. Each pulse has 20,000 times the intensity of sunlight at sea level and each pulse lasts only a few billionths of a second which results in high peak power. The effectiveness of pulsed light inactivation is determined by the intensity (Joule cm^{-2}) and the number of pulses emitted.

Components and Generation

PL system consists of three main components: the power supply, high power storage capacitor and a xenon flash lamp (Fig. 1). When a high voltage, high-current electrical pulse is subjected to the xenon gas in the flash lamp, leads to ionisation, and the formation of plasma near the anode as electrons flow towards it. A huge current pulse is generated and transmitted through the ionised gas, forcing the electrons around the gas atoms and driving them to leap to higher energy levels. While returning to their lower energy levels, electrons emit quanta of energy, resulting in photons. These broad-spectrum photons are stored in a capacitor for a fraction of a second and released in the form of light within a short time targeting the samples. Pulsed light used in fruit processing applications generally generates 1-20 flashes/sec with energy ranging from 0.01 to 50 J cm^{-2} of surface area.

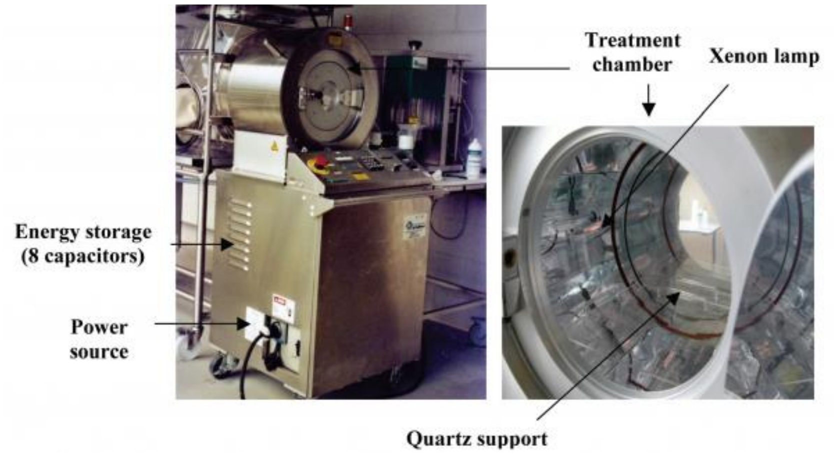

Figure 1. Pulsed Light System (Top: Industrial Scale; Bottom: Laboratory scale)

Mode of Action

Pulsed Light's lethality can be linked to its strong broad-spectrum UV content, short duration, high peak energy, and ability to control the pulse duration and frequency output of flashlights. As ultraviolet light makes up a large part of the PL spectrum, it plays an important role in microbial cell inactivation. It was also discovered that using a filter to exclude ultraviolet (UV) wavelengths less than 320 nm has no effect on microbial inactivation. Mainly there are three modes of action, which are as follows (Bhavya & Hebbar, 2017).

A) Photo Chemical Mechanism:

As DNA is the target cell for these UV wavelengths, nucleic acid is the primary target cell of PL in the photochemical mechanism. As it modifies the DNA and RNA structures, ultraviolet light absorbed by conjugated carbon-carbon double bonds in proteins and nucleic acids generates an antimicrobial effect. The bactericidal effect is linked to the high energy short wave ultraviolet-C spectrum. Changes in DNA occur in the ultraviolet-C range of 250-260 nm due to pyrimidine dimers, primarily thymine dimers. These dimers prevent the creation of new DNA chains during cell replication, resulting in chlorogenic death of afflicted pathogens by ultraviolet. Experiments showed that enzymatic repair of DNA does not occur after it has been damaged by pulsed light.

B) Photo Thermal Mechanism:

Pulsed light can potentially be lethal due to the photothermal effect. At fluences greater than 0.5 joule/cm^2, sterilization is achieved through bacterial rupture induced by absorption of all UV radiation from a flash lamp. The ruptured apex of the spore revealed the escape of an overheated spore content, which became empty after such an internal "explosion" and "evacuation" of its content occurred during the light pulse (Fig. 2).

(C) Photo Physical Mechanism:

The pulsing action of high-intensity light causes the photophysical effect. In pathogens, high-intensity pulses cause membrane disruption, vacuole enlargement, protein elution, and structural damage.

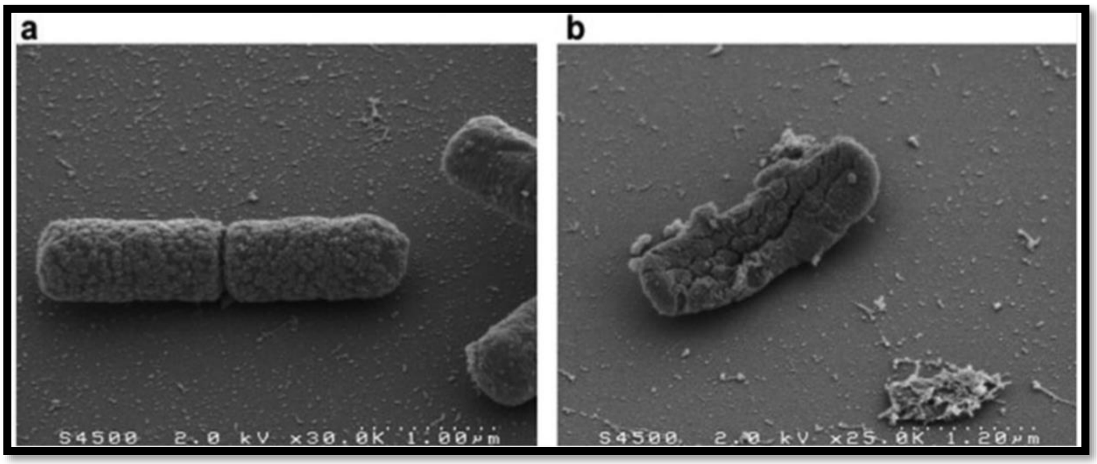

Figure 2. Scanning electron microscopy of ground black pepper inoculated with Bacillus subtilis vegetative cells: (a) untreated samples; (b) treated by PL at 1 J/cm^2/flash (Nicorescu et al. 2013)

Practical application in fruits and vegetables

The primary goal of PL treatment of fruits and vegetables is to achieve microbial reductions and have an influence on the quality characteristics of the respective products. PL treatment is successfully used for surface decontamination of many fresh and minimally processed fruit and vegetables like tomato, apple, plum, raspberry, strawberry, blueberry, fresh cut melon, fresh cut mushroom, fresh cut avocado, fresh cut watermelon, fresh cut mango, spinach, celery, lettuce, cabbage, green onion, etc. (Table 1 & 2).

- Surface disinfection
- Decontamination of liquid food (RTS, Squash, Cordial)
- Reduces browning and oxidation effect on minimally processed products
- Enhance antioxidant and polyphenol content
- Maintains ascorbic acid content
- Enhance lycopene and carotenoid content
- No impact on Total soluble solids (TSS), sugars and pH
- Maintain firmness and sensory attributes

Table 1: The effect of PL treatment on surface decontamination of fresh and processed fruit and vegetable products

Product	Microorganism	Treatment	Log reduction
Apple juice	*Escherichia coli* ATCC 25922 *E. coli* O157: H7	Frequency 3 pulses/s and pulse width 360 µs: Fluence 12.6 J/cm^2	2.66 log CFU/ml 2.52 log CFU/ml
Orange Juice	*E. coli* *Listeria innocua*	Fluence of 6 J/cm^2	2.02 log CFU/g 1.77 log CFU/g
Plum	*Bacilus. cereus*	Duration of the light pulse was 112 µs, frequency 5 Hz: UV light dose 5.4 J/cm^2	1.4 log CFU/g
Blueberries	*E. coli* O157:H7 *Salmonella*	The pulse rate of 3 pulses/s and pulse width of 360 µs for 5–60 s: PL fluence of 5–56.1 J/cm^2	3.8-6.7 log CFU/g 4.8-5.7 log CFU/g
Fresh cut Melons	*E. coli* *L. innocua*	Full spectrum (λ = 180–1100 nm): total fluence of 12 J/cm^2 The fluence of 6 J/cm^2	2.66 log CFU/g 2.02 log CFU/g

Table 2: The effect of PL treatment on quality aspects of fresh and minimally processed fruit and vegetables

Product	Effect on product quality
Strawberry	No significant impact on total phenolic, total anthocyanin, ascorbic acid content, antioxidant capacity, colour or firmness, and no significant differences in weight loss among untreated and treated fruits after storage
Tomato	No impact on ascorbic acid levels; an increase of polyphenols, total lycopene, α-carotene, and β-carotene contents, lycopene isomerization and bioaccessibility of lycopene, no impact on pH and TSS
Fresh cut Mangoes	Maintenance of firmness, colour, carotenoid, phenol, and total ascorbic acid content as well as Phenylalanine Ammonia-Lyase activity
Fresh cut Avocado	Improved colour maintenance due to PL; minimal peroxide formation of lipids and stable specific extinction coefficients at 232 and 272nm; high chlorophyll retention
Fresh cut apple	No increased browning or oxidation; maintenance of phenolic compounds, firmness and vitamin C. Maintenance of sensory attributes scores above rejection limits

Advantages and Disadvantages

Advantages	Limitations
• Retention of quality and nutrient content • Rapid disinfection • Lack of residual compound • Surface decontamination • Uses less energy • Eco-friendly • Highly effective for liquid foods and fruits & vegetables with smooth surfaces	• Effective penetration • Thermal effect in food powders • Foods with rough or uneven surfaces, crevices, or pores are unsuitable due to the shadowing effect • Not adequate for cereals, grains and spices due to its opaque nature

Conclusion

Pulsed light processing presents a groundbreaking method in the food industry as a non-thermal preservation strategy. While implementing pulsed light applications, it's crucial to consider the specific food type, pathogen characteristics, and load, as they influence the effectiveness of the treatment. Despite its limitations, when integrated with complementary processing techniques, this technology can contribute to improved food preservation with minimal effects on quality.

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Quorum Sensing System: A Serious Threat to Aquaculture

Narsale Swapnil[1*], Sourabh Debbarma[1], Patekar Prakash[2], Rishikesh Kadam[3]

[1] *Department of Fish Pathology and Health Management, Fisheries College and Research Institute, TNJFU, Thoothukudi- 628008, India.*
[2]*Fish Nutrition, Biochemistry and Physiology Division, ICAR-CIFE, Mumbai-400061.*
[3]*Department of Aquatic Environment Management, TNJFU, Thoothukudi- 628008.*
[*]*Corresponding author- narsaleswapnil72@gmail.com;*

Abstract

Infectious diseases pose serious risks to aquaculture in several countries. The virulence factors released by microbes that infect aquaculture systems and the development of biofilms, both of which are controlled by quorum sensing (QS), are directly connected to how adverse they are. As a result, QS disruption is a viable method for disease prevention in aquaculture systems. In addition to preventing the expression of genes linked to virulence, QS inhibitors (QSIs) also lessen the virulence of diseases that affect aquaculture. We investigate QS systems in significant aquaculture pathogens in this study, with a particular emphasis on the connection between QS mechanisms and bacterial pathogenicity in aquaculture. Further, clarify QS disruption tactics for diseases in the host that affect aquaculture.

Keywords: Quorum Sensing, Autoinducers, Cell-Cell Communication, Bacterial Diseases.

Introduction

One of the significant rising sectors during the last few decades is aquaculture. The world's population is expanding at an unmanageable rate, and technologies must be developed considering food security. To supplement the supply effect of the fisheries industry, aquaculture has developed. To meet the nutritional demands of customers everywhere, aquaculture is one of the most significant segments of the food supply chain. It is also one of the businesses that are growing the fastest. A significant amount of the human body's requirements for animal protein are met by fish protein, which is produced by aquaculture, the food sector with the greatest rate of development in the world. This business produces around 82.1 million tonnes of food yearly(Jayaprakashvel and Subramani, 2019). To fulfill the worldwide need for human nutrition, aquaculture output is thus growing daily. Aquaculture is thought to be intensifying, which might lead to issues with animal and ecological health. Disease outbreaks are a serious issue that negatively affects the production of aquaculture. Bacterial infections are the most prevalent cause of illness in fish and crustaceans, and they infect aquaculture species, causing a great deal of mortality. One of the major risks to commercial aquaculture is bacterial infections, which result in enormous economic losses. The losses resulting from bacterial illnesses are considerable, nevertheless, in both terms of capital and quality. Both aquaculture operations and hatchery farms may have disease-related shrimp issues. Among these, shrimp infections at hatcheries are the most dangerous, result in significant economic losses, and in the worst cases, they might completely shut down the business. In hatcheries and farms for aquaculture, antibiotics are frequently used to treat bacterial infections. However, frequent and intense use of antibiotics in aquaculture hatcheries and farms develops selective pressure on the aquaculture animals. Additionally, it hurts the environment by breeding diseases and other bacteria in aquatic environments with genes that may be transferred to other bacteria and create reservoirs of bacteria that are resistant to drugs. Through horizontal gene transfer, resistant genes may spread from these reservoirs and influence human infections or drug-resistant bacteria from aquatic environments, which would ultimately be biomagnified and have an impact on public health. Therefore, given the current situation for managing aquatic infections, alternate tactics that won't breed pathogen resistance are preferred. Alternative tactics that can focus on the pathogenicity alone rather than the whole bacterium are now required.

The finding that bacteria are capable of quorum sensing (QS), or cell-to-cell communication, has changed our understanding of their pathogenicity. Small signal molecules termed autoinducers, which build up in the extracellular environment when high cell densities are attained, are produced, secreted, and detected by bacteria. Pseudomonas, Aeromonas, and Vibrio *spp*, which have been revealed to have various QS systems, are among the most prevalent bacterial diseases that harm aquaculture. As an illustration, Pseudomonas has four different QS system types, including LasI/R, RhlI/R, Pqs-PqsR, and Iqs, whereas Aeromonas possesses the AhyRI system. Due to their importance in influencing host survival, QS signals might be seen as an additional virulence factor.

Quorum Sensing

The ubiquitous phenomena of quorum sensing (QS) in bacteria have been recognized. Bacteria use a process known as "quorum sensing" that involves making, releasing, and detecting tiny signal molecules to coordinate the expression of certain genes in response to their population density. In bacteria, cell-to-cell communication is based on the generation and recognition of signal molecules that control gene expression in a cell-density-dependent way. The signal molecules that modify the response are known as autoinducers (AI), and this type of communication is referred to as quorum sensing (QS). QS autoinducers are generated and released during vegetative cell development, and they build up gradually in the microenvironment. The expression of genes involved in a variety of biological processes and responses, including bioluminescence, symbiosis, motility, sporulation, plasmid transference, competence, virulence, biofilm formation, toxins, and antibiotic production, is modulated when the bacterial population reaches a threshold density and a critical concentration of the inducer is reached(Medina-Martínez and Santana, 2012). There are several types of AI-QS systems that have been described, depending on the chemical makeup of the signal molecules and their receptors. All of the highly homologous QS systems and luxR/luxI together comprise the type 1 QS system. The molecules that make up the autoinducers are members of a broad group known as N-acyl homoserine lactones (AHL), which all have a conserved homoserine lactone ring connected to a changeable side chain of fatty acids with varying lengths and chemical substitutions. As shown in Figure 1, there are several sources for AHLs in the marine ecosystem.

