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CRISPR/Cas9 BASED GENOME EDITING: A NEW ERA FOR THE FRUIT CROPS IMPROVEMENT

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Abstract
Fruit crops not only provide vital vitamins and nutrients for human livelihoods, but they also account for the majority of agricultural output in many nations. However, fruit quality and productivity deteriorated due to climate change, biological, and environmental factors, and anticipated hidden conflicts. Combining recently developed biotechnological techniques like CRISPR/Cas9-mediated genome editing with conventional breeding might exacerbate these issues. The possibility of genome editing with CRISPR/Cas9 as an exciting "game-changer" technique for the targeted improvement of fruit crops. It could lead to precise genome modifications without the insertion of foreign genes, therefore avoiding present GM laws. The technique has been effectively employed in numerous fruit crops, resulting in improved biotic and abiotic resistance, fruit quality, production, shelf life, and so on.

Keywords: Fruit quality, Productivity, Climate change, CRISPR/Cas9, GM regulations

Introduction
Fruits share a vital part essential of the human diet as they are appealing, nutritious, medicinal, and have cultural significance. Fruits and fruit-based products are key sources of critical nutrients like vitamins and minerals, phytonutrients (antioxidants), dietary fibres, and bioactive phytoconstituents. Due to their high commercial value and use as a raw material for several processed foods and secondary things, they play a significant role in the global agricultural economy and main production of many nations and regions. However, a wide range of biological and environmental factors, such as abiotic and biotic stresses, short shelf life, highly heterozygous genomes, uncontrolled fruit ripening, reduced fruit quality, and the scarcity of arable land, etc. hinder the production of fruit crops. Therefore, there is an urgent need to improve fruit crop sustainability and production through scientific and technical improvements. The production of fruits with higher quality is strongly linked to the fruit industry's profitability. Prior major scientific advancements were mostly made in fruit crop development using conventional methods of breeding (Penna *et al*., 2023). Even so, conventional breeding needs a lot of labour and time, and their ability to use the existing germplasms is restricted (Kumari*et al*., 2022; Penna *et al*., 2023). In comparison to conventional approaches, biotechnology has provided enormous scope and promise for crop improvement, crop protection, crop quality management, and other horticultural trait modification (Parmar *et al*., 2017). Although this technology caused a lot of controversy shortly after it was introduced, primarily because of safety and ethical concerns,

transgenic plant breeding has advanced quickly over the past century and has emerged as one of the most promising ways to combine several elite traits in one variety (Ma *et al.*, 2023). The development of novel and intriguing molecular approaches, in particular the creation of genome editing technologies based on CRISPR Cas9, proved to be a breakthrough, offering novel tools for enhancing fruit crops and bringing about swift advancements that might potentially lead to a revolution in the fruit industry.This method has been created to produce exact genome alteration without introducing foreign genes, hence obtaining desired plant features. It is simple, adaptable, inexpensive, highly efficient, and versatile (Ma *et al*., 2023). It consists of RNA-guided designed nucleases that identify the corresponding nucleotide sequences in the target sequence (genes) (Zhou *et al*., 2020). The CRISPR/Cas9 genome editing technology will most likely avoid the current GM regulation mechanisms because the CRISPR/Cas9 cassette is not inserted into the genome and Cas9 protein-guide RNA complexes decompose rapidly in regenerating cell cultures, broadening the utility of this technology and increasing its global acceptance levels in comparison to other transgenic technologies. This technique has been effectively utilised in a variety of fruit crops, improving disease resistance, fruit quality, production, and shelf life, among other benefits.Here, we primarily address the mechanism and current state of CRISPR/Cas-9-based genome editing in several fruit crops.

Mechanism of CRISPR/Cas9 Based genome editing

CRISPR/Cas9 originated from a bacterial defensive mechanism against invading bacteriophages and plasmids, in which it cleaves foreign DNA in a sequence-dependent way (Wiedenheft *et al.,* 2012). The mechanism involves the Cas9 endonuclease binding with single-guide RNA (sgRNA), which is a fusion of crRNA and tracrRNA, and is based on RNA-guided designed nucleases. It is complementary to a DNA sequence unique to the target in an area where a protospacer adjacent motif (PAM) is present. Double-stranded DNA breaks (DSBs) are caused by the particular cleavage of target DNA by Cas9 nuclease in the PAM region, which is directed by the sgRNA/gRNA. Two distinct DNA repair processes, homology-directed repair (HDR) and non-homologous end joining (NHEJ), are activated by double-strand breaks (DSBs) (Erpen-Dalla Corte *et al*., 2019; Alvarez *et al*., 2021).The NHEJ repair mechanism typically results in minor insertions, deletions, or substitutions that progressively alter the genome and impair gene function; it does not require a homologous repair template. It is the most common and usually leads to loss of function in proteins or to gene knockout. In contrast, the insertion, mutation, or replacement of DNA segments by the HDR repair pathway necessitates the use of a homologous DNA template (Erpen-Dalla Corte *et al*., 2019).

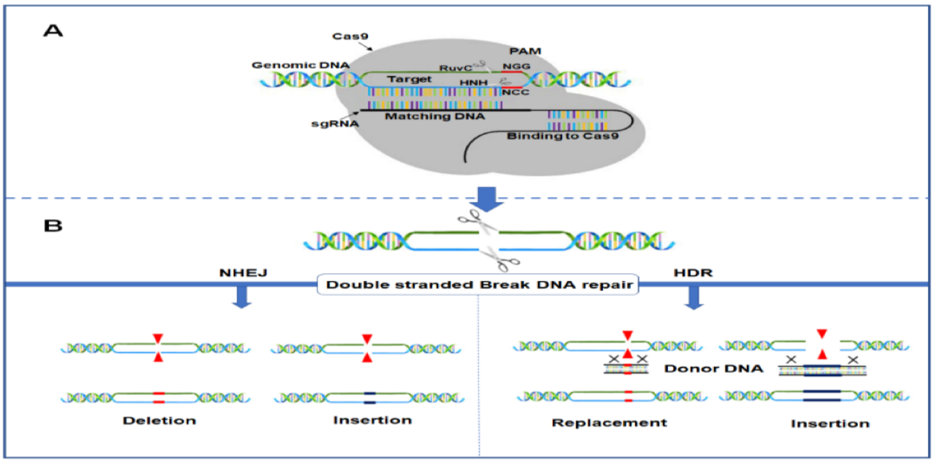

Figure 1. Mechanism of CRISPR/Cas9 based genome editing. (Erpen-Dalla Corte *et al*., 2019)

Application of CRISPR/Cas 9 mediated genome editing in fruit crop improvement

The CRISPR/Cas9 technique was first used to modify plant genomes, as reported in 2013. It has been effectively tried for improving fruit crops including apple, banana, citrus, grape, kiwifruit, and pear, papaya, blueberry etc. in terms of yield, quality trait, resistance to biotic and abiotic stress, and nutritional content. One of the most widely used methods for customising fruit crops is genome editing using CRISPR/Cas 9. This technique can be used to modify single or multiple genes, as in the case of the apple developed semi-dwarf rootstock cultivar 'JM2' (which modifies the apple phytoene desaturase (PDS) gene, fire blight resistance (DIPM1, DIPM2, and DIPM4), albino phenotype and early flowering (PDS and TFL1.1), fire blight resistance (MdDIPM4), and increased anthocyanin content by down-regulating nitrogen transporters (MdMKK9In the case of bananas, many properties are addressed by changing distinct genes, including the albino phenotypic and dwarfing, control of viral pathogenesis, dwarf phenotype, better shelf life, and carotene production. Likewise, multiple genes have been altered using CRISPR/Cas 9 in the case of other fruits like grapes, citrus, papayas, pears, and blueberries to specifically increase various aspects like yield, quality, fortification, resilience to biotic and abiotic challenges, etc. A summary of CRISPR/Cas9 mediated genome editing in fruit crops for yield, quality and nutritional improvement is presented in Table 1.

Table 1. CRISPR/Cas9 mediated genome editing in fruit crops yield, quality and nutritional improvement. (Dongariyal *et al*., 2022; Maria Lobato-Gómez *et al*., 2021; Zhou *et al*., 2021; Ma *et al*., 2023)

Fruit crops	Fruit species/cultivars	Target gene	Improved Traits	References
Apple	JM2	PDS	Enhanced biosynthesis of Carotenoid	Nishitani *et al*. 2016
Apple	Golden Delicious	DIPM - 1, 2 and 4	Increase resistance to fire blight disease	Malnoy *et al*. 2016
Apple	Gala	PDS and TFL1.1	Albino phenotype, early flowering	Charrier *et al*. 2019
Apple	Gala	MdDIPM4	Fire blight resistance	Pompili *et al*. 2020
Apple	Gala	MdMKK9	Increased anthocyanin content by down-regulation of nitrogen transporters	Sun *et al*. 2022
Banana	Cavendish-Williams	PDS	Albino Phenotype and dwarfing	Naim *et al*. 2018
Banana	Gonja Manjaya	eBSV	Control of virus pathogenesis	Tripathi *et al*. 2019
Banana	Gros Michel	MaGA20ox 2	Dwarf phenotype	Shao *et al*. 2020
Banana	Grand Naine	LCYε	Carotene biosynthesis	Kaur *et al*. 2020
Banana	Brazilian	MaACOI	Improved shelf life	Hu *et al*. 2021
Grapefruit	Duncan	CsLOB1	Citrus canker resistance	Jia et al. 2017