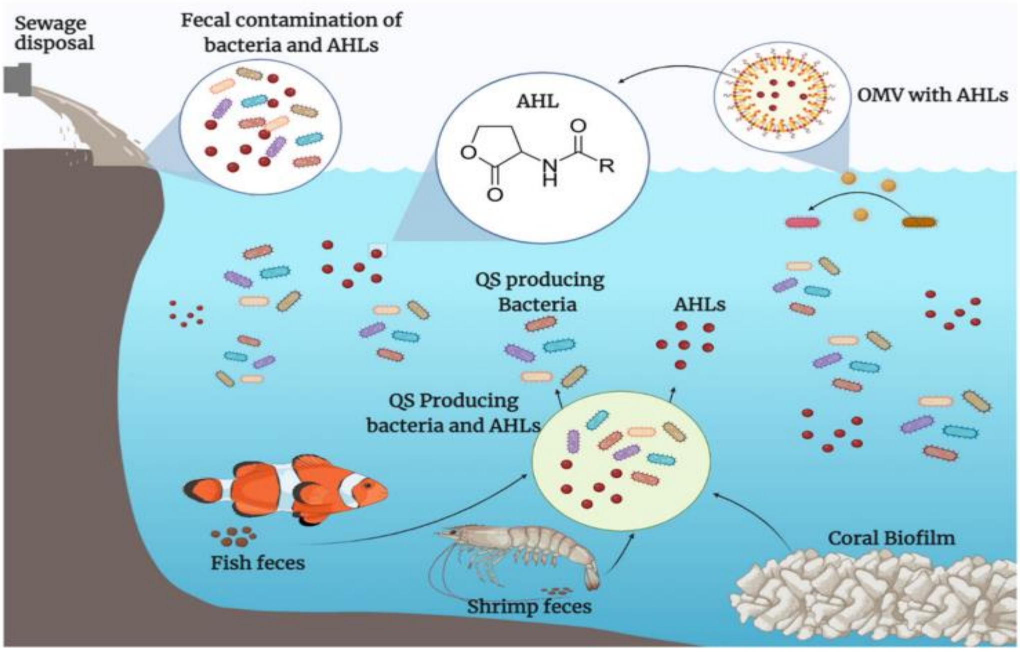

Figure 1. The sources of AHLs (QS Signal Molecules) in the marine ecosystem (Priya et al. 2022)

A single enzyme, the product of the luxI gene or one of its homologs, is responsible for catalyzing the production of AHL from cellular metabolites. An intracellular cytosolic receptor (LuxR and homologues), which activates the transcription of the genes controlled by QS, recognizes AHL. A signal produced by the luxS gene product and associated homologues is the mechanism by which the type 2 QS system functions. In a multistep conversion from ribose homocysteine to a heterocyclic furanosyl molecule, which is frequently connected with a boron atom, AI type 2 is produced as a byproduct of SAM metabolism. The receptor has a receptor-kinase signal transcription complex and is a two-component membrane system. Acylated homoserine lactones (AHLs), also known as autoinducer-1 [AI-1], are the most extensively researched autoinducers and are used by Gram-negative bacteria, whereas peptide-type signals are employed by Gram-positive bacteria. Both Gram-negative and Gram-positive bacteria are capable of recognizing Autoinducer-2 (AI-2). According to reports, these signaling systems have an effect on the expression of genes that code for the creation of virulence factors, bioluminescence, enzyme production, and biofilm development as explained in table 1. By postponing the creation of virulence factors until the population density is high enough to overwhelm the host's immune system, these quorum-sensing pathogens most likely boost their odds of successfully infecting their host.

Table1. The quorum sensing systems of different aquatic pathogens and the link between quorum sensing and virulence factor expression

Species	Signal	QS Regulated Virulence Factors
Aeromonas hydrophila	BHL[a], HHL[b]	Biofilm formation, exoprotease production
Aeromonas salmonicida	BHL[a], HHL[b]	Serine protease production
Vibrio anguillarum	ODHL[c]	Unknown
Vibrio harveyi	OHBHL[d], AI-2	siderophore production, production of type III secretion system components, extracellular toxin production
Vibrio vulnificus	AI-2	protease and hemolysin production, lethality in mice

(Defoirdt *et al.* 2004)

[a] BHL: N-butanoyl-l-homoserine lactone; [b] HHL: N-hexanoyl-l-homoserine lactone; [c]ODHL: N-(3-oxodecanoyl)-l-homoserine lactone; [d] OHBHL: N-(3-hydroxybutanoyl)-l-homoserine lactone.

Impact of QS on Host

Drugs that target bacterial infections destroy those organisms, but the virulence factors that were previously produced by those pathogens persist for a long period. In research, *Vibrio tasmaniensis* and *V. crassostreae* were used to examine the effects of the QS signals on blue mussel larvae. They demonstrated that HAI-1 regulates *V. tasmaniensis* motility, CAI-1 controls *V. crassostreae* biofilm growth, and AI-2-mediated QS system controls *V. tasmaniensis* biofilm formation. Macrobrachium larvae have been demonstrated to be negatively impacted by AHL molecules, perhaps as a result of the bacteria that live around the larvae being stimulated to produce a variety of virulence factors. The survival and growth of the prawn larvae were significantly decreased by the daily injection of the AHL combination (1 mg/L).8 Another research with similar results found that the survival and Larval Stage Index (LSI) of prawn larvae were significantly decreased when fed daily with an AHL combination at a dose of 1 mg/L. As is the case with mammalian cells, the QS signal alone would have triggered several cellular pathways in the larvae, accelerating cell death. The capacity of immune cells to survive and proliferate is heavily influenced by QS signals like AHLs, which also have modulatory effects on other cells, including epithelial cells, as shown in Figure 2. According to another study, *Vibrio parahaemolyticus* and *V. harveyi* exhibit significant levels of expression of QS-related genes and toxin-excoding genes when infected with *Penaeus vannamei*. They have discovered a direct relationship between mortality rate and gene expression levels associated with virulence. This suggests that the host expresses pathogen QS-related genes. Mammalian cells immune systems are compromised by QS signals because they take control of several regulatory pathways (Priya *et al.* 2022).

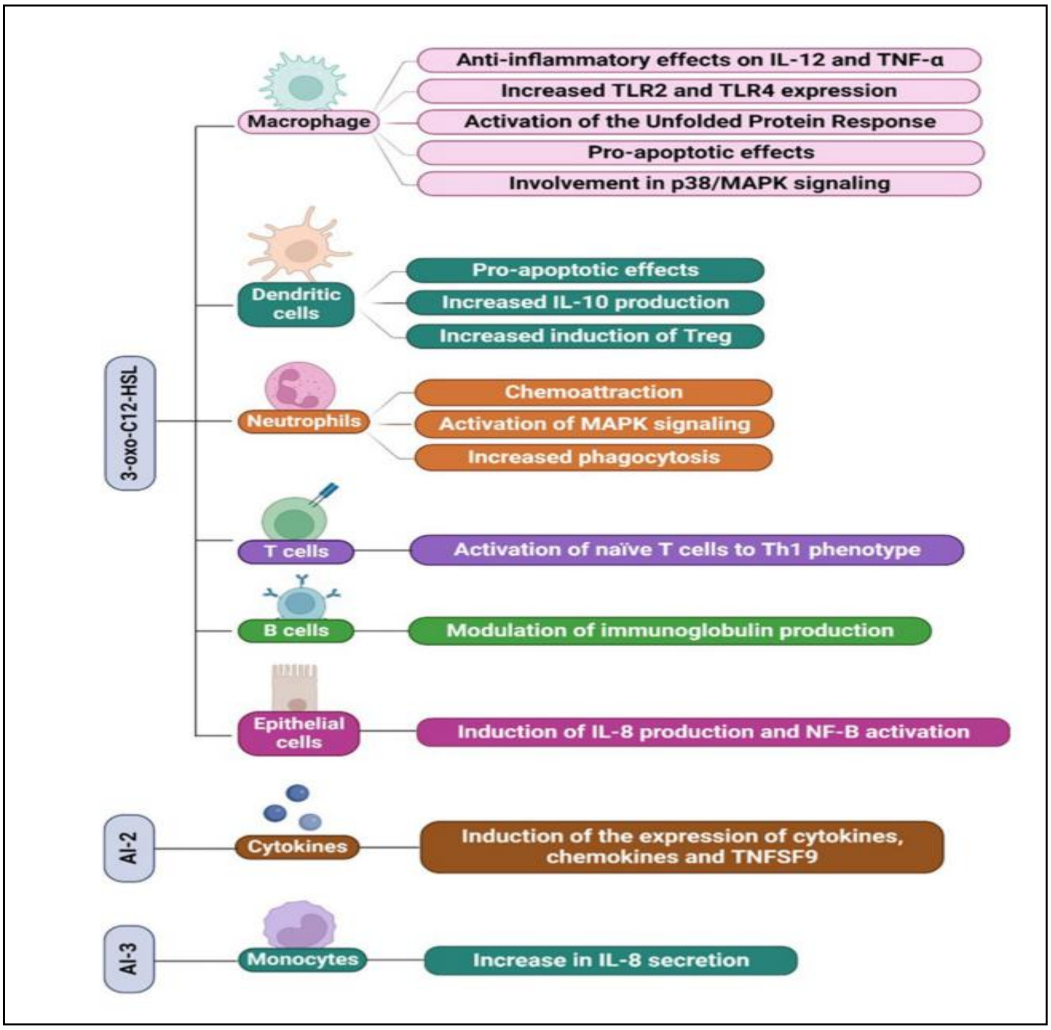

Figure 2. The activity of quorum sensing (QS) signaling molecules in the immune system(Priya et al. 2022).

Impact of QS on Aquaculture Diseases

When exposed to AHLs, several aquaculture species exhibit high mortalities. Giant freshwater prawn and turbot larvae were much less able to thrive and survive when exposed to mixtures of several AHL molecules at a concentration of 1 mg/L. Moreover, when rainbow trout are infected with *V. anguillarum*, elevated AHL levels are seen in many organs. Because the effect is not seen when bacterial growth is inhibited by adding antibiotics along with the AHLs, it is likely that the detrimental effects of AHLs result from the activation of bacterial virulence factors that are regulated by QS. It has been shown that there is a connection between QS and virulence and that the three-channel QS system controls the expression of the empA metalloprotease *in V. anguillarum*, which is in charge of bacterial virulence in Atlantic salmon. It has also been demonstrated that quorum sensing regulates toxin T1, another virulence component that contributes to the pathogenicity of *V. harveyi* in *Penaeus monodon*.

Competition for the LuxPQ receptor is sufficient to stop *V. harveyi* from becoming as virulent against brine shrimp by interfering with the AI-2 signal transduction pathway. In fact, a particular virulence component may be controlled by QS in one species but not in another, or a virulence trait may be positively regulated by QS in one species but negatively regulated in another. For example, QS in *V. cholerae* inhibits biofilm development while inducing it in *V. anguillarum*. Metalloprotease is positively and negatively regulated in *V. harveyi*, while chitinase A. It is crucial to produce virulence at the right time, and the creation and identification of signal molecules may make this possible(Natrah *et al.* 2011).

Conclusion

Our knowledge of bacteria's pathogenicity has evolved as a result of the discovery that they are capable of quorum sensing (QS) or cell-to-cell communication. Targeting QS signals instead of pathogen development or the QS receptor might eradicate infections because QS signals alone are harmful to the host. Now, an approach that can concentrate just on the pathogenicity of the bacteria rather than the entire organism is necessary. Therefore, research on the pathogen-free virulence factors in aquatic environments and their effects on hosts is important.

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Seaweed Cultivation, An Alternate Livelihood for Coastal Fisher Population

S. Saravanan, A. Uma and D. Kaviarasu

Department of Aquatic Animal Health Management,
Dr. M. G. R Fisheries College and Research Institute, Ponneri 601 204,
Tamil Nadu, India. Tamil Nadu Dr. J. Jayalalithaa Fisheries University.
Corresponding author: saravanan@tnfu.ac.in

Abstract

The potential areas in India for luxuriant growth of seaweeds are south Tamil Nadu coast, Gujarat coast, Lakshadweep and Andaman Nicobar Islands. The total standing crop of seaweeds from Intertidal and shallow waters of all maritime states and Lakshadweep Islands was estimated as 91339 tons (wet wight) The quantity of seaweeds growing in deep waters of Tamil Nadu was estimated as 75372 tons (wet wt) in an area of 1863 sq km from Dhanushkodi to Kanyakumari. Every month from 1978 to 1995 from the seaweed landing centres in Tamil Nadu on the quantity of seaweeds exploited from the natural seaweed beds. During this period the quantity of agar yielding seaweeds *Gelidiella acerosa*, *Graci/aria edulis*, G. *crassa* and G. *foliifera* exploited in a year varied from 248 to 1289 tons (dry wt), algin yielding seaweeds *Sargassum* spp and *Turbinaria* spp from 651 5537 tons (dry wt) and all the above seaweeds from 1177 to 6420 tons (dry wt). Since several years, agar yielding red algae are over exploited in Tamil Nadu. The need for conservation of commercially important seaweeds of Tamil Nadu.
Keywords: *Seaweeds, Gracilaria, Gelidella, Kappaphycus alvarezii,* Self-help women

Introduction

Seaweeds are macroscopic algae growing in the marine and shallow coastal waters and brackish water habitats. Seaweeds (macro algae) are wonder plants of the sea, the new renewable source of food, energy, chemicals and medicines with manifold nutritional, industrial, biomedical, agriculture and personal care applications. Seaweeds are also termed as the 'Medical Food of the 21st Century' due to usage as laxatives, for making pharmaceutical capsules, in treatment of goiter, cancer, bone-replacement therapy and in cardiovascular surgeries.

The major industrial applications of seaweeds in India are as a source of agar, agarose and carrageenan used in laboratories, pharmaceuticals, cosmetics, cardboard, paper, paint and processed foods. There are 46 seaweed-based industries, 21 for Agar and 25 for Alginate production, but they are not functioning up to their rated capacity, due to short-supply of raw materials.

1. **Seaweed Resources of India**

Some 844 species of seaweeds have been reported from Indian seas, their standing stock is estimated to be about 58,715 tonnes (wet weight). Among them, 221 species are commercially important and abundant along the Tamil Nadu and Gujarat coasts and around Lakshadweep and Andaman & Nicobar Islands. Rich seaweed beds occur around Mumbai, Ratnagiri, Goa, Karwar, Varkala, Vizhinjam and Pulicat in Tamil Nadu & Andhra Pradesh and Chilka in Orissa.