Fruit crops	Fruit species/cultivars	Target gene	Improved Traits	References
Sweet orange	Wanjincheng	CsWRKY22 PDS, L0B1	Citrus canker Resistance	Wang *et al*. 201; Jia *et al*. 2017
Citrus maxima	_	CsLOB1	Citrus canker resistance	Jia and Wang, 2020
Sweet orange	EV2	*pC-PDS1 and Pc-PDS2*	Increased chlorophyll and carotenoid content	Dutt *et al*. 2020
Sweet orange	Hamlin	CsLOB1	Citrus canker resistance	Huang *et al*. 2022
Sweet orange	N7–3	CsNPR3	Induced biotic stress tolerance mediated by high lipid biosynthesis	Mahmoud *et al.* 2022
Grapefruit	_	ALS	resistant to the herbicide	Huang*et al*, 2022
Grapes	Chardonnay	IdnDH,LOC00232980	Reduced L tartaric acid biosynthesis and increased Vitamin C content	Ren *et al*. 2016
Grapes	Thompson Seedless	VvPR4b	Downy mildew resistance	Li *et al*. 2020
Grapes	Thompson seedless	VvMLO3	Powdery mildew resistance	Wan *et al*. 2020
Grape	--	vvccd8	Plant architecture development (increased shoot length)	Ren *et al*. 2020
Grapes	Pinot Noir	TMT1 and TMT2	Reduced sugar accumulation	Ren *et al*. 2021
Vitis amurensis	--	PAT1	Abiotic stress tolerance (cold response)	Wang *et al*. 2021
Kiwifruit	Hongyang	AcPDS	Albino phenotype (leaves)	Wang *et al*. 2018
Kiwifruit	Hort16A	AcBFT2	Reduced dormancy and early bud break	Herath *et al*. 2022
Pear	Conference	TFL1.1	Early flowering	Charrier *et al*. 2018
Pear	Dull (*Pyrus bretschneideri*)	PbPAT14	Dwarf yellowing phenotype	Pang *et al*. 2019
Papaya	Sunrise	alEPIC8	Resistanceagainst Phytophthora palmivora	Gumtow *et al*. 2018
Strawberry	Hawaii 4	FveTARs and FveYUCS	Enhanced auxin biosynthesis	Feng *et al*. 2019
Strawberry	NingYu	RAP	Fruit colour breeding (White fruited strawberry)	Gao *et al*. 2020
F. vesca	Ruegen (red	FveSEP3	Produced parthenocarpic	Pi *et al*. 2021

Fruit crops	Fruit species/cultivars	Target gene	Improved Traits	References
	fruited), Yellow Wonder, Hawaii 4 (white fruited)		fruits because of repressed flower organogenesis and fruitdevelopment.	
F. vesca	-	bZIPs1.1	Fruit quality improvement (Increased sugar content)	Xing *et al*. 2020
Blueberry	O-Neal (ON) and Blue Muffin(BM)	CENTRIRADI ALIS	Genetic transformation efficiency improvement	Omori *et al*. 2020

Conclusion

In addition to offering the possibility of new commercial fruit varieties with enhanced flavour and nutrient-rich fruit, resistance to biotic and abiotic stresses, and modified flowering and ripening times, the development of new molecular breeding technologies like CRISPR/Cas 9 mediated genome editing not only efficient technology also helps to alleviate some of the regulatory barriers that impede the cultivation of first-generation transgenic crops.Certain genome-edited cultivars are exempt from GMO laws in certain regions. With the use of these methods and instruments, fruit cultivars with qualities that meet the demands of growers, distributors, and consumers may be developed more quickly while still being ecologically benign.

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TRANSFORMING AGRICULTURE: THE IMPACT OF DRONE TECHNOLOGY ON CROP MANAGEMENT AND FARMING PRACTICES IN INDIA

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Abstract

The agricultural sector, supporting around 65% of India's population, plays a pivotal role in the country's economic growth. This article explores the transformative role of drone technology in Indian agriculture, focusing on its applications in precision farming. Drones are employed for diverse operations, including crop monitoring, topographic mapping, soil health analysis, seedling processes, deficiency analysis, and crop fertilization. The flexibility and efficiency of drones have revolutionized tasks such as fertilizer spraying, seed planting, and deficiency identification. The article highlights how drones contribute to precision agriculture, improving crop yield, reducing costs, and providing real-time data for informed decision-making.

Introduction

Agriculture industry sets the livelihood is about 65% of the population of India, directly or indirectly. The Agricultural Industry is the deep-rooted in the systems that its growth affected heavily the Gross Domestic Product (GDP) of our country. Drone technology and applications has brought about improvement in progress, saving time and input or cost.

As a part of the agriculture industry, drones are employed for different operations like mapping of land, inspection of lant, monitoring of the field, spraying fertilizers in field, checking for various diseased or rotting crops, and much more. The diverse kinds of drones are tested to determine the most creative space in agriculture practices, horticulture practices, and different farming practice. For crop fertilization, drones are the most favorable owing to their multi-rotors. Fixed-wing drones suit the determination of crop fertilization, their large structure needful a large space for take-off and landing comes in the way.

Spraying of Fertilizer with the Help of Drone

One of the most serious uses of drones in agriculture is its flexibility to move around in the different motions and locations that is choose or desired. This competence of drones helps to spray fertilizers and insecticides to the crops and provide them with the demanded nutrients. it helps to allow crops to be healthy. The drone operators are free to control monitor and easy to use the drone spraying fertilizers that keep different insects, pests and diseases and increase the crop life longevity.

Monitoring of Soil Health with the Help of Drone

The capabilities of drones help in the different primitive operation for analyzing the soil health properly. In essence, UAVs are collecting and to process the data that are received from monitoring that can help to check, to control, and to the maintenance of the soil's health and nature of the soil that is good for description of soil. Drone technology also provide the essential or important nutrients to the soil to improve their health and fertility. Through their operations of 3D mapping and the processing of data, drones attain this operation of analyzing soil health.

Seedling Process

Agriculture is a highly exhaustive industry because it needs skilled abilities to perform its various operations. Seeding, especially it requires the manual labor cost and physical appearance as it is timeconsuming process. To solve their long process, drone technology is helping to sow the seeds of the different varieties of the crops. As it installed in drones, the lasers, different working sensors, tanks have allowed them to rapidly yet smoothly plant seeds.

Analysis the Deficiency

Another merit or advantage of used of drones for the crop fertilization comes with their various or different feature to analyze, identify, and survey of the different crops for any deficiencies. Their highly resolution cameras and different sensors, with lasers, help to perform different operations quickly use as consume the time in field.

Crop Fertilization through the Drone Technology

Drones and their applications have helped to ease the process attributed to the crop fertilization. Their innovative and powerful nature helps to farmers a great deal with different tasks and operations.

Precision Agriculture:Crop Monitoring: Drones equipped with high-resolution cameras and sensors can capture detailed images of crops. This allows farmers to monitor plant health, identify pests, diseases, or nutrient deficiencies, and take timely corrective actions.

NDVI Imaging: Normalized Difference Vegetation Index (NDVI) maps can be generated using multispectral cameras on drones. NDVI helps assess the health and vigor of crops, enabling farmers to make informed decisions on irrigation, fertilization, and pest control.

Topographic Mapping: Drones can create detailed 3D maps of fields, helping farmers understand the terrain, drainage patterns, and soil variability. This information aids in better planning for planting, irrigation, and harvesting.

Soil Sampling: Drones can be used to collect soil samples across a field efficiently. This data helps in creating precise soil maps, leading to targeted and optimized fertilizer application.

Herd Surveillance: Drones can be used to monitor the health and movement of livestock, helping farmers identify and address issues such as disease outbreaks, missing animals, or irregular behavior.

Real-time Weather Data: Drones equipped with weather sensors can provide real-time data on temperature, humidity, and wind conditions. This information assists farmers in making informed decisions about irrigation, harvesting, and other weather-sensitive activities.

Search and Rescue Operations:

In cases of natural disasters or emergencies, drones can be deployed to survey affected areas, locate stranded animals, or assess damage to crops and infrastructure.

Insurance Assessments:

Drones can be used for quick and efficient assessment of crop damage for insurance purposes, providing accurate and timely information to insurance companies.

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Conclusion

In conclusion, the integration of drone technology in Indian agriculture represents a significant leap towards precision farming. Drones offer farmers a range of tools to monitor, analyze, and enhance various aspects of crop management. From spraying fertilizers to mapping fields and analyzing soil health, drones prove to be versatile and efficient. The ability to address deficiencies promptly, automate labor-intensive tasks, and provide real-time data empowers farmers to make informed decisions for sustainable and optimized crop production. As drone technology continues to evolve, its impact on Indian agriculture is poised to grow, ensuring a more resilient and productive future for the country's vital farming community.

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BITPONICS: IoT-BASED GARDENING

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Abstract

Bitponics or the Bitponics Base Station contains sensors to measure the air temperature, water temperature, pH (acidity), relative humidity and the lighting levels, which are essential for growing a plant indoors. Bitponics include two outlets; one which allows turning on the devices such as growth lights and another pumps to maintain and control the garden system when you are away from home through sensors and computer technology. This online system provides the right conditions for each stage of the plants' growth. One can see the status of the plant, with green indicating that conditions are right and yellow showing that conditions such as pH and light levels are off.

Keywords: indoor plants, bitponics, hydroponics, technology, gardening

INTRODUCTION

Bitponics, a device cum website-company, is a combination of sensor device and open-source software system that promises to simplify hydroponics growing of plants. It is a project and technique developed in 2011 by Amit Kumar and Michael Dohertya, Brooklyn based lead software and hardware engineers from the US (Bitponics Website). Other team members involved in this new invention include software engineers from US, Jack Bishop and Chris Piuggi. This technique seeks to automate home plant growing and operate as a "Personal Gardening Assistant"*via* their stand-alone sensor device and back-end web service. The Bitponics website describes itself as “your personal gardening assistant.”

Bitponics is a path into the future of urban home gardening. It takes hydroponics gardening to a more sophisticated level with its smart device and website that allows people to manage indoor farm right over the internet. Hydroponic systems offer a great way to grow crops indoors when there is scarcity of space. For people who are interested but new to the practice of growing plants indoors (hydroponics), acquiring and understanding all the details of the plant can be difficult and challenging. In addition, for people who work long hours or travel a lot for work, there is always the risk that the indoor plants may not grow properly or die because of lack of maintenance and supervision in terms of water and nutrient requirements. Bitponics solves this issue by bringing “urban gardening” to the homes so that one can control and obtain details on how much water and nutrients a plant (e.g. herbs, flowers, vegetables) is required to get during each and every growth stages even when no one is available at home. Further, Bitponics includes a sensor device that measures a garden’s vital signs, sending information back to a central computer. This then remotely controls water pumps and lights, and Bitponics sends alerts to members suggesting “reservoir” refills and other maintenance (Fig.1).

A customized planting strategy is the first step in the Bitponics system (Fig.2). Growers have the option of coming up with their own strategy or using one that already exists inside the Bitponics online gardening community. Bitponics' sensor set checks in on the plants' pH, humidity, air temperature, water temperature, and light to ensure they stay on track once a plan has been made. The base station acts as a conduit for the sensor data as it travels over Wi-Fi to the cloud. In order to view the information, the user simply needs to log into their dashboard from any online browser. When plant conditions deviate from the optimal range specified in the growth plan, the Bitponics system alerts the user with an explanation and suggests corrections. Two of its electrical outlets are programmable, allowing it to boost the brightness of lights or the flow of water, among other things, without human intervention. The garden owner also has the option of using the web to manage any gadgets that are wired into the Bitponics hub. While it is true that not everything about the garden can be managed automatically, the Bitponics setup does alert the gardener when they need to perform things like replenish the water supply. Bitponics believes that the more people will utilize their system, the better it will be at making optimal expansion plans based on crowd-sourced information and experience. It also provides an open source hardware design to encourage hackers to make modifications and release their creations to the public (Weiss, 2013).

Described as a “shortcut for future hydroponics” and geared towards tech-savvy urbanites that are prone to accidentally “destroy” home grown plants, the aim of Bitponics is to take the conjecture out of indoor plant growing technique and to render the puzzling art of hydroponics gardening a simple, attractive and uncomplicated task for both the scientific and unscientific people.

WORKING OF BITPONICS

The plug-and-play Bitponics system is composed of two mains components:

i) **First component -** A base station that reads and analyzes humidity, pH, air temperature, water and brightness levels *via* several simple sensors placed throughout the garden. An electrical conductivity (EC) sensor that measures the concentration of nutrients in the growing solution of hydroponics (soil-less gardening system where plants are fed through nutrient-packed liquids) will also be available for an additional charge. When the system is set up, the device generates a "personalized growing plan" based on initial readings and other information that are being provided manually, *i.e*. what kind of plants are grown and details about the hydroponics set-up. The data collected from the sensors is then sent from the base station to the second component of Bitponics,

ii) **Second component -** The user’s online Bitponics account complete with dashboard. From the dashboard, users can tweak settings based on "friendly" alerts/recommendations generated by the readings. For example, the system has the ability to tell the user exactly how much light is needed for each plant per day and what balance of nutrients to use. Bitponics will alert the user about this and help to set on the right path. Also, the base station comes equipped with two power outlets allowing users to remotely adjust various aspects of the garden including water pumps and lights, making it ideal for gardeners who travel frequently. However, bitponics users are required to actually refill the reservoirs when water and nutrient levels are running low (Fig.1).

CONCLUSION

In a nutshell, Bitponics user has to enter the setup of a particular plant that is to be grown through computers *via* internet, which in turn provides the user with a personalized growing plan. Sensors in the device send data to the Bitponics website, which consequently sends notifications back to the device to control things such as pumps and lights. It combines hydroponics gardening with computer automation in order to make gardening more accessible to everyone. The whole operation revolves around an online Bitponics community where users can interact with other hydroponics gardeners and share their own trials and tribulations while acquiring tips and suggestions. Bitponics is not just about easy automation with computers; it is also about sharing knowledge and collaborating with other people in and around the world.

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Fig.1. Simple view of the working of Bitponics

Fig.2. Bitponics system in display (*Image source*: Weiss, 2013)

Image Source: http://www.coolhunting.com/tech/bitponics

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METABOLISM OF CALCIUM, PHOSPHORUS AND MAGNESIUM IN FISH

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Abstract

Aquatic animals have unique physiological mechanisms to absorb and retain minerals from their diets and water. Research and development in the area of mineral metabolism of farmed fish have been relatively slow and major gaps exist in the knowledge of mineral requirements, physiological functions and bioavailability from feed ingredients. An excessive uptake of minerals from either diet or gill uptake causes toxicity and therefore a fine balance between minerals deficiency and toxicity is vital for aquatic organisms to maintain their homeostasis either through increased absorption or excretion. Release of minerals from uneaten or undigested feed and from urinary excretion can cause eutrophication of natural waters, which requires additional consideration in feed formulation.

Keywords: Minerals, Fish, Calcium, Phosphorus, Magnesium

Introduction

All aquatic animals require minerals for their vital biochemical and physiological functions. The essentiality of microminerals like calcium, phosphorus and magnesium have been confirmed in fish to maintain their normal life processes. The biochemical mechanisms of mineral metabolism similar to terrestrial animals at cellular level. The exchange of ions from across the gills and skin of fish in surrounding water complicates the determination of the quantitative dietary requirement. Almost 99% of calcium and 80% of phosphorus (as phosphate [HPO_4^{2-}]) in the fish's body are present in the skeletal tissues.Ca and P are deposited as tricalcium phosphate [$Ca3(PO_4)2$], and exist as hydroxyapatite [$Ca10(PO_4)6(OH)_2$] crystal in the organic matrix of the skeletal tissue. During the process of development, the ratio of Ca to P in scales and bones may range from 1.6:1 to 2:1 in several fish species. Fish scale (important site of calcium metabolism and deposition)the rate of Ca exchange of fish scale is three times that in bones. During periods of increased Ca demand (sexual maturation and starvation), the amount of calcium in the scales decreases (resorption of scales in fasting salmons during spawning migration).In body fluids and other soft tissues, calcium exists as **non-diffusible calcium** which is bound to proteins like vitellogenin (a calcium-binding protein), a major component of egg protein (during the reproductive period, the plasma Ca level increases in females) and **diffusible or ionized calcium** which participate in muscle activity and osmoregulation. The distribution of phosphorus in extra- skeletal as component of cell walls, a major signaling molecule essential for the nucleic acid helical structure (i.e., RNA and DNA) and component of high-energy compounds (i.e., AMP, ADP and ATP)

CALCIUM

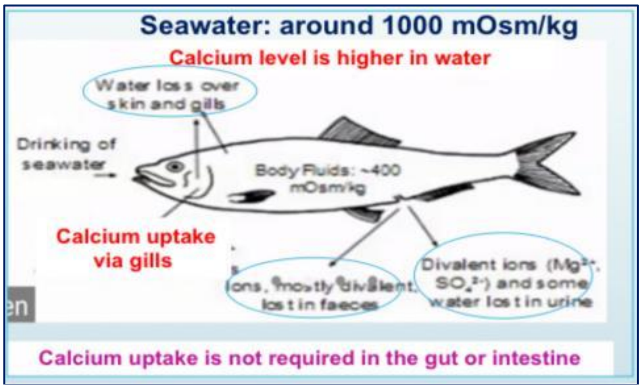
Functions of calcium:

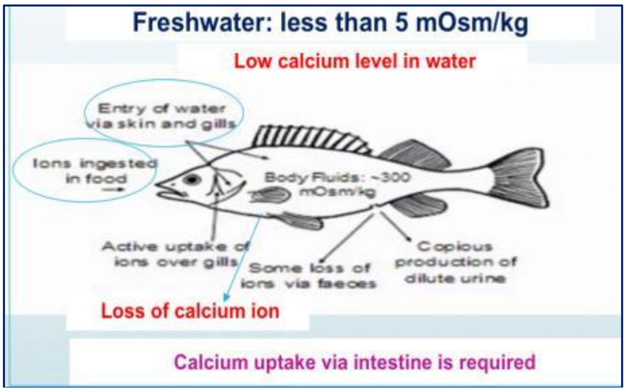
i. Bone formation and maintenance of skeletal tissues: calcium along with phosphate, is required for the formation (of hydroxyapatite) and maintain physical strength of skeletal tissue.
ii. Muscle contraction: Ca_2^+ interacts with troponin C to trigger muscle contraction. Calcium also activates ATPase, increases the interaction between actin and myosin.
iii. Blood clot formation: blood clotting process are dependent on $Ca_2^{+.}$
iv. Nerve transmission.
v. Maintenance of cell membrane integrity and permeability: in the cell membrane calcium is closely bound to phospholipid, where it controls the permeability of membrane and thus regulates the uptake of nutrients by the cell.
vi. Activation of enzymes: like lipase, ATPase and succinate dehydrogenase.
vii. Calcium as an intracellular messenger.