2. **Cultivable Species of Seaweed**

Red Seaweeds: *Gelidiella acerosa*, *Gracilaria edulis and G. dura* are farmed for manufacturing Agar, while *Kappaphycus alvarezii* is farmed for manufacturing Carrageenan; Brown Seaweeds: *Sargassum wightii* and *Turbinaria conoides* are farmed for manufacturing Alginates. Seaweed cultivation is a highly remunerative activity involving simple, low cost, low maintenance technology with short grow-out cycle.

3. **Seed Material**

Seed stock of seaweeds is traditionally collected from natural waters along the southeastern coast of Tamil Nadu. But, continuous, indiscriminate, and unorganized harvesting has resulted in depletion of natural resources. The main objectives these studies are Creation of livelihood opportunities for coastal populations under Blue Revolution Scheme. Provide alternate income source for fishers, especially during fishing ban period. Meet the ever-increasing industrial demand for manufacture of Agar, Agarose, Carrageenan and Alginates from Seaweeds. Mass production of seed material for commercialization of the seaweed culture and conserving natural resources.

4. **Beneficiaries**

Coastal fisher-families, especially fisherwomen, their societies/ SHGs, and farmers/ entrepreneurs.

5. **Implementation**

1. Seaweed cultivation would be undertaken in shallow coastal waters of maritime States, wherein Bamboo-rafts or Tube-nets would be held in clusters.
2. CSIR-Central Salt Marine and Chemicals Research Institute (CSMCRI), Gujarat & Mandapam Regional Centre, Tamil Nadu would be the Technology Partner.
3. Department of Fisheries of coastal States/UTs would be the Implementing Agency.
4. National Fisheries Development Board, Hyderabad, would provide financial assistance

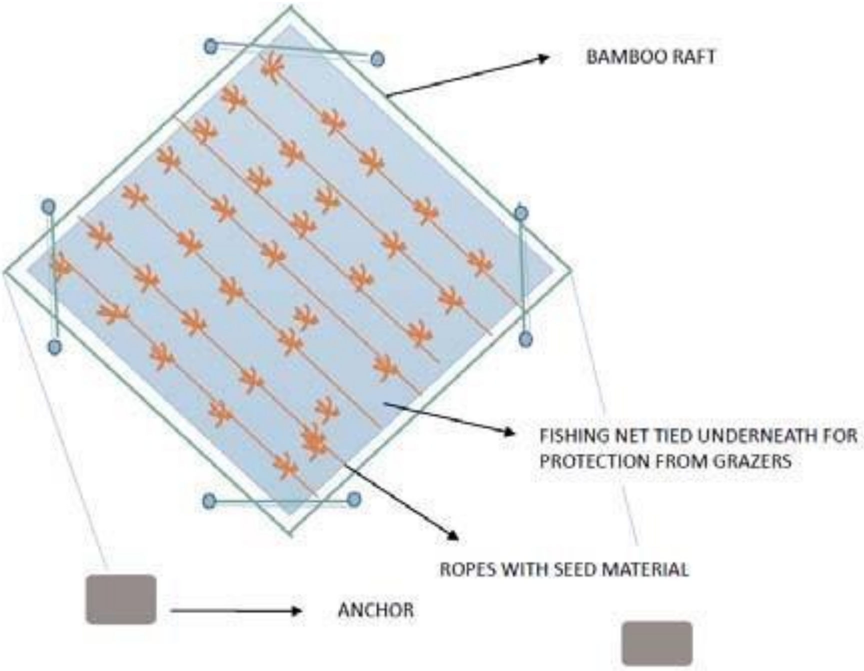

Figure 1. Tying Seedlings of Seaweed on a Bamboo Raft

Gracilaria edulis

Gracilaria dura

Kappaphycus alvarezii

6. **Expected Outcome**

1. Mass production of Spores: An approach to vigorous seed development for commercial
2. farming of Gracilaria edulis by CSIR-CSMCRI MARS, Mandapam, Tamil Nadu.
3. Farming of red seaweed Gracilaria dura on Gujarat Coast for promoting inclusive economic growth in coastal rural settings by CSIR-CSMCRI, Gujarat through participation of coastal fisher population.
4. Large-scale cultivation of commercially important seaweeds in the coastal waters of maritime States would fill the demandsupply gap of Agar and Alginate producing industry in the country.

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Empowering Sustainability: Unveiling Pectin-Based Biodegradable Films as the Eco-Friendly Marvel of Green Innovation

Vathsala. V, Sajeel Ahamad and Vivek Saurabh*

Division of Food Science and Post Harvest Technology,
ICAR – Indian Agricultural Research Institute, New Delhi – 110012, India.
***Corresponding author**: vivek.bhu12@gmail.com*

Abstract

Pectin is a complex polysaccharide present in higher plants and is widely used in the food industry as an emulsifier, gelling agent, and thickener. Due to its excellent film-forming property, pectin-based biodegradable films have emerged as a promising solution for sustainable packaging materials. This article explores the growing interest in pectin-based biodegradable films, their current applications, and the projected future demand driven by the global shift towards eco-friendly alternatives. It also delves into the challenges and opportunities in harnessing pectin's potential to meet the evolving demands of industries and consumers seeking greener packaging solutions.

Keywords: pectin, biodegradable, packaging, sustainability

Introduction

In recent years, the growing concern over environmental degradation and plastic pollution has led to a significant shift in industries towards more sustainable practices, in that packaging is at the forefront of this transformation. One remarkable innovation that has gained traction is the development and rise of biodegradable films. These films, derived from natural sources, offer a promising solution to the global plastic crisis (Moshood *et al.* 2022).

Conventional plastics are versatile and durable but it has contributed significantly to environmental degradation due to their resistance to decomposition. The urgency to reduce plastic waste has spurred innovations in the field of biodegradable materials (Moshood *et al.* 2022).

Pectin, a naturally occurring polysaccharide present in various plant tissues, has garnered significant attention for its diverse applications in the food, pharmaceutical, and cosmetic industries, and the development of active packaging material (Wang *et al.* 2019). From its role in creating delectable jams and jellies to its potential health benefits and contributions to sustainable packaging, pectin stands as a remarkable example of nature's versatility harnessed for human innovation.

Pectin has emerged as a versatile material for crafting biodegradable films. These films offer a range of benefits that align with sustainability and environmental responsibility principles. The ability of pectin films to biodegrade naturally, reducing the burden on landfills and ecosystems, positions them as a compelling solution in the era of plastic waste management (Barone *et al.* 2021).

This article aims to shed light on the current landscape of pectin-based biodegradable films, their applications, benefits, challenges, and their potential to revolutionize industries while fostering a greener and more sustainable future.

A brief history of biodegradable films: Biodegradable films can trace their roots back to the mid-20th century when researchers began experimenting with various natural materials as alternatives to traditional plastics. The initial focus was on creating materials that could be broken down by microorganisms, thus reducing their environmental impact. Over time, advancements in technology and research have led to the development of biopolymers, such as polylactic acid (PLA), polyhydroxyalkanoates (PHA), and starch-based polymers, which serve as the foundation for modern biodegradable films (Kumari *et al.* 2022).

Development of pectin-based biodegradable film:

Pectin-based biodegradable films can be prepared using various methods similar to those used for other biodegradable polymers. Here are some methods to prepare pectin-based biodegradable films:

1. Solution casting:

- ✓ This is the most common method to prepare biodegradable films, where a film-forming solution is cast onto a substrate and then dried to form a solid film (**Fig. 1**)
- ✓ Dissolve pectin in a suitable solvent to create a film-forming solution.
- ✓ Optionally, additives like plasticizers, crosslinking agents, or reinforcement materials can be added to improve film properties.
- ✓ Cast the solution onto a flat surface, allow the solvent to evaporate, and obtain a solid film.

2. Solvent evaporation method:

- ✓ Similar to solution casting, pectin is dissolved in a solvent.
- ✓ The solution is then spread onto a substrate or mold and the solvent is allowed to evaporate over time.

3. Blending with plasticizers:

- ✓ Pectin can be blended with plasticizers (e.g., glycerol, sorbitol) to enhance its flexibility and processability.
- ✓ The pectin-plasticizer mixture is heated to a molten state, and the resulting mixture can be cast into films.

4. Crosslinking:

- ✓ Crosslinking agents can be used to improve the mechanical properties and water resistance of pectin-based films.
- ✓ Common crosslinking agents include metal ions (e.g., calcium, aluminum), citric acid, and formaldehyde.
- ✓ The crosslinking agent is mixed with the pectin solution before casting, and crosslinking occurs during film formation.

5. Electrospinning:

- ✓ Pectin solutions can be electro-spin to create nanofiber-based films with increased surface area and potential applications in drug delivery and wound healing.
- ✓ The pectin solution is electro-spin onto a collector, where the solvent evaporates, leaving behind nanofiber mats.

6. Compression molding:

- ✓ Pectin can be mixed with other biopolymers or additives and then compression molded into films.
- ✓ The mixture is placed in a mold and subjected to heat and pressure to form a solid film.

7. Incorporating reinforcements:

- ✓ Pectin films can be strengthened by incorporating natural reinforcements such as cellulose fibers or nanocellulose.
- ✓ The reinforcements are dispersed in the pectin solution before casting or other film-forming methods.

8. Layer-by-layer assembly:

- ✓ Pectin-based multilayer films can be prepared by alternating the deposition of pectin solutions and solutions of oppositely charged polymers or particles.

Pectin, derived from sources like citrus peels, apple pomace, and sugar beet pulp, possesses inherent film-forming capabilities. The development process involves extracting pectin from these sources, followed by modification to optimize its film-forming properties. This can include adjustments to the degree of esterification and molecular weight, which influence the film's mechanical strength, flexibility, and water resistance (Mekonnen *et al.* 2013).

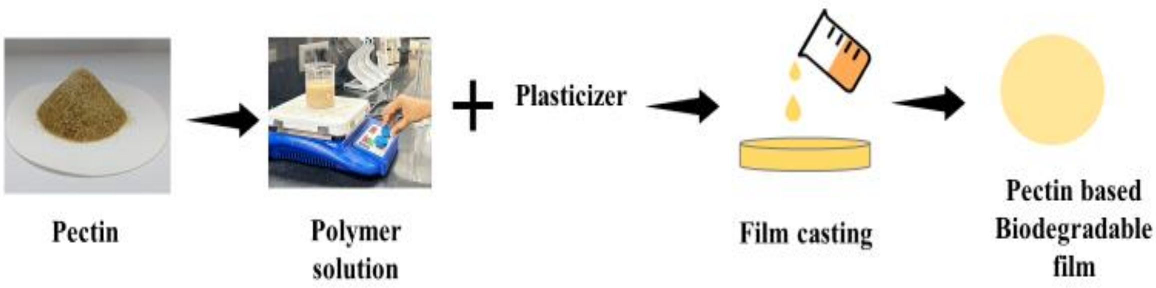

Figure 1: Schematic representation of the development of pectin-based biodegradable film.

Unveiling the mechanism of pectin in biodegradable films

- ➢ **Film formation through molecular interaction:** Pectin molecules consist of galacturonic acid units linked by various sugar molecules. When pectin is dissolved in water, its hydrophilic segments interact with water molecules, leading to the formation of a hydrated gel network. This network can then be cast into films, where the interconnected pectin molecules create a cohesive structure.

- **Gelation and cross-linking:** Pectin contains carboxyl groups that can be ionically cross-linked with divalent cations such as calcium ions. This cross-linking creates junction points between pectin chains, strengthening the film's mechanical properties and reducing its water solubility. The formation of these cross-links transforms the gel-like pectin solution into a stable film.
- **Influence of degree of esterification (DE):** The DE of pectin, which refers to the proportion of galacturonic acid units esterified with methoxy groups, plays a crucial role in film formation. Low DE pectin has a higher capacity for gelation due to the presence of more free carboxyl groups available for cross-linking. High DE pectin, on the other hand, can form films with improved water resistance due to their reduced solubility.
- **Plasticizer incorporation:** The addition of plasticizers, such as glycerol or sorbitol, to pectin films, enhances their flexibility and overall mechanical properties. Plasticizers reduce intermolecular forces between pectin chains, allowing them to move more freely. This plasticizing effect counteracts brittleness and increases film elasticity, making pectin films more suitable for various applications.
- **Composite structures:** The biocompatibility of the pectin molecule allow it to blend with other compounds, that can provide tailored characteristics through incorporation of natural polymers, nanoparticles, or reinforcing agents for specific applications. These composite structures can further improve mechanical properties, barrier properties, and film stability. For instance, adding cellulose nanofibers can enhance film strength, while incorporating antimicrobial agents can extend shelf life in food packaging.
- **Application-specific modifications:** The mechanism of pectin in biodegradable films allows for tailoring film properties based on application needs. By adjusting parameters such as the type of pectin, cross-linking agents, plasticizers, and additives, researchers can create films with varying degrees of transparency, barrier properties, and mechanical strength to suit specific industries like food packaging, agriculture, pharmaceuticals, and cosmetics.

Industrial application: Applications of biodegradable films have been found in a diverse range of industries, including packaging, agriculture, food service, medicine, textile, cosmetics, edible coating, meat and poultry packing, and more (Moshood *et al.* 2022). In the packaging sector, these films are utilized for single-use items like bags, cutlery, and food containers, providing a more environmentally friendly alternative to traditional plastics. The agricultural industry benefits from biodegradable mulch films that can be ploughed into the soil after use, reducing waste and promoting soil health. Moreover, the medical field employs biodegradable films for wound dressings, drug delivery, and sutures due to their biocompatibility and controlled degradation.

Advantages and environmental benefits: There are multifaceted advantages of biodegradable films. Firstly, they are sourced from renewable materials, decreasing reliance on fossils and non-renewable resources. Secondly, their ability to decompose naturally mitigates the long-lasting environmental impact caused by conventional plastics. As they break down, biodegradable films release fewer harmful pollutants, making them a viable option to combat soil and water pollution. Furthermore, their reduced carbon footprint and energy consumption during production contribute to overall greenhouse gas emissions reduction.

Challenges and prospects: While biodegradable films hold great promise, they are not without challenges. Achieving optimal mechanical and barrier properties comparable to traditional plastics can be difficult. Balancing these attributes with biodegradability remains a persistent challenge. Additionally, the disposal of biodegradable films requires specific conditions, such as industrial composting facilities, to facilitate proper breakdown. Public awareness and waste management infrastructure must be developed to ensure these films are disposed of correctly.

The scope of pectin-based biodegradable films extends beyond conventional packaging. From food to pharmaceuticals, agriculture to cosmetics, their applications are diverse and multifaceted. While pectin-based biodegradable films, ensuring consistent film quality, improving mechanical properties, and optimizing production processes are areas of active research like enhanced barrier properties, active and smart packaging, anti-microbial properties, nanocomposite films, and packaging for specialty foods (Kumar *et al.* 2020).

Conclusion:

The rise of biodegradable films marks a pivotal moment in the ongoing battle against plastic pollution and environmental degradation. As these films gain traction across industries, their potential to replace conventional plastics becomes increasingly evident. While challenges persist, the commitment to sustainability, technological advancements, and responsible waste management can pave the way for biodegradable films to become a cornerstone of a more ecologically harmonious world. As the global movement toward eco-friendly solutions gains momentum, pectin-infused biodegradable films stand as a testament to the ingenious ways in which science and nature can collaboratively pave the way to a greener, more sustainable future.

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Synthetic Seeds: A Novel Approach to Reproduction

Sultan Singh and Shivani

Department of Seed Science and Technology
CCS Haryana Agricultural University, Hisar, Haryana-125004
Corresponding Author: sultan.hau@gmail.com

Introduction:

Artificial seed technology stands as a crucial tool for plant tissue culture researchers and breeders, commonly known as "synseeds." These synthetic seeds, an outcome of advancements in this field, were defined by Gray *et al.* (1991) as "somatic embryos engineered for practical application in commercial plant production." They serve as a viable alternative to conventional micropropagation, facilitating the growth and dissemination of cloned plantlets. An artificial or synthetic seed, kept within a gel bead, comprises essential components: a somatic embryo, a shoot bud, growth regulators, and nutrients. The term covers somatic embryos enclosed within coatings or other vegetative elements such as shoot buds, cell aggregates, auxiliary buds, or any other micropropagules capable of being planted like seeds and nurtured into plants within controlled in vitro or ex vitro environments. Artificial seeds have been created using a variety of plant parts, including shoot tips, auxiliary buds, somatic embryos, microshoots, protocorm-like bodies (PLBs), nodal segments, and embryogenic calluses. Antibiotics, insecticides, and other necessary agents must be present for encapsulated somatic embryos or shoot buds to mature successfully into fully grown plantlets. The structural resemblance of artificial seeds to natural seeds is remarkable. The explant material imitate the zygotic embryo in conventional seeds, while the encapsulating capsule (comprising gel agents and additional materials like nutrients, growth regulators, bio-controllers, anti-pathogens, and biofertilizers) emulates the role of the endosperm in natural seeds (Cartes *et al.* 2009). While most artificial seeds originate from in vitro propagules encapsulated in protective coatings, certain plant species have exhibited the capability to generate synthetic seeds from in vivo propagules.

Why Synthetic Seeds?

The utilization of synthetic seeds arises due to challenges in propagating certain horticultural crops, owing to factors such as:

• The presence of heterozygosity in seeds, particularly in crops that undergo cross-pollination.
• Limited seed size, as observed in cases like orchids.
• Insufficient development of the endosperm within the seed.
• The requirement for mycorrhizal fungus association for successful germination of certain seeds, exemplified by orchids.

Two types of artificial seeds (encapsulated somatic embryos) are commonly produced:

- **Desiccated seed**
- **Hydrated seed**

Desiccated synthetic seeds:

These seeds are formulated through the encapsulation of multiple somatic embryos, followed by exposing them to desiccation, a process involving the complete removal of moisture from the seeds. To serve as a protective layer for the somatic embryos, we employ polyoxyethylene (Polyox) as an encapsulation material. This choice is advantageous as it poses no harm to the embryos and effectively inhibits bacterial growth. The production of desiccated artificial seeds involves desiccating somatic embryos, which can either be in a bare state or enclosed within a polyoxyethylene glycol coating. Desiccation can be achieved in two ways: a rapid process where synthetic seeds are placed on uncovered petri plates to air-dry overnight, or a gradual method by exposing them to reduced relative humidity over an extended timeframe. (Ara *et al.* 2000).

Hydrated synthetic seeds:

These seeds are produced by enclosing somatic embryos within hydrogel capsules, offering a solution for plant species with sensitive and recalcitrant somatic embryos that are prone to desiccation. Among the various techniques, the utilization of calcium alginate encapsulation stands as the prevalent approach to forming these hydrated seeds. To generate hydrated synthetic seeds, the initial step involves embedding plant materials within a sodium alginate gel (ranging from 0.5% to 5.0% w/v). Subsequently, this mixture is gently dispensed using a pipette into a solution of calcium chloride (ranging from 30 mM to 100 mM). In this process, an ion exchange transpires, wherein calcium ions displace sodium ions. The outcome is the creation of a spherical, firm bead composed of calcium alginate, enveloping the somatic embryos within. (Reddy *et al.* 2012).

Distinctive Attributes of Synthetic Seeds:

- Synthetic seeds offer diverse possibilities for scaling up propagation on a substantial level.
- They uphold the genetic consistency of plants.
- Facilitate swift multiplication of plant populations.
- Contribute to reducing per-plantlet expenditures significantly.

Distinguishing Benefits of Synthetic Seeds over Somatic Embryos for Propagation:

- Simplified transport logistics.
- Convenient handling during storage.
- Extended viability duration during storage without compromising viability.
- Guarantees the preservation of clonal identity in the resultant plants.
- Facilitates the direct introduction of newly developed plant lines from biotechnological innovations to cultivation environments.
- Enables economical large-scale multiplication of superior plant cultivars.

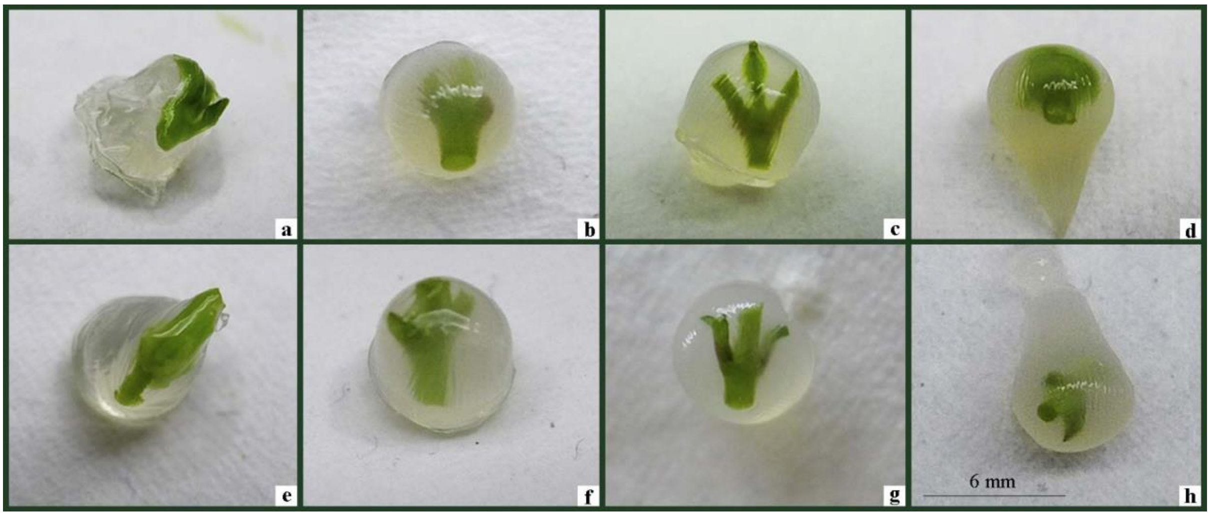
Synthetic Seed Production Process:

The generation of somatic embryos for the purpose of artificial seed production takes place within a laboratory setting, involving the culturing of somatic cells and the application of specific hormonal treatments to stimulate the development of root and shoot tissue.

The process of producing synthetic seeds involves several sequential phases:

- Initiation of somatic embryogenesis
- Maturation of developed somatic embryos
- Synchronization of somatic embryos developmental stages
- Large-scale production of somatic embryos
- Maturation of embryos to the desired developmental state for encapsulation
- Desiccation of fully matured somatic embryos
- Transplanting the desiccated embryos into field conditions

This systematic approach ensures the controlled development and successful production of synthetic seeds.



(Gantait *et al.* 2017)

In-vitro cultivation of synthetic seeds:

Encapsulation is regarded as the optimal approach for providing safeguarding and transforming in vitro micropropagules into what are termed 'artificial seeds' or 'synseeds'. This represents a crucial application of micropropagation aimed at enhancing the efficacy of delivering field-ready plants sourced from in vitro cultivation. However, it's essential to encase somatic embryos in a compatible substance that facilitates their germination. To create moisture-rich seeds, the plant materials are mixed with a solution of sodium alginate gel (with concentrations ranging from 0.5% to 5.0% w/v). By using a pipette, this mixture is subsequently dripped into a solution of calcium chloride (ranging from 30 to 100 mM). This process triggers an ion exchange, leading to the formation of spherical and robust beads comprised of calcium alginate. These beads encapsulate somatic embryos, brought about by the substitution of sodium ions with calcium ions (Reddy *et al.* 2012). The firmness and robustness of the capsules primarily depend on the quantity of sodium ions substituted by calcium ions. Thus, it's feasible to adjust the solidity of the calcium alginate gel by modifying the concentrations of sodium alginate and calcium chloride solution, in addition to altering the duration of the mixing process. When 2% sodium alginate gel was combined with a 100 mM calcium chloride solution, it typically resulted in the production of high-quality synthetic seeds for a variety of plant species (Oceania *et al.* 2015). Ca-alginate capsules can be hard to handle since they are extremely wet and have a tendency to slightly clump together. Furthermore, the calcium alginate quickly dehydrates and rapidly transforms into rigid pellets within a short span of time when the beads come into contact with the standard environment. However, these challenges can be effectively addressed by enveloping the capsules with Elvax 4260. Additionally, to prevent the risk of bacterial contamination, an antibiotic blend comprising rifampicin, cefatoxime, and tetracycline-HCl can be introduced into the matrix.

Conclusion:

The synthesis of synthetic seeds turns out to be a potential and novel strategy in modern plant biotechnology. This technology offers a number of advantages while addressing numerous issues with traditional propagation methods. Synthetic seeds make plant replication more feasible by encasing somatic embryos in protective coatings that are easy to handle, store, and transport. The significance of this technology can be seen in its capacity to preserve genetic homogeneity, assure clonality, and increase the viability of seeds throughout storage. Synthetic seeds can enable the quick distribution of novel plant lines created through biotechnological discoveries by acting as an intermediary between laboratory developments and field applications. Synthetic seed production bears significant promise for the development of agriculture as a low-cost method of mass production and distribution of superior plant varieties.

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Unleashing the Power of Microbes: The Promising Potential of the Aquaculture Microbiome

Samad Sheikh[1*], Patekar Prakash[2], Indulata Tekam[3], Sagar Vitthal Shinde[4], Baig Laika Reyaz[5]

[1*]*Department of Aquatic Animal Health Management, ICAR- CIFE, Mumbai*
[2]*Division of Fish Nutrition, Physiology and Biochemistry, ICAR-CIFE, Mumbai*
[3]*Department of Aquaculture, College of Fishery Science, NDVSU, Jabalpur, Madhya Pradesh*
[4]*Department of Aquaculture, ICAR-CIFE, Mumbai*
[5]*Department of Fisheries Resource Management, SKUAST-K, Rangil, Ganderbal,*
[*]*Corresponding author: Sheikh.samad13@yahoo.in*

Abstract

Aquaculture, the fastest-growing sector of agriculture, relies on the microbiome, which influences fish health and productivity. Microbes in the gut system of finfish exhibit symbiotic relationships, impacting hereditary traits, disease defence, and immunity. Research has focused on microbiome diversity and taxonomic identification in finfish and shellfish, with implications for physiological functions. Beneficial microbes can serve as alternatives to antibiotics, reducing superbug emergence and enhancing production rates. Microbiomes offer preventive measures against infectious diseases and accelerate drug development in various industries. Understanding host-microbiome interactions can modulate the aquaculture microbiome to promote aquatic organism health and industry growth. Targeted modulation of the shrimp and aquaculture microbiome is key for effective treatment strategies. By harnessing the microbiome's potential, aquaculture can achieve sustainable fish production, reduce antibiotic use, and prevent antibiotic-resistant superbugs.

Keywords: Aquaculture, Microbiome, Superbug, Infectious disease, Antibiotic, Gut microbes

Introduction

Aquaculture, responsible for half of the world's seafood production, reached a record of 214 million metric tons in 2020 (FAO, 2020). However, the industry faces challenges from infectious diseases caused by microorganisms, leading to economic losses. Traditional measures like antibiotics and vaccines have protected cultured species but have also led to the emergence of antimicrobial-resistant strains, raising concerns about environmental and human health. Safer and environmentally-friendly treatment strategies are now needed to address these challenges. Microbiome manipulation can enhance water quality and reduce infections, decreasing antimicrobial reliance in aquaculture. Modulating the microbiome of aquatic species as probiotics can overcome sector challenges. The gut microbiome positively influences aquatic health and growth, serving as a defense against infection-causing microbes and maintaining gut balance (Yukgehnaish *et al.* 2020). The aquaculture microbiome is crucial for the health and development of aquatic animals since they are in direct contact with water.

Microbiome

The microbiome is defined as a distinct microbial community with specific physiochemical properties (Berg *et al.* 2020). A healthy microbiome is characterized by a resistant, resilient, and functional core capable of maintaining stability despite internal or external factors (Lloyd-Price *et al.* 2016). Microbiomes in different habitats, such as the skin, gills, and gastrointestinal tract of finfish and shellfish, can limit pathogens through competition for resources and the production of antimicrobial compounds. Gut microbiomes are complex communities influenced by microbe-host interactions, diet, and environment, and are often considered an "extra organ" due to their crucial roles in intestinal development, overall health, and metabolism. Understanding the composition and functions of the microbiome is challenging due to its variability among individuals, growth stages, and geographic areas (Sandrini *et al.* 2015). Despite this complexity, a healthy microbiome is characterized by a stable and balanced ecology capable of resisting perturbations and maintaining the host's health.

Skin-associated microbiome

Through antagonistic behaviour and competition for adhesion sites/nutrients, the skin microbiome of fish may prevent the colonisation of pathogens. Aerobic heterotrophic bacteria on fish skin are similar in abundance to the surrounding water, but the composition of the healthy fish skin microbiome differs from rearing water, with potential higher abundances of *Micrococcus*, *Enterobacteriaceae* and *Bacillus* in warm water species (Gram and Ringø, 2005).

Gills-associated microbiome

The gills of fish have been suggested to represent a challenging habitat for microbial colonization, with restricted areas of protected spaces such as clefts between pharyngeal arches and lamellae. Fish gill microbiota diversity is reported to be lower than that of fish skin, and culture-based studies have shown similarities between gill microbiota and surrounding water in various fish species such as stripe bass, rainbow trout, turbot nile tilapia and atlantic salmon (Al-Harbi and Uddin, 2005). The microbiota of the fish's gills and skin have been believed to be impacted by stress factors such as overcrowding, poor water quality, parasitism, temperature variations, and trauma and the evidence supports the impact of seasonality and poor water quality on gill microbiota (Cahill, 1990).