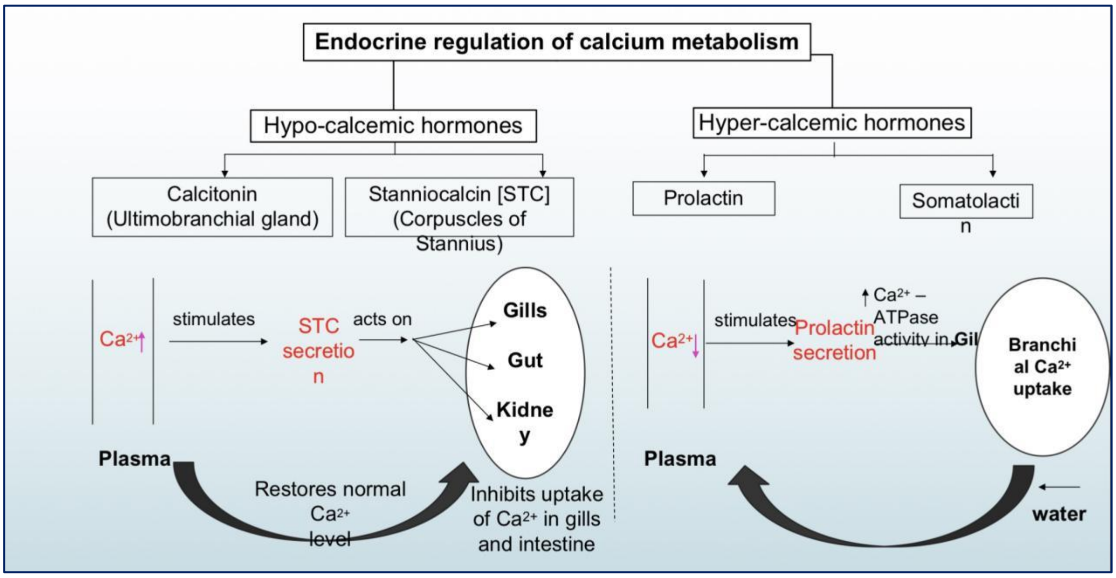
Calcium Metabolism

Absorption:

- Dissolved calcium is directly extracted from their surrounding aquatic environment through the gills, fins, oral epithelia and indirectly from food via intestine.
- Gills (having large surface area) are the most important site of calcium influx and efflux in both freshwater and marine water fish.







Deposition:

- The absorbed calcium is deposited in bone and skin.

Excretion:

- Besides gills, any surplus calcium taken up by the fish is excreted largely via extra-branchial routes i.e., renal system – kidney (urine) or intestinal tract (feces).
- In seawater fish, the divalent ions (Ca_2^+, Mg_2^+, SO^{2-}) are excreted via kidney.

Deficiency Signs of Calcium

- Reduced bone mineralization,
- Reduced growth and poor feed conversion, and
- Anorexia

PHOSPHORUS

Functions of phosphorus:-

i. Formation of bone and teeth.
ii. Formation of high-energy phosphate compounds: like ATP, GTP, creatine phosphate, etc.
iii. Formation of phospholipids, phosphoproteins and nucleic acids (DNA and RNA).
iv. Component of several nucleotide coenzymes: like NAD^+, $NADP^+$, ADP, AMP, pyridoxal phosphate.
v. Several protein and enzymes are activated by phosphorylation.
vi. Phosphate buffer: for maintenance of pH in blood (~ 7.4).

Phosphorus Metabolism:

Absorption:

- Food is the main source of phosphate for fish and extraction of phosphorus via gills is negligible (as both FW and SW are low in phosphate).
- Absorption of dietary calcium and phosphorus begins in the upper gastrointestinal tract.
- The amount of phosphate absorbed from the food is affected by the level of phosphate in the blood.
- Na-dependent absorption of inorganic PO43- occurs in intestine (reported in carps) and movement into cells is mediated by sodium–phosphate co-transporters.

➢ By rise in water temperature, decrease in the Ca content of water, and by the presence of glucose in the diet, phosphorus absorption increases.

Table 1. Dietary Sources of Phosphorus

Origin	Source	Phosphorus(%)
Plant	Cereal grain	0.3-0.4
	Vegetable protein	0.5-1.4
Animal	Fish meal	1.5-3.2
	Meat and bone meal	3.5-5.5

The hormones involved in phosphate regulation include STC, prolactin and parathyroid-like hormones (Pth1h).

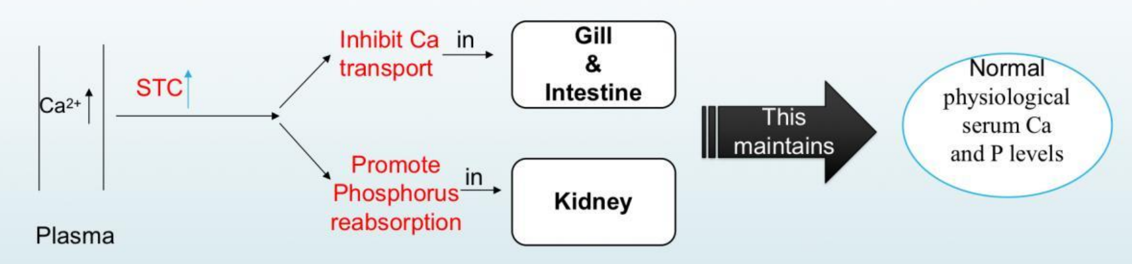


Figure1. Endocrine control of phosphorus metabolism

Deposition:

➢ The absorbed phosphorus accumulates in soft tissues (heart, liver, kidney, muscle, and blood, etc.) and deposition in skeletal tissues is low.

Excretion:

➢ Urinary loss of phosphate is much higher in freshwater than seawater fish because of the large volume of urine produced in freshwater fish.

➢ 90% of phosphate lost from the body is excreted via renal system.

Deficiency Signs of Phosphorus

➢ Reduced feed utilization & weight gain,

➢ poor mineralization of bones & scales,

➢ curved spines and soft bones,

➢ skeletal & cranial deformity, and

➢ increase in liver or body fat

MAGNESIUM

Functions of magnesium

i. Formation of bones and teeth.

ii. Mg_2^+ serves as a cofactor for several enzymes requiring ATP: like hexokinase, glucokinase, phosphofructokinase, adenylate cyclase.

iii. Mg_2^+ is necessary for proper neuromuscular function: low Mg_2^+ levels lead to neuromuscular irritability.

Magnesium Metabolism:

Distribution

- In fish, most of the magnesium is located in skeletal tissue (50–70%) and the remainder is found within the cells of soft tissues (20% in muscles).
- The RBCs of fish contain significantly higher levels of Mg and lower levels of Ca (than found in humans).

Absorption:

- Food is the main source of magnesium, however, some part of its requirement is also met by uptake from water via the gills.
- In SW, fish absorb Mg by drinking.

Table 2. Dietary Sources of Magnesium

Origin	Source	Magnesium (%)
Plant	Cereal grain	0.15-2
	Vegetable protein	0.6
Animal	Meat and fish meal	Rich source of Mg

Deposition:

- In bones and scales.

Excretion:

- Excess magnesium is excreted via kidney.

Deficiency Signs of Magnesium

i. Anorexia, reduced growth, sluggishness, high mortality.
ii. calcinosis of the kidney (nephrocalcinosis).
iii. reduced bone mineralization, vertebral deformity, and
iv. degeneration of muscle fibers and epithelial cells of gill filaments.
v. A low concentration of Mg in water reduced the Mn concentration of eggs in carp, which reduced the hatchability of eggs and survival of offspring and also caused deformities and tissue necrosis.

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A2 MILK: FAD OR FUTURE? EXPLORING THE SCIENCE BEHIND THE HYPE

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Abstract

In the ever-evolving world of dairy, A2 milk has emerged as a contender, boasting potential health benefits and capturing the attention of health-conscious consumers. This article explores the historical evolution and science behind A1 and A2 milk, scrutinizes its claimed advantages and navigates the ongoing discourse on whether it marks a revolutionary shift in dairy consumption or remains a subject of scepticism or a myth. Additionally, we explore the beta-casomorphins, and the health implications that come to light and the crucial role indigenous cattle breeds play in shaping the A2 milk narrative.

Introduction

In recent years, the dairy market has witnessed a notable disruption with the advent of A2 milk, an innovative alternative to traditional cow's milk. Pioneering promises of enhanced digestibility and potential health advantages, A2 milk distinguishes itself by the absence of the A1 beta-casein protein. This crucial difference has sparked discussions surrounding its suitability for individuals with digestive sensitivities, leading to a dynamic discourse on whether A2 milk signifies a groundbreaking shift in dairy consumption or remains shrouded in scepticism.

At the heart of the A2 milk revolution lies the intricate genetic landscape of the β-casein gene, situated on the sixth chromosome. This gene plays a pivotal role in shaping the essence of cow's milk, orchestrating the synthesis of β-casein—a protein comprised of 209 amino acids. Our exploration navigates through the 13 genetic variants of the β-casein gene, where A1 and A2 take centre stage in reshaping the dairy narrative. The nuanced amino acid substitution at the 67th residue emerges as a focal point, setting the stage for uncovering the potential health benefits that characterize A2 milk. Join us as we delve into the scientific foundation of A2 milk, explore its claimed advantages, and navigate the ongoing discourse surrounding its place in the evolving landscape of dairy consumption.

The history behind β-casein gene and A1 and A2 Milk

β-casein (CSN2) is one of the major caseins present in cow milk and it has several polymorphic forms depending on the genetic makeup of cows. Caseins are encoded by a single autosomal gene located in a stretch of about 200 kb on the sixth chromosome. The size of the β-casein gene is 10321 bp and is composed of 9 exons. β-casein protein consists of 209 amino acids.

Due to natural genetic variation, about 13 genetic variants of the β-casein gene are reported namely A1, A2, A3, A4, B, C, D, E, F, H1, H2, I and G. Among these 13 variants, A1 and A2 are the most frequently observed variants in dairy cattle. The difference between the A1 and A2 types of β-casein is an amino acid substitution at the 67th residue of β-casein protein. The A1 variant has histidine and the A2 variant has proline which is due to the code difference between A1 (CAT) and A2 (CCT) variants that has arisen due to spontaneous mutation during the course of evolution a few thousand years ago.