Gut-associated microbiome

Izvekova *et al.* (2007) describe the gut microbial flora of marine and freshwater fish. Due to the differences in environmental circumstances, the gut microbial composition of freshwater fish differs. The gut of freshwater fish is dominated by *Aeromonas, Acinetobacter, Lactococcus, Pseudomonas, Flavobacterium*, obligate anaerobes (*Clostridium, Bacteroides* and *Fusobacterium*), and members of the Enterobacteriaceae family. Fish and other aquatic creatures have a unique connection with their surroundings and the microorganisms that live there. The most common bacteria found in the guts of marine fish includes *Flavobacterium,* *Alteromonas, Pseudomonas, Alcaligenes, Moraxella, Aeromonas, Vibrio, Micrococcus, and Carnobacterium.*

Factor affecting the microbiome

1. Host physiological conditions and starvation: According to Dai *et al.* (2018), *L. vannamei* under starvation stress exhibits digestive and immunological functions that are correlated with the gut microbiota as shown in Figure 1. Starving shrimp lost critical gatekeeper microbial species including *Rhodobacteraceae sp*. and *Mesorhizobium sp*., making other crucial microbial species unstable and less effective and more vulnerable to pathogen attack. *Alphaproteobacteria* and *Actinobacteria*, which have the potential to produce antimicrobial and growth-promoting compounds, were abundant in the healthy *L. vannamei* microbiome, whereas *Vibrio* and *Pseudoalteromonas*, which are frequently found in aquaculture environments, were also present in significant quantities in the diseased shrimp. Therefore, the diseased condition may reduce the host's ability to filter the invasive strains.

2. Temperature: According to Austin and Austin (2016), in aquaculture temperatures over the optimum temperature for growth have been shown to cause stress, slow growth and disrupt the microbial communities in the fish gut. Several studies claimed that variations in water temperature are said to affect the load, pathogenicity and diversity of gut microbes in salmonids. In tilapia, exposure to cold significantly altered the makeup of the gut microbiome by elevating Proteobacteria (Vibrionales and Alteromonadales) and decreasing all other phyla.

3. Salinity: The gut and skin microbiomes of anadromous fish, such as Atlantic salmon, showed compositional shifts between freshwater and marine environments. In aquaculture, the transition from freshwater to saltwater induced changes in skin mucus and gut microbiomes, including increases in Proteobacteria and Firmicutes, and decreases in Bacteroidetes, Actinobacteria, Cyanobacteria, and Verrucomicrobia (Lokesh and Kiron, 2016; Rudi *et al.* 2018).

4. Diet: Vatsos (2016) found that feeding practices significantly affect the structure and make-up of the gut microbiota. The diversity of the gut flora in omnivores and herbivores is often greater than in carnivores, whose flora eventually decreases in contrast. Aquatic animals' gut microorganisms also produce vitamins and amino acids there. For instance, in Nile tilapia, the quantity of vitamin B12 positively associated with the prevalence of anaerobic bacteria from the genera Bacteroides and Clostridium.

Role of microbiome

1. Digestion: Diet and the gut microbiome have a long-standing association that reveals details about the commensal interaction between certain bacteria and the host. Ray *et al.* (2012) found that the teleost gut microbiota produces a wide range of digestive enzymes, including carbohydrases, cellulases, phosphatases, esterases, lipases, and proteases. In zebrafish, gut colonization by microorganisms enhances epithelial absorption of fatty acids. In contrast to germ-free fish without microbiota, fish with an intact microbiota exhibit greater levels of lipids in the intestinal epithelium.

2. Immunity: Since pathogenic and opportunistic commensal bacteria are present in water, which fish are continually in contact with, gut microbial communities have important relationships with immunity. Interactions between the immune system and gut microbiota are bidirectional. For example, fish secretory immunoglobulins recognize and coat intestinal bacteria to stop them from reaching the gut epithelium.

3. Stress response: The microbiome influences the HPA axis, the stress response, and behaviours including anxiety and locomotion, which may have an effect on feeding behaviour and energy homeostasis. For example, improving the microbiota in zebrafish decreases anxiety-like behaviour and stress response by reducing CRH expression and cortisol levels as shown in figure 2 (Forsatkar *et al.* 2017). Conversely, stress can alter intestinal mucosa structure, leading to changes in gut immune system and increased risk of infections. Acute stress in fish can result in shedding off the mucus and removal of beneficial bacteria, potentially decreasing feeding rates.

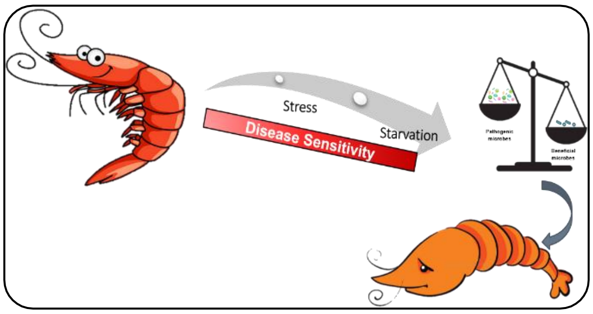

Figure 1. Factors influencing microbiota of shrimp

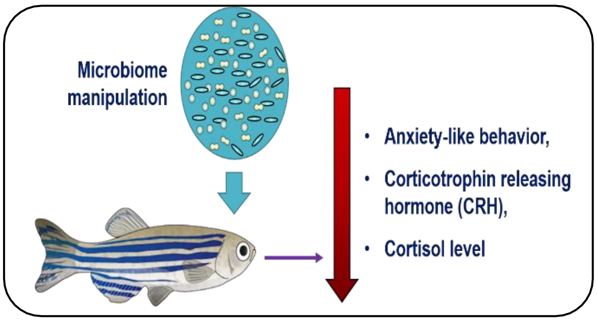

Figure 2. Stress response in zebrafish after microbiome manipulation

Table 1: Microbiome-based products (Dittmann *et al.* 2017)

Target environment	Product	Purpose	Composition
Water and pond	PRO 4000X, AquaPro B	Degrade organic matter, reduce ammonia, Vibrio reduction	*Bacillus subtilis, Bacillus licheniformis*
	Waste and Sludge Reducer	Improve water and bottom quality, pathogen control	*Bacillus cereus* RRRL B-30535
	Pond Plus	Pathogen control, decomposition of organic substances	Spore forming bacteria
	Pond Protect	Ammonia and nitrite reduction	*Nitrosomonas eutropha, Nitrobacter winogradskyi*

Gut microbiome (feed, feed additive)	AquaPro F	Organic matter degradation, improved digestion of feed	Five strains of bacillus
	EcoBiol	Improve gut health	*Bacillus amyloliquefaciens*

Conclusion

The gut microbiome of commercially important fish is linked to digestion, metabolism, infectious diseases, and overall health, and has potential as a biomarker for fish health. Fish-derived bacteria have shown to inhibit biofilm formation by gram-negative pathogens. However, more research is needed to understand the relationship between fish disease and specific microbial species, and to optimize gut microbiome composition for disease mitigation. Further investigation into microbiome composition, diversity, and identification of microbes up to species level is crucial for disease management and improving aquaculture practices. The bio-pharma and aquaculture industries are interested in supporting such research for sustainable aquafarming.

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Phytobiomes for Resilient Agriculture: Cultivating Diversity for Crop Health

K. Aravind[1], E. Rajeswari[1], B. Srinivas[1] and R. Sreenath Reddy[1]

[1]Department of Plant Pathology, College of Agriculture, PJTSAU, Rajendranagar, Hyderabad

Corresponding author: aravindkarni@gmail.com

Abstract:

In the relentless pursuit of achieving global food security and ensuring the sustainability of modern agriculture, the agricultural sector finds itself at a significant juncture. The escalating challenges posed by climate change, the reduction of cultivable land, and the rising demand for increased crop production have converged to present a pivotal moment. Within this context, the concept of phytobiomes has emerged as a promising beacon of optimism. Phytobiomes encapsulate intricate networks of interactions among plants, microorganisms, and their surrounding environment. This innovative paradigm offers a novel perspective on fortifying crop vitality and establishing resilient agricultural systems that can withstand these formidable challenges.

Key words: Phytobiomes, crop health, sustainability and food security

Introduction:

The phytobiome represents a dynamic ecosystem where plants, microorganisms, and the environment coalesce. It encompasses not only the visible parts of plants but also the intricate networks of microorganisms living on and around them. These microorganisms include bacteria, fungi, archaea, viruses, and other microscopic life forms (Brisson *et al.*, 2019). This intricate web of interactions forms a complex and dynamic system that shapes plant health and resilience.

At the heart of the phytobiome concept lies a profound truth: diversity is the cornerstone of resilience. Just as a diverse ecosystem is more robust and adaptable, a diverse phytobiome contributes to a plant's ability to withstand environmental stresses, fend off diseases, and thrive in changing conditions. The interactions between these microorganisms and plants are a dynamic dance of coexistence, where beneficial microorganisms bolster plant health, while harmful ones are held in check.

Phytobiomes have far-reaching implications for crop health and agricultural practices. By nurturing the right balance of beneficial microorganisms, we can reduce the need for chemical interventions, enhance nutrient uptake, and stimulate the plant's immune responses (Da Silva *et al.*, 2014). This holistic approach not only mitigates the impact of diseases but also promotes the overall well-being of crops, translating into higher yields, improved quality, and reduced environmental impact.

Key Interactions within Phytobiomes:

Beneficial Microbes: Within the phytobiome, beneficial microorganisms hold the key to sustainable agriculture. Mycorrhizal fungi, for example, form a symbiotic relationship with plant roots, enhancing nutrient uptake, water absorption, and overall plant growth.

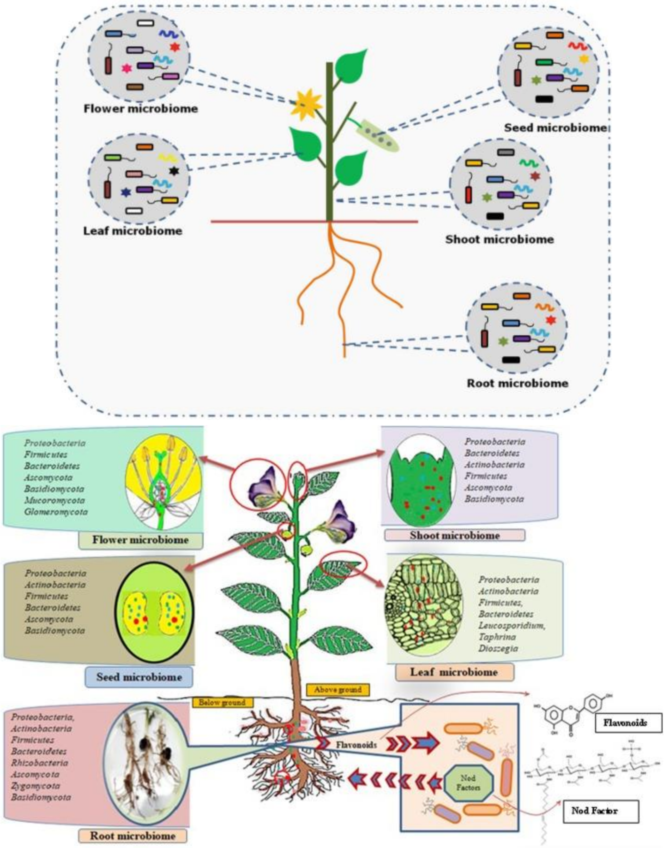

Figure 1. Diagrammatic representation of Phytobiome

- Plant-growth promoting rhizobacteria (PGPR) stimulate root development and enhance nutrient availability to plants (Chouhan *et al.*, 2021). These beneficial microorganisms can also produce antimicrobial compounds that help suppress pathogenic microorganisms.
- **Pathogenic Microbes:** On the other hand, pathogenic microorganisms can disrupt plant health and reduce yields. Understanding the dynamics between beneficial and pathogenic microorganisms is crucial for devising effective disease management strategies.

Importance of Phytobiomes for Resilient Agriculture:

- **Enhanced Disease Resistance:** Phytobiomes can serve as a natural defense mechanism for plants. Beneficial microorganisms within the phytobiome can induce systemic resistance in plants, making them less susceptible to diseases. For example, certain bacteria can trigger the plant's immune response, preparing it to fend off potential pathogens.
- **Stress Tolerance:** Climate change-induced stressors, such as drought, heat, and soil salinity, pose significant challenges to agriculture. Phytobiomes play a pivotal role in enhancing a plant's stress tolerance. Microorganisms within the phytobiome can help

plants cope with stress by improving water and nutrient uptake, and by producing stress-related compounds.

- **Reduced Pesticide Dependency:** The reliance on chemical pesticides has raised concerns about environmental impact and human health. Phytobiomes offer an alternative by promoting natural disease suppression mechanisms. By enhancing the presence of beneficial microorganisms, phytobiome management can reduce the need for chemical interventions.

The Role of Phytobiomes in Disease Management:

Plant pathogens (soil and seed borne pathogens, aerial borne pathogens) pose formidable challenges to modern agriculture. Soil and seed borne pathogens encompass a range of microorganisms, including fungi, bacteria, nematodes, and viruses, which reside in soil or on seeds, waiting for the opportune moment to strike. These pathogens can lead to devastating diseases that compromise crop growth, yield, and quality. Aerial borne pathogens ride the wind currents, making them formidable adversaries for crops. They can infect plants through leaves, flowers, or even the stomata, leading to diseases that cause leaf spots, blights, and reduced photosynthesis.

However, through the lens of phytobiomes, we gain new insights and tools to tackle these threats head-on. By nurturing diverse and beneficial microorganisms within the phytobiome, we can create a natural defense system that not only suppresses pathogens but also fosters resilient and sustainable agricultural systems (Verma *et al.*, 2018).

1. Harnessing Phytobiomes To Combat Soil and Seed Borne Pathogens:

- ***Fusarium* Wilt:** *Fusarium* wilt affects numerous crops, including tomatoes, bananas, and cotton. Harnessing the power of phytobiomes involves encouraging beneficial microorganisms to suppress *Fusarium* pathogens, preventing their entry into plants and mitigating disease progression.
- ***Rhizoctonia* Root Rot:** *Rhizoctonia* root rot plagues crops like beans, potatoes, and sugar beets. By nurturing a balanced phytobiome, we can create an environment that suppresses the growth of *Rhizoctonia* and enhances plants' natural defenses.
- **Nematode Infestations:** Nematodes, microscopic worms, are notorious for causing root damage. Through phytobiome interventions, the soil can be enriched with antagonistic microorganisms that reduce nematode populations, limiting their destructive impact.

Applying Phytobiomes to Soil and Seed Borne Pathogens:

- **Bio fumigation:** Certain plants, like mustard, release natural compounds when grown, acting as biofumigants that suppress soil borne pathogens. Incorporating these biofumigant crops into crop rotations can help manage diseases like clubroot in brassicas.
- **Seed Coating:** Treating seeds with beneficial microorganisms before planting can establish a protective shield against seed borne pathogens. This approach has shown promise in reducing diseases like damping-off in young seedlings.

2. Harnessing Phytobiomes to Combat Aerial Borne Pathogens:

- **Late Blight in Potatoes and Tomatoes:** Late blight, caused by a water mould, threatens potato and tomato crops. Manipulating the phytobiome involves promoting the growth of beneficial microbes that outcompete the pathogen, thereby reducing its impact.

- **Powdery Mildew in Cucurbits:** Powdery mildew affects cucurbits such as pumpkins and cucumbers. Harnessing the phytobiome can involve introducing beneficial fungi that actively parasitize the powdery mildew pathogens

Applying Phytobiomes to Aerial Borne Pathogens:

- **Microbial Sprays:** Applying sprays containing beneficial microorganisms onto crops can create a protective barrier against aerial pathogens. These microorganisms can crowd out the pathogens or produce compounds that inhibit their growth.
- **Enhanced Plant Defense:** Phytobiome management can bolster a plant's natural defense mechanisms. For instance, certain beneficial microbes can induce systemic resistance, making the plant less susceptible to aerial borne diseases.

Examples of Successful Phytobiome Interventions:

- ✓ **Wheat Rusts:** Wheat rusts, caused by fungal pathogens, are a perpetual threat to wheat crops worldwide. Utilizing beneficial microorganisms within the phytobiome could potentially prime wheat plants' defenses against these pathogens, reducing the need for frequent fungicide applications.
- ✓ **Rice Blast:** Rice blast, caused by a fungus, is a major concern for rice cultivation. The phytobiome approach can help promote the growth of antagonistic microorganisms that suppress the rice blast fungus, thereby curbing disease spread. For instance, the application of specific strains of bacteria, such as *Bacillus* spp., can trigger systemic resistance against rice blast disease, a major threat to global rice yields. This strategy has demonstrated both disease reduction and yield enhancement.
- ✓ **Rice Bacterial Blight:** Bacterial blight is a serious threat to rice. Manipulating the phytobiome by introducing beneficial bacteria can activate the plant's immune responses, offering protection against bacterial blight.
- ✓ **Maize Diseases:** Maize crops suffer from diseases such as *Fusarium* ear rot and northern corn leaf blight. Enhancing the diversity of microorganisms within the phytobiome can lead to the development of natural disease-suppressive environments that limit the impact of these diseases.
- ✓ **Biocontrol Agents for Cotton:** Cotton crops are vulnerable to various pathogens, including fungal wilts. Researchers have successfully introduced beneficial fungi into the phytobiome, which compete with and inhibit the growth of pathogenic fungi, resulting in reduced disease incidence.
- ✓ **Soybean Cyst Nematode:** Soybeans are plagued by nematode pests that stunt growth and reduce yields. Through the manipulation of the phytobiome, researchers are exploring the potential of beneficial nematodes to suppress the soybean cyst nematode population.
- ✓ **Tomato and Soil-Borne Pathogens:** Tomato crops are susceptible to soil-borne pathogens that cause root diseases. By manipulating the phytobiome through cover cropping or introducing specific microorganisms, researchers have achieved disease reduction and improved yield.

- ✓ **Grapevine Downy Mildew:** Downy mildew is a constant threat to vineyards. Through the manipulation of the phytobiome, researchers have identified specific bacteria that help vines resist the pathogen, reducing disease incidence.
- ✓ **Apple Scab:** Apple scab, caused by a fungus, impacts apple orchards. By fostering beneficial microbial populations on apple leaves, researchers have managed to suppress the development of apple scab lesions.
- ✓ **Citrus Greening Mitigation:** Huanglongbing (HLB) or citrus greening is a devastating disease affecting citrus crops. Research into the phytobiome has identified microorganisms that play a role in suppressing the HLB-associated bacterium, offering potential solutions for disease management.
- ✓ **Vineyards and Grapevine Diseases:** In the vineyards of France, researchers have explored the phytobiome to combat grapevine trunk diseases. Certain fungi that are beneficial to grapevines have been identified as potential antagonists to pathogenic fungi causing these diseases.
- ✓ **Maize and Nutrient Uptake:** In maize cultivation, certain fungal species within the phytobiome form symbiotic relationships with plant roots, enhancing nutrient uptake, especially phosphorus. This has the potential to reduce the need for synthetic fertilizers.

Conclusion:

Phytobiomes represent a paradigm shift in agriculture, recognizing the power of diverse microbial communities to shape plant health and resilience. Disease management in major field crops is a critical challenge in modern agriculture. Phytobiome-based interventions offer a novel approach to mitigate the impact of crop diseases while fostering sustainable agricultural practices. By understanding and harnessing the intricate interactions within the phytobiome, we have the opportunity to fortify crop health, ensure food security, and cultivate resilient agricultural systems in the face of evolving disease threats. The phytobiome narrative presents a compelling path towards sustainable and productive crop cultivation, where diversity becomes our greatest asset in the fight against crop diseases.

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Aspergillus infection in Silkworm: Mode of Action, Symptoms and its Management

Arasakumar, E[1]., Manimegalai, S[1]. Jeyamurugan, [1] Vasanth, V[1] and Priyadharshini, P[1]

[1]*Department of Sericulture, Forest College and Research Institute, Tamil Nadu Agricultural University, Mettupalayam – 641 301.*

Corresponding author: arasu20595@gmail.com

Introduction

In tropical countries like India the success of silkworm rearing depends upon the protection of crop from the disease causing pathogens. In temperate sericulture regions ideal climate, superior quality of mulberry leaves and restricted number of rearing in a year reduces the chance of disease incidence. The reason for outbreak of silkworm diseases in India includes continuous rearing throughout the year, availability of large population of different stages in a limited area, inferior quality of mulberry leaves and unhygienic rearing condition etc. Disease outbreak not only affects the income of the farmers but also scuttles the seed cocoon and silk production plans. Domestication for the past several thousand years has rendered the silkworm, highly susceptible to different pathogens leading to diseases and crop loss. Different micro-organisms such as viruses, bacteria, fungi and microsporidia cause infectious diseases in silkworm.

Aspergillosis

Aspergillosis is a major silkworm disease in several sericultural countries. This is caused by a number of Aspergillus species of fungi. This disease is commonly called `Kojickabi' in Japan and also known as brown muscardine. Many aspergillus species have been reported to infect silkworm. More than 10 species of Aspergillus were reported from Thailand, Indonesia, Srilanka and India as pathogenic to silkworm, viz., *A. flavus, A. tamari, A. oryzae, A. niger, A. ochraceus, A. sojae, A. fumigatus, A. nidulans, A. flavipes*, A. *clavatus, A. terreus, A. melleus, A. elegans, A. parasiticus,* etc. *A. flavus* Link and *A. tamari* Kita are most common in India. *A. bombycis* Peterson is a recently described species known only from domesticated silkworm culture in Indonesia and Japan.

Aspergillus is a facultative fungus and is able to live saprophytically in the silkworm rearing environment like soil surface and rearing appliances, silkworm faeces etc. These form the source of the fungus and thus disease spreads rapidly. Though Aspergilli are saprophytic, they are reported to be pathogenic to several insects in addition to *Bombyx mori*. The early instars first and second instar silkworm larvae are more susceptible and later stage silkworms are fairly resistant to this disease. High temperature and high relative humidity conditions maintained during young stage are reportedly contributing factors to greater disease incidence during young age. *Aspergillus flavus* Link and *Aspergillus tamarii* Kita are commonly found strains in India.

Systematic position of the pathogen

The Genus Aspergillus belongs to the Family *Trichocomaceae*, Order *Eurotiales*, Class *Eurotimycetes*, Phylum *Ascomycota*, Kingdom fungi and Domain Eukarya. Though there are hundreds of species of *Aspergillus*, all are not pathogenic to silkworm. The systematic position of the genus is:

Domain: Eukarya
Kingdom: Fungi
Phylum: *Ascomycota*
Class: *Eurotiomycetes*
Order: *Eurotiales*
Family: *Trichocomaceae*
Genus: *Aspergillus*

Mode of infection of Aspergillus

Majority of aspergilli grow well and sporulate abundantly at 23 - 26°C. Temperature between 30 - 35°C for Aspergillus flavus and 20°C for *A. tamarii* are congenial for good growth. The thermal death point is 54°C for *A. flavus* and 55°C for *A. tamarii*. According to Kawakami temperature range of 28 - 30°C and relative humidity from 85 to 95% favours the growth of silkworm, which in turn is congenial for aspergillus development. 100% mortality occurs at all combinations of temperature (20, 25 and 30°C) with humidity levels (80, 85, 90 and 95%).The disease development is slow at low temperature and more rapid at high temperature.

Aspergillus spp. infects the silkworm through the integument. The conidia are the infectious units and these on coming in contact with host-integument under congenial conditions of temperature and humidity germinate to put forward the germ tube that penetrates through integument.

The penetration is generally observed in the inter-segmental region, the top of leg, the connecting part of seatae and around spiracles. In the low pathogenic fungi, the penetration is significantly delayed or unable to penetrate the larval integument. The germ tube after entering through the epithelium branches at the spot of entry. At the point of entry black marking may be noticed. The fungus does not form short hyphae as in case *of B. bassiana* and grows only at the site of infection and finally the larva dies due to the secretion of aflatoxin. At the hardened site, aerial hyphae protrude to form the conidiophores. The conidiophores are thick and expand into a globular or oval structure called apical vesicle, bearing 1-2 rows of radiating sterigmata. The conidia attach in chains to the sterigmata. The conidia are light and are easily dispersed to spread the disease.

Symptoms of Aspergillus infection

Aspergillosis is caused by various species of *Aspergillus*, the symptoms are not always same. Young silkworms are very much susceptible, compared to the mature worms.

- Infected larvae stop feeding, become letharginc, show body tension and lustrousness and the victim die soon due to Aflotixin produced by the fungus in the host.

- Aerial hyphae appear a day after death and later conidia cover the body giving particular colour according to the Aspergillus species.
- Hardening of the body is limited to the site of infection and the rest of the body decay. Diagnosis of the disease is based on the hardening of the corpse and the morphology of the hyphae.

Physiological changes in infected silkworm larvae

The pathogen has been observed to produce kojic acid (C6H6O4). The virulence of the strain of *A. flavus* and their resistance to formalin is related to the production of Kojic acid. Two toxic fractions also have been isolated from *A. flavus* that kills the larvae of mosquitoes *Culex peus* and *C. tarsalis*. The Aspergillus species also produce toxins called aflatoxins. The aflotoxins are very potent carcinogens and produce tumours primarily in the liver of vertebrates, including human being Four aflotoxins B1, B2, G1 and G2 have been detected from *A. flavus*. Aflotixin B1 was highly toxic and G1 was moderately toxic to silkworm larvae. There is correlation between the presence of aflotoxin and the pathogenicity to the silkworm, their tolerance to formalin, and the ability to produce pigments. A strain of *A. flavus* in addition to aflotoxin, also produce two more toxins, cyclopiazoic acid (indole tetramic acid) and aflatrem (indole mevalonate metabolite). *A. ochraceus* which also infects silkworm produces destruxins. Toxins produced by *A. fumigatus* include fumagillin, helvolic acid, fumitremorgins, phthioic acid and gliotoxin among others.

Incidence and loss

The percentage of disease incidence ranged from 5.32 (February-March) to 21.36% (July-August). Incidence of Aspergillosis is more during June and August and less during September. The disease is noticed on first to third instar larvae during January to February and on fourth and fifth instar larvae during July. The maximum crop loss per 100 layings (50000 larvae) was 1.35±0.73 to 1.61±1.46 kg cocoons. Incidence was higher in bivoltine silkworm rearing than in multivoltine and cross breed.

Disease management

- Preventive measures such as disinfection and hygiene maintenance in the rearing environment is the best way to keep the disease at bay.
- Many studies have proved that many *A. flavus* strains are resistant to formaldehyde (CH2O). The use of disinfectant should be judiciously chosen.
- Sodium penta chloro phenoxide monohydrate as a disinfectant against Aspergillus fungi invaded into rearing tools was more effective than 3% formalin.
- Benzalkonium chloride, iodine disinfectant, benzalkonium chloride + dodecyl diaminoethylglycine, didecyl dimethyl ammonium chloride, etc are proved to be effective.
- In vitro studies by Graham and Graham have shown that, mycelial growth and toxin production by A. parasiticus were inhibited by garlic concentration of 0.3 - 0.4%.

- Sun drying of rearing equipments is an effective way of destroying Aspergillus pathogens to some extent.
- Sick worms discovered before conidification should be incinerated or placed in lime jars and never thrown around indiscriminately.
- The faeces and bed refuses should be disposed properly and disinfection with anti muscardine powder should be carried out immediately.

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Status of agricultural labourers: An overview

M.Deepika

Gandhigram Rural Institute (Deemed to be University), Dindigul, Tamil Nadu

Corresponding author: dpsrish@gmail.com

Introduction

Agricultural labourers are mostly landless and form a significant section of rural society who mainly dependent of wage employment on agriculture. Unlike the industrial worker who are well organized, Agricultural labourers are neither well organized nor well paid. Their income is low and irregular employment . They are mostly assetless, illiterate, and socially backward .

Classification of labourers

- **Attached labourers** are those workers who are attached to some other farmer households on the basis of a written or oral agreement. They work both in the house and farms of their masters

- **Casual labourers** are those workers who are free to work in any farm on the payment of daily wages.

In India casual labourers are small farmers having a very small size of holdings who devote most of their time working on the farm of others. They are also landless labourers who exclusively work for others. They are often called astenants who work on leased land but work most of the time on the land of others.

- **Waged agricultural labourers**
  - Permanent(Full time workers)
  - Temporary or casual
  - Seasonal agricultural workers
  - Migrant agricultural workers
  - Piece-rate workers
- **Non waged workers** – They are family workers

Opinions on agricultural labourers

- **Vetrivel V and Manigandan R. (2015)** According to ILO, about 1,70,000 agricultural workers were each year run out its means due to the high risk in agricultural sector as compared to the workers in other sectors.

- Further, they pointed out that agricultural mortality rates have remained consistently high in the last decades as compared with other sectors.

- They concluded that in order to confirm sustainable agricultural development in the new minimum, rural workers and their families should have access to adequate health facilities

- **Sunita AS and Srija and SS Vijay (2015)** Economy transforms from an agricultural economy to an industrial economy decline in participation of female labours force has been observed.
- Declining fertility rate, caring of child and other factors which have caused for the decline of women participation in outer works in India
- **Venkateshwarlu & M. Ramakrishna Reddy (2017)** The agriculture labour is counted in the category of unorganized sector so the income is not fixed they are not covered any insecure and full uncertainty in their earnings
- **Sawant T.R (2017)** Agricultural labours' condition is not good in India and government should twice its budgetary allocation to improve the condition of agricultural labours

Causes of agriculture labour growth

- Increase in population
- Growth of indebtness due to low income from marginal land holdings
- Displacement means of subsidiary occupation
- Decline of cottage industries and handicrafts
- Uneconomic land holdings

Women agriculture labourers

- Agriculture sector employs 4/5th of all economically active women in the country.
- Triple marginalization of women farm workers.
- Exploitation, long works hours, unhealthy working condition, insecurity of Job, low wages, health hazards and low socio economic status etc

"If women had the same access to productive resources as men, they could increase yields on their farms by 20-30%."   -UNFAO, 2018

What could make them better?