Embarking on a historical journey through the annals of cattle domestication reveals that over 10,000 years ago, only the A2 genetic variant of β-casein existed in the population. During the course of evolution, 8000 years ago a natural single gene mutation occurred in Holstein Friesian cattle resulting in the production of the A1 genetic variant of β-casein gene. This mutation subsequently generated 13 other variants of the β-casein gene of which A1 and A2 are predominant. The mutation was later transferred to other breeds as Holstein Friesian cattle were used to genetically improve the production traits of other cattle owing to its high genetic merit in terms of milk production. Thus A1 β-casein variant became established in other cattle populations throughout the world. The percentage of A1 and A2 genetic variants of β-casein varies between breeds, countries and provinces.

Beta-casomorphins Unveiled

Shining a spotlight on beta-casomorphins in the realm of β-casein gene variants becomes essential. These opioid-like peptides, varying in chain length from 4 to 11 amino acids, add an intriguing dimension to the A2 milk narrative. Originating from the tyrosine residue at position 60 within the β-casein protein, beta-casomorphins remain inactive within the parent protein sequence. However, they become active on proteolytic cleavage by digestive enzymes. Proteolytic cleavage sites are unique in all β-casein gene variants and arise due to structural variation in gene and associated protein structure resulting in a plethora of beta-casomorphin peptides. Like BCM 4, b-CN f(Tyr-Pro-Phe-Pro),BCM 5, b-CN f(Tyr-Pro-Phe-Pro-Gly) and BCM 10, b-CN f(Tyr-Pro-Phe-Pro-Gly-Pro-Ile-P ro-Asn-Ser-Leu) are a few to the name.

Structural Variation and Digestive Consequences of A1 and A2

The structural divergence between A1 and A2 β-casein protein variants at the 67th amino acid residue unravels a cascade of digestive consequences. A2 β-casein, with proline at the 67th position, stands apart from the A1 variant due to a spontaneous mutation during evolution. This subtle substitution induces a cleavage site between the 67th histidine and its adjacent amino acid in A1 β-casein, susceptible to the action of proteolytic enzymes in the digestive tract. This culminates in the formation of the bioactive opioid peptide beta-casomorphin 7 (BCM-7)which sparks interest, especially in light of its correlation with human diseases as revealed by epidemiological studies. The absence of this cleavage site in A2 β-casein, thanks to the presence of proline at the 67th amino acid residue, differentiates the digestive fate of these two variants.

Beta-casomorphin-7 (BCM-7) and Health Implications

Beta-casomorphin-7 (BCM-7), an opioid peptide, wields significant influence over gastrointestinal tract motility, mirroring the effects of morphine. Research indicates that it not only reduces the frequency and amplitude of intestinal contractions but also suppresses lymphocyte proliferation. Furthermore, its pro-inflammatory effect, mediated through signalling pathways, introduces a layer of complexity to the health implications associated with A1 β-casein milk intake. The induction of oxidative stress via epigenetic regulation of gene expression adds another dimension, contributing to the ongoing debate on the potential impact of A1 milk on human health. It is also known that research on the impact of the A1 β-casein on type 1 diabetes indicates the incidence of type 1 diabetes mellitus in humans with the correlation between A1 β-casein and type 1 diabetes is extremely high with an r-value of 0.92.

A2 Milk and Indigenous Cattle Breeds

Diving into the nuances of A2 milk, it becomes evident that indigenous cattle breeds play a crucial role in this dairy saga. Research conducted on zebu cattle, buffaloes, and exotic cows provides valuable insights. Exotic cattle demonstrate a higher prevalence of the A1 allele, emphasizing the genetic diversity within the global cattle population. Conversely, indigenous Indian breeds, with their rich milk-yielding heritage, showcase a predominantly A2 allele status. The prominence of the A2 allele reaches 100% in five high milk-yielding indigenous breeds, namely Red Sindhi, Sahiwal, Tharparkar, Rathi, and Gir, reinforcing the unique genetic composition that contributes to the A2 milk phenomenon.

A2 Milk: A Future Food or a Myth?

The debate surrounding A2 milk has gained significant attention in recent times, with conflicting views on its potential health benefits and the need for consumers to switch from A1 milk. The emergence of several A2 milk players in the market indicates a growing interest among consumers to pay a premium for perceived better quality and safer milk. However, the question remains: Is A2 milk a future food or a myth?

On one hand, it's important to acknowledge that the scientific evidence supporting the alleged health benefits of A2 milk is not conclusive. The predominant protein in milk is either A1 or A2 beta-casein, and some studies suggest that A1 milk may produce a compound called BCM-7 during digestion, which has been linked to digestive discomfort. However, the evidence is not strong enough to make definitive conclusions about the negative health effects of A1 milk.

Moreover, lactose intolerance, associated with the inability to digest lactose, is a distinct issue from the debate between A1 and A2 milk. Both A1 and A2 milk contain lactose, and switching to A2 milk may not necessarily address lactose intolerance. The prevalence of A1 milk protein in India is not currently a major problem, given the predominance of A2 milk in Indian cattle. With increased consumer awareness over time, the demand for A2 milk might not sustain itself in the long run.

Dairy players could potentially cater to the premium segment by offering alternative value propositions, such as high-protein milk, lactose-free milk, adulterant or antibiotic-free milk, and certified organic products. These options may resonate more strongly with consumers, addressing specific concerns without relying solely on the A1/A2 debate. The calcium-to-magnesium ratio in milk is another aspect to consider. A high calcium-to-magnesium ratio, as found in A1 milk, has been associated with increased risks of various health conditions. A2 milk, with a lower ratio, may indirectly indicate health benefits, but further scientific research is needed to establish these claims globally.

While there is oral evidence in Vedic literature highlighting the unique beneficial effects of Indian cow milk, scientific exploration in this area is still limited. Value-added products derived from cow's milk, such as curd, ghee, and buttermilk, are traditionally believed to have anti-ageing, antifungal, anti-cancer, and heart- and brain-tonic effects. However, more comprehensive scientific studies are necessary to validate these claims on a global scale.

In conclusion, whether A2 milk is a future food or a myth remains an open question. The scientific community needs to conduct more research to provide conclusive evidence regarding the health benefits of A2 milk and explore the unique properties of Indian cow milk as mentioned in Vedic literature. Until then, consumers are encouraged to make informed decisions based on their individual health needs and preferences.

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MAXIMIZING SYNERGY: AGRIVOLTAICS AS A SUSTAINABLE SOLUTION FOR FOOD AND ENERGY INTEGRATION

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Abstract

This article explores the innovative approach of agrivoltaics, the integration of solar photovoltaic systems with agricultural operations, as a solution to the dual challenges of escalating food consumption and the imperative shift to clean energy. Agrivoltaics optimizes land use, enhances resource efficiency, and provides significant environmental and economic benefits. By utilizing the same area for solar energy generation and agriculture, farmers can diversify revenue streams, improve crop yields, and contribute to renewable energy production. The article highlights the benefits, challenges, and considerations of agrivoltaics, emphasizing its potential to address global concerns such as climate change and food security.

Introduction

As the globe grapples with the simultaneous issues of rising food consumption and the need to shift to clean energy sources, creative solutions that combine agricultural and renewable energy generation have gained prominence. Agrivoltaics is one such option, which integrates solar photovoltaic (PV) systems with agricultural operations on the same area. This innovative technique maximizes land use efficiency, optimizes resource use, and provides significant environmental and economic advantages.

Agrivoltaics, also known as agro photo voltaics or solar sharing, ("Agri" refers to agriculture, which means food production. "Voltaics" refers to photovoltaic solar cells.), involves the use of solar panels and plants to maximize farm land utilization. In simple terms, it is the process of placing solar panels alongside crops on agricultural property. Traditional solar PV systems often take up large amounts of land, raising worries about land-use disputes and environmental effect. Agrivoltaics is a novel method that makes agricultural use of the area beneath and surrounding solar panels. This strategy converts underutilized land into lucrative assets that help with both food production and renewable energy generation.

How Agrivoltaics is Beneficial?

Agrivoltaics maximizes land use efficiency by using the same area for both solar energy generation and agriculture. This practice enables farmers to earn additional cash from their land while maintaining food production. Furthermore, the shade offered by solar panels can lower evaporation rates and water requirements, making agrivoltaic systems ideal for dry and semi-arid environments. Solar panel integration in agriculture provides several benefits to crops. The panels create shade, which protects crops from overheating and sunburn, resulting in higher crop yields and quality. Furthermore, the panels operate as a windbreak, lowering wind speed and limiting soil erosion. This protected atmosphere can produce microclimates that lengthen the growing season and allow more delicate or temperature-sensitive crops to be grown. Agrivoltaics capitalise on resource synergy by combining the production of renewable electricity with agricultural commodities. The area behind solar panels receives less direct sunshine, resulting in colder surface temperatures. This modifies the microenvironment, decreasing crop water requirements and minimising heat stress. Furthermore, the solar panels generate energy, which may be used to operate irrigation systems, storage facilities, and other on-farm operations, further optimising resource use. Farmers find agrivoltaics to be an appealing economic proposition. Farmers can avoid risks linked with crop price volatility or climate-related issues by diversifying their revenue streams. The increased cash generated by solar energy generation can help farms to be more profitable and sustainable. Furthermore, agrivoltaic systems frequently benefit from government subsidies and assistance programmes aimed at encouraging the use of renewable energy, increasing their financial feasibility.

In India, agrivoltaics is gaining popularity as a feasible solution to the difficulties of land scarcity and the demand for renewable energy. The government has been actively pushing solar energy as part of its aim to decreasing greenhouse gas emissions and boosting the amount of renewable energy in its total energy mix. The Indian government has launched a number of efforts and programmes to promote the use of agrivoltaics. For example, the Ministry of New and Renewable Energy (MNRE) created the "Kisan Urja Suraksha evam Utthaan Mahabhiyan" (KUSUM) initiative, which intends to assist the building of grid connected solar power plants on agricultural areas. Farmers may generate solar power and sell the excess to the grid under this arrangement, giving them with an extra source of revenue. Several Indian states have made proactive initiatives to encourage agrovolatics. For example, Gujarat, a western Indian state, has launched the "Suryashakti Kisan Yojana" (SKY) plan, which encourages the installation of solar panels on agricultural areas for electricity generation. Similarly, Maharashtra, Karnataka, and other states have launched pilot programmes and research studies to evaluate the feasibility and advantages of agrivoltaics.