- Technology advancements in designing tools
- Knowledge in veterinary yield better results
- Skill development programs
- Policy emphasis must be to recognise equal pay

Migrant farm labourers

- Migrant farm labourers are another unnoticed and most exploited sector
- Unemployment ,Under employment,poor infrastructure in rural areas,Low wages, job insecurity, poverty were the pushing factors for their migration.

Drudgery and hazards of agricultural labourers

The intensity of work, referred to as work severity categorization, was expressed in terms of the energy demand relative to ones aerobic capacity (VO2 max)

Industrial health, 2014

- (<25% VO2 max) - light work
- (26-50% VO2 max) - moderate work

- (51-75% VO2 max) - Heavy work
- (>75% VO2 max) - Extremely heavy work
- Most of the farm works require about 38 to 75% of energy
- On average, the work severity of agricultural labour ranges from Moderate to extremely heavy work.

Condition of agricultural labourers in India

- Most exploited unorganised class of the rural population of the country.
- In the beginning landlords and zamindars exploited and converted some of them as slaves or bonded labourers and forced to continue the system generation after generation.
- After 70 years of independence, the situation has improved.
- But they remain largely unorganised, and as a result their economic exploitation continues. Their level of income, standard of living and the rate of wages have remained abnormally low.
- Agricultural wages are very low
- Level of agricultural wages prevailing in india is very poor and thus the living conditions of agricultural labourers in india are indeed pathetic.

Conclusion

- Better implementation of legislative measures
- Improving the bargaining position
- Resettlement of agricultural workers
- Creating alternative sources of employment
- Protection of women and child labourers
- Public works programmes should be for longer period in year
- Improving working conditions
- Regulations of hours of work
- Credit at cheaper rate of interest on easy terms of payment for undertaking subsidiary occupation
- Proper training for improving the skill of farm labourers

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Augmenting Livelihood Security through Urban Agriculture during Covid -19

M.Deepika

Gandhigram Rural Institute (Deemed to be University), Dindigul, Tamil Nadu
Corresponding author: dpsrish@gmail.com

Introduction

Urban agriculture, urban gardening or urban farming is the practice of cultivating, processing and marketing of food and food products in and around urban localities. According to the reports of FAO, by 2030, 60 per cent of the people in developing countries will likely live in cities. The minimal land available in heavily populated town or so called concrete jungles are utilized for cultivation of crops. Alleviates poverty and reduces food insecurity resulting from urbanization at the sametime improve the health of residents and conserving the environment.

Classification

Vertical farming

It is practice of growing crops in vertically stacked layers – lined vertically. This type of farming attempt to produce food in challenging environment like where there is minimal space or no land area for farming.

Kitchen Gardening

Growing of vegetables and Herbs for everyday use in and around domestic sector.The main objective of kitchen garden is to maximise the output and continuous supply of vegetable throughout the year.

Roof top Gardening

Developing vegetables and herbs for family or society on the roof of a building. It mainly emphasise on utilization of vacant space . It reduces demand resilience

Street Landscaping

Empty lands next to the streets, roadsides, community garden avenues.It is mainly for education, entertainment.

Greenhouse farming

It is defined as unique farm practice of growing high value crops within the controlled environmental conditions. The main purpose is to protect crops from unfavourable weather and to get year round production

Urban bee keeping

It is the practice of keeping bee colonies in farms, cities or towns.. Maintenance of bee hives aids in pollination . It helps in production of honey and wax

Urban Agriculture and Pandemic

- Pandemic resulted in multiple challenges . During the pandemic conditions of COVID-19, it offers a more consistent food supply, prevented market disruptions, and helped with stabilizing food prices. It also helped people become physically stronger and spiritually enriched. It aid in localizing food shortages. It prevented people who lost the ability to provide support services and who lost income. It also helped in reductions in output because of reduced labor supply

Why Urban Agriculture matters during Pandemic ???

One of the alternatives that has the ability to reduce the effects of climate change and increase of demand of various vegetables and fruits in addition to food production is urban agriculture.

An increase in the number of young business people who quit their lucrative jobs to pursue urban agriculture, particularly hydroponics and aquaponics, where they may develop their technological expertise and enthusiasm for farming. Many companies, like iKheti and Earthoholics, reported a rise in the number of people who were interested in their online training, seminars, and information sharing on cultivating, composting, and managing gardens.

COVID-19 has inspired people, communities, and organizations in India to start urban gardening activities, whether as a pastime, a way to complement a nutritious diet with a few herbs and microgreens, or even as a possible new source of income. (Maitreyi Kodungati, 2021)

Agricultural extension services – During pandemic

- Bridged the gap of medical professionals in agriculture
- Safe labour practices by creating awareness via mobile phones, radio and television
- Motivating farmers to adopt labor saving practices

Immediate access to required agricultural technologies and digital Agri-solutions

- The dissemination of agricultural technology and digital agriculture through extension tools which linked farmers to buyers and logistic services
- Reduce the impact of control measures
- Indian government launched new application **"Kisan rath"-** April 18th 2020
- ICAR issued an agro advisory system to maintain hygiene and social distancing
- Toll-free help lines in local languages to answer the queries regarding government initiatives & for grievance purpose and other farming related information (Riti,2020).

Challenges in Urban Agriculture

- Soil quality: Poor soil quality is one of the key problems. The soil in metropolitan areas is frequently contaminated by chemicals generated from industry and automobiles, which can make it challenging to grow crops.
- Unreliable water supply is another issue that the framers must deal with. It might be challenging to get the water necessary to irrigate crops in locations with limited water supplies.
- Lack of space: There is frequently little space available for agriculture in metropolitan areas.
- Insect pests and diseases : Many insect pests and diseases that might harm crops are found in cities.
- High initial cost in the case of vertical farming
- Conflict with other urban activities like living and working.
- It might not be as healthful as anticipated.

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Stakeholder-Driven Fisheries Governance: Towards Sustainable Co-Management

Harsh Pandey[1*], Shrishti Sharma[2] and N. Karthik[1]

[1]Division of Fisheries Resource Management, [2]Division of Fisheries Resource Management, [2]Division of Aquatic Animal Health Management, Faculty of Fisheries, SKUAST-Kashmir, Jammu and Kashmir (190 006), India

**Corresponding email: harshpandeymfscfofy@skuastkashmir.ac.in*

Abstract

The article delves into the concept of fisheries co-management as an effective approach for sustainable governance of fisheries resources. It provides an in-depth exploration of the principles, benefits and challenges of involving stakeholders in decision-making processes. The chapter emphasizes the importance of collaboration, participation and adaptive management in fisheries co-management efforts. Through case studies and examples from different regions, the chapter highlights successful co-management initiatives and the lessons learned from these experiences. It also discusses the role of supporting institutions, policy frameworks and capacity building in empowering stakeholders and enhancing co-management efforts. The chapter underscores the need for continued support, capacity building and policy integration to ensure the long-term success of fisheries co-management. Overall, the chapter recommends valuable insights and practical guidance for policymakers, practitioners and researchers interested in promoting sustainable fisheries governance through stakeholder engagement and collaborative management approaches.

Keywords: Co-management, Fisheries, Stakeholders, Sustainable governance

Introduction

Fisheries co-management is a collaborative and participatory approach that recognizes the importance of involving various stakeholders in the decision- making process. Instead of relying solely on top-down directives from centralized authorities, co-management emphasizes the importance of local knowledge, community engagement and shared responsibility. It values the voices and expertise of fishers, local communities, government agencies and non-governmental organizations, recognizing that they possess valuable insights and a deep understanding of the intricacies of their respective fisheries. The rationale for adopting a participatory approach in fisheries governance is rooted in the belief that sustainable management of fisheries resources requires collective action and shared responsibility. Fisheries co-management involves stakeholders in a collaborative space, promoting sustainable practices and equitable distribution of benefits. This approach differs from centralized management, which often relies on top-down regulations and enforcement mechanisms. Fisheries co-management bridges the gap between policies and local needs by combining local knowledge, traditional practices and scientific expertise. This approach has transformative potential and emphasizes adaptive management, stakeholder collaboration and supportive policy frameworks. Stakeholder engagement and collaboration are essential pillars in shaping the sustainable future of fisheries resources. This section delves into the descriptive aspects of stakeholder engagement and collaboration, exploring the significance of involving a range of stakeholders in decision-making processes, the crucial role of building trust and partnerships and the value of local knowledge and traditional practices in co-management efforts. The significance of engaging a variety of stakeholders in decision-making processes is paramount; this serves as an essential foundation for fisheries co-management. This entails engaging fishers, local communities, government agencies, non-governmental organizations, scientists and other relevant groups. Each stakeholder brings a distinct perspective, knowledge base and expertise, thereby enriching the decision-making process. By involving a diverse range of stakeholders, co-management ensures the consideration of various interests, concerns and values, leading to more balanced and sustainable outcomes. Moreover, by including those who directly depend on the fisheries resources, co-management nurtures a sense of ownership and responsibility, augmenting the prospects for successful implementation and compliance with management measures. Establishing trust, cultivating partnerships, and promoting effective communication among stakeholders are essential components of successful fisheries co-management. Trust is essential for cooperation, allowing an atmosphere conducive to open discussion and collective problem-solving to thrive. Effective communication channels play a vital role in facilitating the exchange of information, knowledge and perspectives. Regular meetings, workshops and forums serve as valuable platforms for dialogue, enabling stakeholders to voice their views, comprehend divergent perspectives and collaboratively work towards shared goals. By fostering strong partnerships, including formal agreements or memoranda of understanding, co-management initiatives harness the power of cooperation, synergy and sustained collaborative efforts. Local knowledge and traditional practices play crucial roles in co-management efforts within fisheries. They are invaluable in guiding and informing decision-making processes. Fishers and local communities possess an intimate understanding of their fishing grounds, encompassing seasonal patterns, species behavior and ecosystem dynamics. This traditional ecological knowledge, accumulated over generations, complements scientific research and enriches decision-making processes. Recognizing and integrating local knowledge and traditional practices into participatory management not only improves the accuracy of management strategies, but also creates a sense of ownership and empowerment of local stakeholders. This ensures management measures are culturally appropriate while respecting the customs and traditions of the communities involved. As a result, compliance is improved and long-term sustainability is encouraged.

Rights-based Approach

A rights-based approach to fisheries management is an effective tool for ensuring sustainable resource use while balancing the interests of different user groups. This approach involves allocating and securing fishing rights, implementing Individual Transferable Quotas (ITQs) and managing community-based fisheries. ITQs allocate a portion of the total allowable catch to individual fisherman or organizations, providing a market-based, tradable fish stock management mechanism. ITQ encourages responsible fishing practices and promotes a sense of governance among rights holders. Community-based fisheries management empowers local communities to jointly manage and operate their fisheries resources, recognizing their rights and responsibilities and emphasizing their role as stewards of the resource. Balancing individual interests with conservation goals is a delicate challenge in rights-based approaches. While fishing rights can be economically beneficial and promote responsible practices, it is essential to ensure they do not affect the long-term health of fish stocks and ecosystems. Balancing individual interests with conservation requires setting clear conservation goals, setting science-based catch limits and implementing monitoring and enforcement measures to prevent overfishing and habitat degradation. This may involve designing management strategies that encourage collaboration, cooperation and adaptive management among rights holders, enabling them to jointly address conservation challenges while conserving their personal interests.

A rights-based approach to fisheries management is crucial for ensuring sustainable resource use and long-term viability of the fisheries ecosystem. By allocating fishing rights, implementing ITQs and balancing individual interests with conservation goals, these approaches promote sustainable resource use and long-term viability.

Adaptive Learning and Management

Adaptive management and learning form the backbone of effective fisheries co-management, allowing for continual improvement of management strategies in response to changing conditions. This section explores descriptive aspects of management and adaptive learning, including incorporating feedback loops and continuous learning into co-management processes, the importance of monitoring, evaluation and adaptive decision-making and the role of science, research and monitoring, adaptive management support programs. Incorporating feedback loops and continuous learning into co-management processes means using adaptive management to create a system where we regularly gather and use feedback to improve how we work together. It's all about fostering a culture of ongoing learning to make our co-management efforts more effective and responsive. This means actively seeking input and feedback from stakeholders, including fishermen, local communities and scientific experts, to assess the effectiveness of management measures and their impact on fisheries and ecosystems. Regular forums, seminars and collaboration platforms provide opportunities for stakeholders to share their knowledge, insights and experiences. By assessing and incorporating this feedback, co-management initiatives can tailor and refine management strategies, ensuring that they remain relevant to changing fisheries needs and challenges. Adaptive management means regularly monitoring and evaluating our actions in response to changing conditions. It helps us make better decisions as we learn and adapt along the way. Performance monitoring and evaluation are essential for this process to ensure we stay on track and make effective choices. By collecting and analyzing data on key indicators such as fish stocks, habitat health and socioeconomic factors, stakeholders can track the implementation of management actions and evaluate their impact. Monitoring provides valuable information on fisheries status, identifies emerging trends or issues and informs adaptive decision-making. Based on the information gathered, stakeholders can collaborate on revising management strategies, adjusting catch limits, implementing seasonal closures, or introducing new conservation measures. This iterative process of monitoring, evaluation and decision-making ensures that management approaches remain flexible and responsive to changing conditions, thereby safeguarding the long- term sustainability of the profession fish. The role of science, research, and monitoring programs in supporting adaptive management is crucial. These programs provide valuable insights and information that help us make better decisions and respond effectively to changing conditions. These initiatives generate the scientific knowledge and data needed for informed decision making. Scientific research provides insight into fish population dynamics, ecological interactions and the impact of fishing practices. By integrating scientific findings into co-management processes, stakeholders can make evidence-based decisions and take actions consistent with the best available knowledge. In addition, monitoring programs, such as fisheries monitoring, stock assessment and ecosystem surveys, provide the data needed to assess the effectiveness of management measures and identify areas where areas that need adjustment or additional research. Collaborative partnerships among scientists, regulators and stakeholders ensure that scientific research and monitoring efforts provide direct information for adaptive management approaches. The integration of feedback loops, continuous learning, monitoring, evaluation, adaptive decision-making and scientific knowledge enables stakeholders to navigate the complexities of fisheries co-management. By applying adaptive management principles, co-management initiatives can remain dynamic, responsive and resilient to changing challenges. This iterative process of learning, monitoring and adaptation improves the effectiveness of management actions, supports the sustainable use of resources and enhances the long-term sustainability of fisheries.