Challenges and Consideration

Agrivoltaic system design and management need careful planning and consideration of several elements, including crop selection, panel orientation, shade patterns, and maintenance access. To ensure the cohabitation of solar panels and agricultural productivity, efficient irrigation systems, effective pest management measures, and specialized cultivation practices must be used. Solar panels and agricultural practices may need the development of novel technology and equipment. Adaptations in panel design, mounting structures, and irrigation systems that reduce shade-induced crop losses while optimising energy output are continuing research and development projects. Promoting agrivoltaics involves information transfer and training programmes for farmers in order for such systems to be properly adopted and managed. Government policies, financial incentives, and regulatory frameworks all play an important role in promoting wider use of agrivoltaics. Policies that encourage collaboration between the agricultural and energy sectors can hasten the implementation of this sustainable method.

Implication and Future Prospects

Agrivoltaics has enormous promise for tackling important global concerns such as climate change, food security, and the transition to renewable energy. Its wider use might assist to optimize resource utilization, cut greenhouse gas emissions, and develop synergistic solutions that benefit both the agriculture and energy sectors. Continued research and development, as well as supporting legislation and public awareness, are critical for agrivoltaics' broad use and advancement.

Conclusion: Agrivoltaics emerges as a promising solution with the potential to transform global agricultural and energy landscapes. The coexistence of solar panels and crops not only maximizes land use efficiency but also creates sustainable, synergistic ecosystems. The benefits extend beyond financial gains for farmers, encompassing enhanced water conservation, improved crop quality, and reduced environmental impact. Government initiatives, exemplified by India's KUSUM and SKY programs, underscore the growing recognition of agrivoltaics. However, careful planning, technological advancements, and supportive policies are essential for widespread adoption. As agrivoltaics aligns with the global push for clean energy and sustainable agriculture, continued research and collaborative efforts will drive its integration into mainstream practices, offering a holistic solution to the interconnected challenges of food security and renewable energy transition.

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MEETING FUTURE CHALLENGES OF AGRICULTURE SUSTAINABILITY IN INDIA: ROLE OF EXTENSION

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Abstract

The concept of sustainable agriculture involves using farming activities that are economically viable and socially responsible. It is a means to address environmental concerns, ensure food security, and enhance farmer livelihoods. Sustainable agriculture in India has gained significant attention in recent years. It aims at optimising agricultural productivity while preserving natural resources and ecosystems through sustainable agriculture practices which promote using renewable resources, minimise chemical inputs, and foster the well-being of farmers and rural communities. This paper highlights the strategies to achieve the goal of agriculture sustainability in India.

Introduction

The principal objective of sustainable agriculture is to meet the increasing demands of food and other commodities and improving standards of living, alleviating drudgery and human sufferings and providing a respectable way of life for a majority of the population. Undoubtedly, adoption of green revolution technologies during 1960s eliminated the prevailing acute foodgrain shortages through significant increase in yields of mainly wheat and rice but this could not be sustained for the reasons mentioned in **Box 1**. Farmers are in a great fix. The major problems facing farmers as summarized in **Box 2** which need attention of all stake holders to accelerate growth in agriculture to sustain a growth of 8–10% in GDP, as is being aimed at. In the context of the current production levels, doubling food production in the next five years will be a great challenge and test of our capacity to successfully employ all possible growth-inducing measures.

Quantum jump in food production will have several positive spinoffs. It will drive investment in infrastructure for storage, processing, transportation and packaging. It will also boost the prospects of the agro-processing industry. It will create jobs in the rural sector. Capacity building of our rural youth should, therefore, go hand in hand. Better livelihood opportunities in rural areas will reduce the pressure of migration on urban centers. Growth in food production will also help in conservation of natural resources. With the technologies at our disposal, it will be possible to utilize farm wastes from increased food production and feed for livestock and aquaculture. This will reduce pressure on forest lands which are currently used as pastures for grazing animals.

Box 1. Loose Ends of First Green Revolution

- Intensive agriculture with cereal based fixed crop rotations, mostly rice-wheat in the north and rice-rice in the south and east) that too confined to irrigated areas.
- Elimination of fertility-restoring pulses and oilseed crops particularly in the high productive north-western plain zone.
- Increasing incidence of biotic and abiotic stresses.
- Transformation of 'traditional animal-based subsistence farming' to 'intensive chemical and energy intensive tractor-based conventional agriculture.
- Degradation of natural resources (soil, water, biodiversity).with intensification of agriculture.
- Intensive tillage to prepare fine seed- and root-bed for sowing to ensure proper germination and initial plant vigour and faster absorption of moisture and control of weeds and other pests (virtually clean cultivation.
- Complete removal of crop residues and other biomass from the fields.
- Burning of crop residues after harvesting led to depletion of organic contents of the soil and soils nutrient capital.
- Impoverishment of soil fertility and soil quality (chemical, physical and biological properties) mainly due to neglect of organic inputs-FYM/compost and green manure, penning of cattle in the field, biofertilizers, crop residue recycling, discontinuation of traditional legume based crop rotations, mulching, intercropping/mixed cropping etc.
- Nutrient additions through fertilizers being less than nutrient removals by the crops causing nutrient mining and problems of multi-nutrient deficiencies.
- Inadequate and unbalanced use of chemical fertilizers in cereals, pulses and oilseeds and excessive use of N and P in potato, sugarcane and other commercial crops causing problem of nutrient imbalance in soil-plant system.
- Neglect of secondary and micronutrient deficiencies due to poor soil testing services.
- Burning of fossil fuels, crop residues, excessive tillage including puddling for rice cultivation are leading to emission of greenhouse gases, which are responsible for climate change and global warming.
- Decline in input use efficiency and factor productivity, and increase in environmental problems and multiple issues associated with agriculture sustainability.
- Adoption of the recommended best management practices for high yield agriculture in piecemeal led to stagnation/decline in foodgrains productivity in northern states with passage of time.
- Indiscriminate use of pesticides led to accumulation of their residues in food chain, ground water and also increased pests immunity etc.
- Water resources are under great stress due to their indiscriminate exploitation and also getting polluted due to various human interferences Over exploitation of ground water in tube well irrigated areas and seepage and secondary salinization in canal command areas are the real challenge.
- Injudicious use of water, fertilizers and pesticides is not only increasing the cost of cultivation but also adversely affecting the soil quality, efficiency of inputs and environment.
- Technology fatigue
- Lack of capacity enhancement of fertilizer production and
- Instable fertilizer policy. Lack of well blending of research finding with fertilizer policies.

Box 2. Array of Problems Being Faced by the Farmers

1.Shrinking natural resources (soil, water and biodiversity) due to continually increasing population
2. Small holdings and poor economy constraining adoption of improved farm technologies.
3. Lack of faith in soil testing service. Soil testing being confined to N, P and K is unable to address the actual soil fertility problems of the field. Due to poor follow up programs, soil testing service could not became popular among farming community, often the question about the quality of data.
4. Unawareness about secondary and micronutrient deficiencies, their deficiency symptoms and unavailability of needed fertilizers to correct these deficiencies.
5. Competing use of animal dung constraining production and use of FYM/composts
6. Lack of requisite knowledge about biofertilizers and their timely availability in the market.
7. Lack of rehabilitation of irrigation system and efforts to increase water use efficiency.
8. Farmers feel interested to know about of alternate more suitable crop rotations i in place of rice-wheat system in tube well irrigated where ground water has already been excessively exploited.
9. Poor availability of needed seeds of pulses and oilseeds, sesbania/sunnhemp for green manuring, smaller millets and fodders.
10. Lack of drought resistant varieties and technologies for pulses and oilseeds.
11. Minimum technological breakthroughs to address current field problems.
12. Poor farmers education coupled with very poor extension services.
13. Distress sale of produce and problems related to credit and marketing of produce.
14. Poor extension service and
15. Increasing problems of blue bulls, stray cattle, monkeys making cultivation of pulses and oilseeds, green manure crops particularly during summers very difficult.

1. Transforming Agriculture Towards Sustainable Agriculture

There is urgent need for developing a strategy document for assessing the present trends of crop productivity vis-a-vis the potential yield of major crop systems, so that specific action plans could chalked out for bridging the yield gaps, which in turn will contribute to enhanced productivity of farming systems through holistic approach. Experimental findings of IPNI-India Program in rice-wheat and rice-rice cropping systems and IFFCO's "Soil Rejuvenation and Productivity Enhancement" project under its flagship **"SAVE THE SOIL"** Mission have clearly established that there is lot of scope to double the crop productivity through site specific nutrient management. However, with increasing yield goals, the "nutrient basket" demanded by the crops not only grows bigger but also become more varied and complex. Therefore, feeding crops for high yields in India is no longer a simple NPK story. This in no way minimizes the importance of NPK (fertilizer pillars) but emphasizes that the efficiency of NPK and returns from their application can be maximized only when due attention is also paid to other nutrient deficiencies.

Strengthening the Roots of Indian agriculture

The central Government has started thinking of agriculture not merely as a tool to feed the country, but also as a basic means to uplift the socio-economic indicators of the country. To complement the view, the government has initiated a number of development measures and schemes which have the potential to immensely benefit the agrarian communities by boosting the roots of Indian agriculture (**Box 3**).

Box 3. Boosting Indian Agriculture: Government's Initiative

Soil Health Scheme: For scientific appraisal and monitoring of soil fertility status, Soil Hearth Card scheme has been launched with Budget allocation of Rs 200 crore with target of 2.53 crore samples, states will have to bear 50% of the total cost.

Prime Minister's Krishi Sinchai Yojana (PMKSY): The major objectives the PMKSY Iis to achieve covergence of investment in in irrigation at the field level, expand cultivable area under assured irrigation, improve on-farm water use efficiency to reduce wastage of water, enhance the adoption of irrigation, and adoption of water saving tecnologies (More crop per Drop), enhance recharge of aquifers and introduce sustainable water conservation practices by exploring the feasibility of reusing treated municipal based water for peri-urban agriculture and attract greater private investment in precision irrigation system.

Price Stabilization Fund: The farmers are compelled to sell their produce at throwaway prices and on the other hand, middlemen make windfall profits. To check the phenomena, the government has established a price stabilization fund.

Agricultural Credit: Committing suicide by the farmers after having failed in breaking the credit net of local financers, is very often heard. To improve credit support, government has increased the target of agricultural funding by Rs. 50,000 cr. to 8.5 lakh cr. For 2015-16, the NABARD had projected an annual credit potential of Rs. 47,756.43 cr. for some of the priority sectors including water resources, land development, farm mechanisation, dairy, poultry, fishery, construction of storage godowns and market yards and promoting renewable sources of energy and waste management.

Farm Insurance: The goverment has initiated new insurance scheme wherein the farmer would be able to atleast recover the basic inputs that he puts in, in the event of uncertainties created by more than one reasons.

Warehousing: The estimated wastages of the agricultural produce during 2013 were to the order of : 22% of the total production of wheat and 40% of the total production of fruits and vegetables due to lack of warehouses and cold storage facilities. Over all we waste foodgrainns worth Rs. 44,000 cr. annually. The NABARD aims to create scientific storage space of 9.23 lakh tonne by construction of godowns and warehouses.

Launch of DD Kisan: The government launched DD Kisan Channel which is a unique initiative to fill a major gap in knowledge related to improved farm technologies, weather conditions and price of agricultural produce across the country.

Promotion of city Compost: The government initiated a scheme to produce city compost and made it mandatory to ensure its sale through fertilizer industry along with fertilizers to improve soil health. This scheme has been connected with "*Swaksh Bharat Abhiyan*'.

Box 4. INNOVATIVE PROMOTIONAL PROGRAMS

1. Diagnosis, and correction of nutrient deficiencies in standing crops: Some of the nutrient deficiency symptoms which are important in the context of Indian agriculture are being elucidated in**Box 5.**

2.Reliable soil testing service: To achieve the goal of balanced plant nutrition, a reliable soil testing service assumes great importance. There is need to overhaul soil testing service with regard to infrastructure, quality of data and soil test based fertilizer recommendations to develop faith of farmers. Fertilizer recommendation in India is seldom linked with socio-economic conditions of the farmers. Prescribing certain arbitrary fertilizer rates does not allow marginal and small farmers with resource constraint to attempt a gradual upward investment and subsequent benefit, keeping them trapped in a low input-low output cycle. This actually hinders the increase in fertilizer demand/consumption. Fertilizer recommendations linked with socio-economic conditions will help farmers for large scale adoption suiting to their pocket.

3.Balanced use of fertilizers: With a changed face of balanced fertilization, more systematic and enlarged efforts would be needed for the promotion of K, S, Mg and micronutrients (Zn, B etc.) along with NPK on the principle of FBMPs. There is lot of scope and need to educate farmers about FBMPs to increase food, feed, fiber and fuel production to meet future demand. Needless to emphasize that suitable literature in simple language should be developed.

*4.**Correction of multi-nutrient deficiencies***: With a changed face of balanced fertilization, more systematic and enlarged efforts would be needed for the promotion of S, Mg and micronutrients along with NPK on the principle of FBMPs. There is lot of scope and need to educate farmers about FBMPs to increase food, feed, fiber and fuel production to meet future demand. Needless to emphasize that suitable literature in simple language should be developed.

Availability of needed fertilizers: Availability of needed fertilizer inputs of genuine quality at right time and at right place and the knowledge needed to correct the existing nutrient deficiencies should be made available (**Picture 1**).

5.Soil amendments*:* Soil amendments (gypsum in sodic soils, lime in acid upland soils), moisture conservation in the semi-arid and arid regions, efficient application of water in irrigated areas, use of organic manures in coarse-textured soils etc. pave the way for higher nutrient use efficiency. Unfortunately, marketing and distribution of soil amendments has received far less attention than that of fertilizers in India. If constraints are to be removed, then the necessary inputs and resources should be easily available to the cultivators.

6. Fine tuning of technologies**:**Technologies available for optimizing plant nutrition must not only be adopted at the farm level but a collaborative program of the researchers, field executives of the state department of agriculture and industry must fine-tune these to match local conditions and resources (as for example through SSNM). Site and crop-specific foolproof production system packages should be developed as farmers' participatory model which should include the best of all controllable factors needed to produce the highest possible yield ensuring highest profits to the farmers.

7.Beyond Grain Crops: In the initial years of green revolution in India, most of the work on soil fertility evaluation and plant nutrition was targeted at the nutrient needs of field crops in general and foodgrains in particular to achieve the goal of food self sufficiency. Recently, horticulture sector is also gaining importance and so the initiative in research and extension programs in this sector are being strengthened through the initiative of National Horticulture Mission.

8.Beyond irrigated agriculture:To improve dryland/rainfed agriculture, sincere efforts are needed.

Strategies for Sustainable Agriculture

Technological change has been the major driving force for increasing agricultural productivity and promoting agriculture development in all OECD countries. In the past, the choice of technologies and their adoption was to increase production, productivity and farm incomes. Over many decades, policies for agriculture, trade, research and development, education, training and advice have been strong influences on the choice of technology, the level of agricultural production and farm practices. Today, farmers, advisors and policy makers are faced with complex choices. They are faced with a wide range of technologies that are either available or under development; they must deal with the uncertainties of both the effects these new technologies will have throughout the agri-food chain and the impact that a whole range of policies will have on the sustainability of farming systems. In addition, there is increasing pressure on agricultural research and advisory budgets that must be accommodated. Some important tools are suggested below:

(A) Towards Enhancing Crop Productivity and Farmers Income

New initiatives to Upgrade Farmers Skills for Agriculture Sustainability: New initiatives are needed to upgrade the crop production skills of farmers which will ensure high productivity as well as high produce quality. The fertilizer industry can possibly energize the local research and extension system to meet these challenges, at least in the plant nutrition sector. It is possible, when mobile phone and PCs are a common sight in many villages even where they lack adequate sanitation and potable water, it is possible that farmers ask for soil-test based fertilizer recommendations and dealers are equipped to provide the fertilizers needed for SSNM. The industry would certainly represent as a logical, need – based and resource–efficient organization to address the emerging issues.

Industry-Scientists-FarmerInterface: Fertilizer use development requires teamwork through collective and coordinated effort of several agencies involved in research, extension and input supply. In the larger context even agencies providing irrigation, energy and produce markets are also important because fertilizer use is a means to increase crop productivity leading to a marketable surplus, which can be sold.

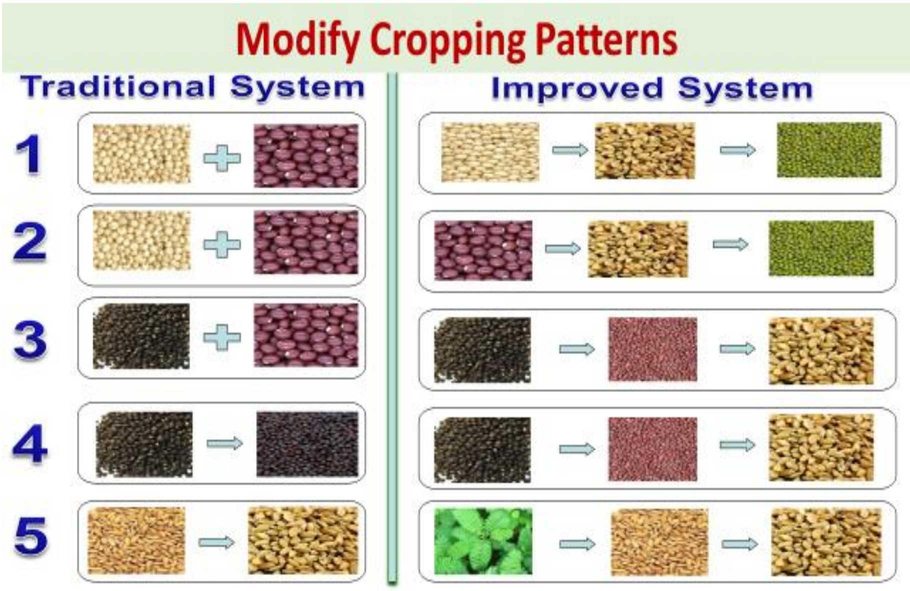
***Diversification of Agriculture*:** Diversification of agriculture in the First Green Revolution areas such as Punjab, Haryana and Western U.P. seems need of the hour. To promote diversification on ecological principles, will require making monetary equivalence (profit margin) between the replaced crop/commodity and enterprise with the ones planned to be introduced. Farmer is mainly concerned with the profit he gets from a particular crop or commodity. Crops like maize, soybean, pulses, oilseeds, fruits and vegetables have the potential to replace rice and wheat in this area. Upward push in MSP in favour of proposed diversification crops will be a practical option to achieve this objective.

***Promotion of Horticulture Sector*:** Recently, horticulture sector is gaining importance and so the research and extension programs in this sector are being strengthened through the initiative of National Horticulture Mission. India is a major producer of horticultural crops growing close to 100 crops. It is the second largest producer of fruits and vegetables after China accounting for close to 10% of world production. Fertilizer industry can play a key role in maximizing productivity and product quality of horticultural crops through FBMPs by inclusion of these crops in the promotional programs which on date is practically missing.