Examples of Successful Co-Management Initiatives in Different Parts of India

A look at successful co-management initiatives in different parts of India reveals inspiring examples about collaborative efforts. From coastal communities to inland fisheries, there are many examples of effective co-management. For example, the Kerala Fishery Resource Management Association (KPRMS) has successfully implemented a co-management approach in Lake Vembanad, involving fishermen, government agencies and researchers in the decision-making process. Similarly, in Odisha, the Lake Chilka Fisheries Cooperation Association demonstrated the benefits of community co-management to achieve sustainable resource use. Co-management in fisheries requires clear governance structures, effective communication channels and collaborative decision-making processes. Challenges in implementing co-management can arise from conflicts of interest, power dynamics and limited resources. Despite this, alternative approaches yield creative solutions, such as establishing platforms for dialogue and conflict resolution or developing livelihood options to reduce pressure on fishermen. Context-specific approaches and flexibility are crucial in co-management strategies, as they consider the ecological, social and cultural context of each fishery. Tailoring management practices to the fishery's needs ensures their suitability and effectiveness. By adopting context-specific approaches and flexibility, co-management strategies can better respond to the dynamic nature of fisheries, leading to more sustainable outcomes. Supporting institutions and policy frameworks is essential for effective fisheries co-management. Government agencies, NGOs and international organizations play a key role in facilitating and supporting co-management initiatives. Policy, legal and institutional frameworks provide the foundation for effective co-management, defining roles and responsibilities of different stakeholders. Training and capacity building programs aim to build the knowledge, skills and capacity of fishermen, local communities and other stakeholders to participate actively in co-management processes.

Socio-Economic and Environmental Outcomes

Assessing the socioeconomic and environmental outcomes of fisheries co-management is crucial for understanding its effectiveness and impact. This assessment involves evaluating factors such as increased incomes, livelihoods, food security and social and cultural well-being in fishing communities. However, real-world examples and rigorous logic reveal innovative solutions can measure the positive impact of co-management on poverty reduction, job creation and overall quality of life. The assessment of economic and social dimensions highlights the equitable distribution of benefits and empowers disadvantaged groups through co-management initiatives. Ecological resilience, biodiversity conservation and sustainable fisheries outcomes are also essential aspects of co-management. By integrating scientific knowledge, local knowledge and adaptive management approaches, co-management strategies can support the restoration and maintenance of fish stocks and ecosystems. These factors include women's participation and representation in decision-making, access to resources and benefits and recognition of rights according to custom and traditional knowledge. Real life examples can provide successful examples of co-management initiatives that prioritize gender equality, social justice and inclusivity, leading to equitable outcomes and more comprehensive strategies. In conclusion, assessing socioeconomic benefits, community welfare, ecological resilience, biodiversity conservation and gender equality and social justice in fisheries co-management is essential for developing effective strategies that promote sustainable fisheries, support thriving communities and ensure long-term ecosystem health.

Conclusion

In this chapter we have studied possible impacts of many aspects of fisheries co-management, emphasizing its importance for the sustainable management of fisheries resources. Key points discussed throughout the chapter provide valuable insight into the principles, strategies and outcomes of co- management initiatives. We value the importance of engaging diverse stakeholders in decision-making, building trust and partnerships and integrating local knowledge and information, traditional practices in co-management efforts. These factors ensure the comprehensive, effective and culturally appropriate management methods. These illustrate us the successful co -management initiatives in a variety of regions, demonstrating the positive socioeconomic and environmental outcomes achieved through partnerships and adaptive management. They emphasize empowering local communities, restoring fish stocks, conserving ecosystems and promoting sustainable livelihoods. It is clear that fisheries co-management is a powerful approach to promoting responsible resource use, community welfare and biodiversity conservation. By integrating science, local knowledge and adaptive decision-making, co- management offers a path to long-term sustainability and resilience. However, moving towards effective fisheries co-management is an ongoing process that requires ongoing support, capacity building and policy mainstreaming. Stakeholders at all levels, including government, NGOs, communities and researchers, must work together to strengthen co-management efforts. This involves strengthening institutions, providing resources for capacity building and training and integrating co-management principles into policy and regulatory frameworks. By applying the things learned, best practices and challenges discussed in this chapter, we can promote inclusive and adaptive fisheries resource governance. This is the way we can ensure a fair distribution of benefits, build ecological resilience and protect the livelihoods of present and future generations. Through collaborative efforts, capacity building and policy integration, we can booster a future where fisheries thrive, communities prosper and our natural resources are safeguarded for generations to outcome.

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Agriculture 4.0 - Emerging fourth wave revolution in Indian Agriculture

B. Srishailam
Agricultural Extension Specialist
Corresponding author: sribathini15@gmail.com

Agriculture plays a significant role in India's growing economy. With around 54.6% of the total workforce involved in agriculture and allied sector activities, the sector contributes to 17.8% of the country's gross value added (GVA). During 2021-22, the country recorded US$ 50.2 billion in total agriculture exports with a 20% increase from US$ 41.3 billion in 2020-21. It is projected that the Indian agriculture sector will grow by 3.5% in FY23. With the use of conventional farming methods, there's comparatively less improvement in efficiency and agricultural yields which resulted in lower productivity. Due to this concern, the government initiated the fourth wave of revolution in the agricultural sector to introduce technological advancement in these activities to improve yields and promote the involvement of the population in this sector. Agriculture 4.0 is a considerably advanced version of precision farming methods. It has the potential to transform the existing methods of farming. Precision farming focuses on a comprehensive approach towards maintaining the field and soil well-being with a focus on improving the quality and quantity of yield with minimum environmental harm. The idea of revolution in agriculture involves the use of the Internet of Things (IoT), big data, artificial intelligence, and robotics to accelerate and improve the efficiency of activities throughout the entire production chain. It has the potential to transform the conventional farming industry. Conventional farming practices control crop watering and spraying pesticides or fertilisers uniformly across the field. Instead, the farmers will need to be more targeted and data-driven in the context of farming. Future farms will be more productive owing to the employment of robotics, temperature and moisture sensors, aerial photos, and GPS technology. These cutting-edge methods will improve farm profitability, efficiency, safety, and environmental friendliness. They are together referred to as advanced or high-tech precision farming.

Around one-third of food produced for consumption which is worth over US$ 1 trillion is lost or wasted in transit. This leads to millions of people sleeping hungry every night. The UN World Food Programme reports state that the primary cause of rising hunger around the globe is food wastage or loss due to uneven handling of food. The concern about food wastage gave rise to the involvement of technology in agriculture to improve productivity and reduce wastage by proper handling of food. The data analytics and AI will help farmers to monitor the activities of seeds to the final crop. This will result in better yield and as a result, people will be involved in agriculture and eventually, the nation will target the least hunger issues. These challenges led to the introduction of Agriculture 4.0 wherein farmers won't be dependent on water facilities, fertilizers, and pesticides uniformly across entire fields. Instead, farmers will be suggested to use minimum quantities and target specific areas for different crops to get better productivity.

Prospects of Indian Agriculture: The continuous technological innovation in the Indian agriculture sector plays a critical role in the growth and development of the Indian agriculture system. It will be crucial for ensuring agricultural production, generating employment, and reducing poverty to promoting equitable and sustainable growth. Constraints include diminishing and degraded land and water resources, drought, flooding, and global warming generating unpredictable weather patterns that present a significant barrier for India's agriculture to grow sustainably and profitably. The future of agriculture seems to involve much-developed technologies like robotics, temperature and moisture sensors, aerial images, and GPS technology. Farms will be able to be more productive, efficient, safe, and environmentally sustainable owing to this cutting-edge equipment, robotic systems, and precision agriculture.
Various factors such as data analysis matrix and technological advancement in the existing agricultural machinery contribute to the production of food grains for consumption and commercial needs. The production of commercial food grain supports the economy and improves the GDP. Hence, the future growth of Indian agriculture appears to be growing with an upward graph which is backed by technological advancements and government initiatives.
Recent Trends in Agriculture: India's agriculture mainly depends on nature, however changing climate and global warming are making farming unpredictable. The need to use modern technologies to increase productivity and profitability led to the emergence of Agriculture 4.0 in India. There have been significant changes in India in the context of agriculture over the decades and many new technologies have been developed. Several new-age farmers are using soil mapping software as well to determine the optimum level of fertilizers used in the farms. These emerging technologies in farming and agriculture pave the way for more opportunities. The aggrotech start-ups and traditional farmers are also using the latest solutions and trends to improve production in the food value chain. It includes the adoption of new technologies such as cloud-based solutions and other relevant advanced agricultural management techniques to increase farmer efficiency and produce more crops.

Examples:

- Grape farmers in India who have begun spotting and geo-locating crop diseases or pestilence, allowing them to control infestations earlier and in a more precise manner. This also leads to lower use of harmful pesticides on the crop. Soil mapping software is used by several new farmers to determine the optimum level of fertiliser use in their farms. They are also using drones which allow spraying pesticides in a more targeted manner.

- Sugarcane farmers in India have started using technology to gauge the most appropriate time to harvest their crops, which allows them to better plan their harvest and maximise output. Several Indian farmers have also begun to use AI/ML-powered technologies to forecast crop yield, weather conditions and price trends in mandis. A few farmers have also begun testing self-driving tractors and seed-planting robots to free their farms from the vagaries of labour shortages.

- Emerging trends in the agricultural sector that are quite prominent in the post-liberalization era include increased production, increased investment, diversification of the sector, use of modern techniques, development of horticulture and floriculture, increasing volume of exports and development of the food processing industry. Some of the recent trends in agricultural technology:

Agricultural Drone Technology-

Drones are used widely for medical delivery to protection assistance and are used in agriculture to improve the growth of crops, maintenance, and cultivation methods. For example, these ariel carriers are used to access crop conditions and execute better fertilization strategies for more yields. Even the accessibility of hovering robots help farmers through a survey of large areas and data collection to generate better insights about their farms. Using drones in agriculture has provided more frequent, cost-effective remote monitoring of crops and livestock. It also helps analyse field conditions and determine appropriate interventions such as fertilizers, nutrients, and pesticides.

Diversification of Agriculture-

The agricultural sector produces generic consumption needs as well as crops like fruits, vegetables, spices, cashews, areca nuts, coconuts, and floral products such as flowers, orchids, etc. With the increasing demand for these products, there's a huge potential in terms of production and trade of these products. This shows how the agricultural sector is being transformed into a dynamic and commercial sector by shifting the mix of traditional agricultural products towards higher quality products, with a high potential to accelerate production rates.

The diversification in agriculture is being supported by changes in technology or consumer demand, trade or government policy, transportation, irrigation, and other infrastructure developments.

Increasing Trend in Horticulture Production-

The availability of diverse physiographic, climatic, and soil characteristics enables India to grow various horticulture crops. It includes fruits, vegetables, spices, cashew, coconut, cocoa, areca etc. The total horticulture production in FY22 is estimated at 342.333 million tonnes which is an increase of about 7.03 million tonnes (2.10% increase) from 2020-21.

Development of Agriculture in Backward Areas-

In the post-green revolution era, the introduction of new agricultural strategies, research, and technology was mostly limited to producing specific food grains, i.e., wheat and rice. However, under the wave of liberalization, with the growing demand for agricultural exports, many new sectors of agricultural activities have become favourable and profitable.

In some agriculturally backward areas with no irrigation system and access to fewer resources, dryland farming has been introduced. Other activities were also encouraged such as horticulture, floriculture, animal husbandry, fisheries, etc. To support the development in those areas, various modern techniques have been installed in the backward areas.

Ariel Imaging

Ariel imaging involves the use of geographic information system (GIS) technology to analyse the potential of irrigation projects and their impact on land degradation, erosion, and drainage. The visuals of this technology allow assessment of an individual plant's foliage. These visuals are actively used to detect pests and diseases to protect crops from environmental threats. It mostly helps farmers to monitor the soil conditions of farms and is useful in the summer season when there is the least availability of water.

Hydroponics and Vertical Farming

The concept of hydroponics farming focus towards better yields, texture, and taste of the final product with less water consumption. Plants which are grown hydroponically do not need extensive root systems and it allows them to contribute more energy towards the production of leaves and fruits. Because of indoor cultivation, these plants mature quickly and possess better immunity against pests and other diseases. In the context of sustainability, vertical farming allows farms to be located near or within areas of high population density which reduces the need for transportation and any harmful emissions. Vertical farming provides the ability to grow crops in urban environments and contributes to the availability of fresh foods conveniently. This farming significantly reduces the amount of land space required to grow crops compared to conventional farming methods.

IoT in Agriculture-

IoT supports agriculture through the installation of various sensors in agricultural farms. These sensors are used to monitor light, humidity, soil moisture, temperature, crop health, etc. Some of the major uses of IoT in agriculture are as follows:

- Various farm sensors such as autonomous vehicles, wearables, button cameras, robotics, control systems, etc help in the collection of data to analyse the performance of the farm.
- Use of aerial and ground-based drones for crop health assessment, irrigation, monitoring and field analysis.
- Use of tools to predict rainfall, temperature, soil, humidity, and other forecasted natural calamities.

Government Initiatives

The government has taken various initiatives to enable the potential digitalization of the agricultural sector in India. It focuses on promoting Agri-tech businesses which are working towards boosting productivity.

- The government has finalised an India Digital Ecosystem of Agriculture (IDEA) framework that will establish the architecture for the federated database of farmers. This database is being built by taking the publicly available data as existing in various schemes and linking them with the digitalized land records. The IDEA would serve as a foundation to build innovative Agri-focused solutions leveraging emerging technologies to contribute effectively to creating a better Ecosystem for Agriculture in India. This Ecosystem shall help the Government in effective planning towards increasing the income of farmers and improving the efficiency of the agriculture sector.

- To facilitate agricultural engineering research, operations, and technology diffusion, the Central Institute of Agricultural Engineering, Bhopal (ICAR-CIAE) of the Indian Council of Agricultural Research (ICAR) has created the Krishi Yantra App. A web portal has been made available by ICAR-CIAE on their website to guarantee that businesses choose the proper mechanisation technology. This aids current and potential business owners in choosing machines and purchasing options. The portal also offers the option of user and specialist engagement.
- Farm Safety app was developed by ICAR-CIAE which provides information about safety guidelines and Safety Gadgets to avoid accidents while using different types of agricultural machinery.
- A smartphone app called Water Balance Simulation Model for Roof Water Harvesting assists decision-makers in recommending design criteria. It provides that where the implementation of a roof water harvesting system may result in water savings and water security.

Conclusion: Agriculture is an important sector of the country. It is one of the market-driven industries that employ a large segment of the country's population. The new changes over the last few years have been enormously helpful to contribute more towards economic growth. Recent advancements such as drones, and data-driven facilities help to monitor the process of farming. It has been supporting farmers to increase productivity and contribute more towards the agricultural economy. The future of Indian agriculture seems bright and promising with the advent of new technologies. The government has increased its focus on the sector, implementing various policies and initiatives to boost productivity and growth. India's vast and diverse agricultural landscape, coupled with advancements in technology, provides immense opportunities for farmers to harness their potential and increase yield. In addition, start-ups in the agricultural sector are working towards providing innovative solutions to farmers in terms of supporting them with better productivity, measuring tools and other data-driven strategies.

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