Promotion of Intensive Vegetable Production: Promotion of intensive vegetable production using improved varieties, organic manure and drip irrigation, can provide five times higher annual income, to the tune of Rs. 2 lakhs per acre (BAIF's experience in Andhra Pradesh, Karnataka and Maharashtra). Farmers in semi-arid areas with 2-3 cows or 8-10 goats and cultivating dual purpose food grain crops on 0.4 ha land, have been earning Rs. 60,000 – 75,000 per annum. With efficient watershed development, land use planning and selecting of suitable crops, the income of the farmers can go up by 80-100% to generate an annual income of Rs. 40,000 to Rs. 60,000.

Promotion of More Remunerative Crop Rotation: Crop rotation means changing the type of crop grown on a particular piece of land from year to year. Crop rotation is absolutely critical for weed, disease, and insect and fertility management. Rotations will have a greater effect on weed species and densities than tillage practices. Research evidences showed that 84% of the farmers indicated that a rotation, including forage crops, significantly reduced weed problems. Innovative cropping/farming systems, which must be highly productive and fit within the socioeconomic, political and cultural frame work of the farming community, should be developed.

Promotion of Pulses and Oilseeds: The average yield of pulses and oilseeds (2013-14) was 764 and 1135 kg/ha, respectively. The total production of pulses was 19.27 Mt from an area of 25.23 Mha. The total production of oilseeds during that period was 32.88 Mt from 28.53 Mha. Leguminous pulses and oilseeds play important role towards improving soil, human and animal health, Inclusion of these crops in cropping systems is, therefore, esssential for soil, human and animal health and for ensuring food and nutrition security (**Picture 1**).



Picture 1: Some examples of modifying cropping systems for enhancing food and nutrition security and farmers profit

Promotion of Contract farming: Contract farming requires better inputs and skills than otherwise. The fertilizer industry can make a definite contribution to this sector by creating greater awareness for and catalyzing the development of plant nutrition packages to meet the needs of market-oriented agriculture.

Promotion of Export Markets: Export markets are also being sought for the farm produce including fresh fruits and vegetables. For such produce to meet the expectations and specifications of buyers, its production will need the inputs, services and skills of a much higher level that what most farmers have access to thus for.

Strengthening Organic Food Program: Strengthening Organic Food Program for India to make 10% of the global 60 billion USD market for each. is desirable. Major parts of India such as NER, HP, J&K, Uttarakhand, MP, Chhatisgarh, Jharkhand, which are organic by default, must be made Organic by Process for the producers to get advantage of market value.

Establishing Special Agriculture Zones (SAZ) **:**Establishing Special Agriculture Zones (SAZ)by selecting export oriented and industrial use crops and promoting Crop Stewardship Programs, and Certification, formation of Global Commodity Boards, on the pattern of California Walnuts, Washington Apples etc., can help to increase agri-exports, which will benefit farmers significantly. We need to globally position Indian food and agri-produce such as North Eastern region as Organic Zone, Spices of Kerala, Cardamom of Sikkim, Mango of Malihabad, Orange of Nagpur, Kashmiri Apples, Bihari Litchies and Ratnagiri Mangoes, Tea of Darjeeling, Soybean of Indore and Nilgiris…and so on and promoting Geographic Appellation. Like tea belt of Assam, cotton belt of South India, the nation has to streamline rice belt, wheat belt, corn belt, oil seed belt, Pulses belt, sugarcane belt, tomato belt, mango belt, apple belt, ginger belt, turmeric belt, orange-lime-lemon belt, orchid belt, cut flower belt, jack fruit belt, peach and plum belt. Likewise livestock, fishery, apiary and sericulture belts shall also be created across the country with the objective to improve production and export.

Promotion of Integrated pest management systems*:* It involves the integration of all cultural, biological and chemical inputs to minimize damage by insects, diseases, and weeds. Potash can play a vital role in inducing pest resistance in plants. There is a need to develop integrated pest management systems, specific to local conditions. Pest management, encompassing weed and disease control plus reduced damage by insects, should be an integral part of cropping/farming system management.

Promotion of Climate Resilient Agriculture: The phenomenon of climate change brings both the challenge and opportunity for identifying the precise changes that will be needed in various agro-ecological zones of India. The crop-planning exercise that was conducted fifteen years ago needs to be revised in the new light of evidences on the reductions in the yields of crops due to climate change. There is a need to reorganize the production priorities for the agro-ecological zones in light of climate change. Identifying new set of production activities and delivering the appropriate technologies to farmers will remain a challenge for some time to come. The effective use of bio-technological tools to optimize the use of soil, water and other inputs with a view to enhancing the productivity will be a key for addressing a major challenge. Setting priorities for crop, livestock, and fisheries research that takes into account the productivity changes and improving the quality and quantity of irrigation systems through appropriate institutional mechanisms for supply of electric power will help to reduce climate change effects on agricultural systems.

Promotion of IT applications: Farmers in remote villages are being given access to e-commerce. Many other developments are taking place such as the entry of large corporations in the agri-produce marketing sector which will be mostly sourced through contract farming. This is right time for the industry to promote information technology (IT) at dealers' level. With increasing availability of IT related services, dealers can be networked into not only using these but also providing the much needed knowledge to the farmers about availability of various inputs and their efficient use. They can then get feedback from the field about the performance of specific inputs towards increasing the yield and farmer profits. This will be possible when more and more rural areas have access to computers, internet and user-friendly software in local languages.

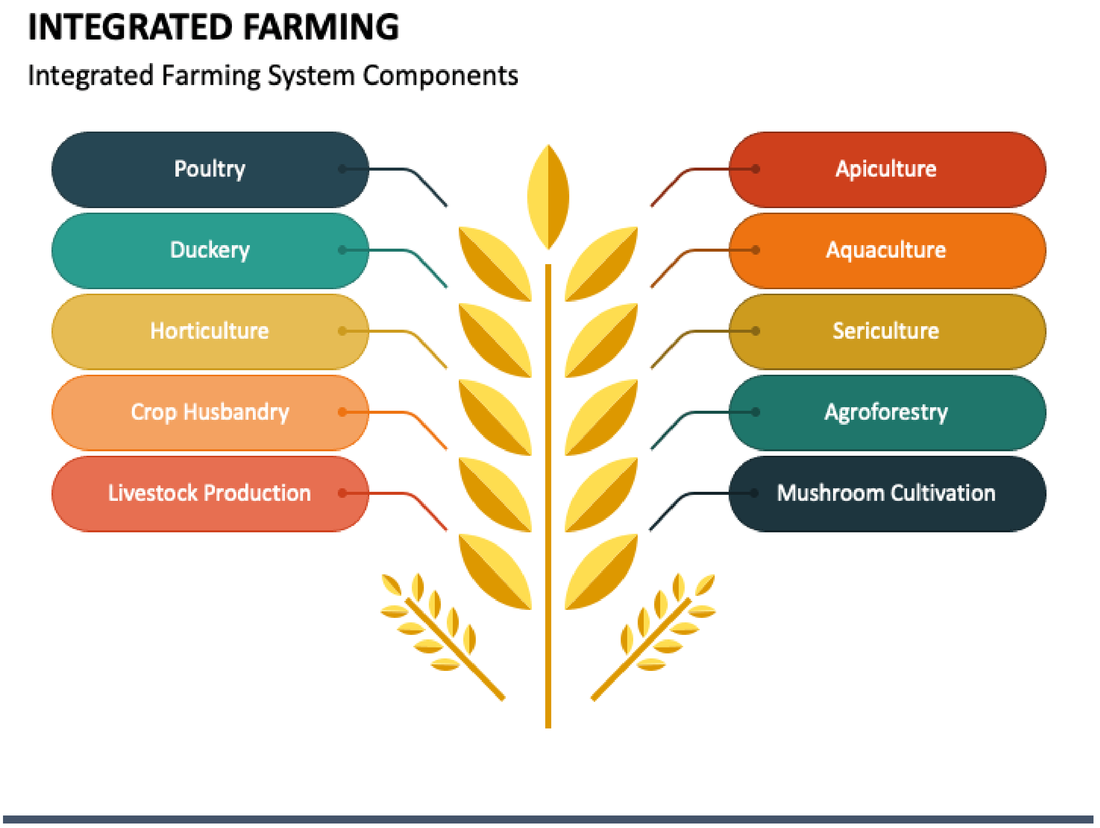
A viable solution comes in the form of SAPSs, which are capable of achieving multiple outcomes:
• Reduce financial burden of external inputs for farmers by increasing the use of readily available local resources
• Increase the resilience of farm lands in the face of extreme climate events, improve soil health, and enhance biodiversity through practices such as minimal tillage, crop rotation, and multi-cropping Improve nutritional security by reintroducing the diverse and local foods in our diets.

Women's Self-Help Groups: There are now over 2.2 million Women's Self-Help Groups (SHGs) linked with banks. The plan is to enroll at least 50 per cent of all rural women as members of SHGs during the next 5 years. We need a similar movement to promote a Small Farmers SHGs. for water and climate management as well as postharvest technology.

Integrated Farming Systems
Among most important strategies for escaping from poverty and hunger, the development of most appropriate farming systems for small and marginal farmers would be important. Dairy husbandry is a boon for small farmers, as a family with three cows or buffaloes can earn an annual income of Rs. 50,000 to 60,000, while conserving our precious native breeds. With stall-fed, high yielding animals, the dung availability will increase by3 to 4 times, giving a boost to biogas and agricultural production. Thirty five million goat keepers in the country who are living below the poverty line, can enhance their income by four folds from Rs. 8000 to 35,000 per annum (BAIF's experience in Jharkhand, Odisha and Rajasthan). The Poultry, piggery, fish farming, beekeeping, mushroom etc. are the other options**.** A view of the components of integrated farming system Integrated Farming System and a model related to Indian farming system have been illustrated in **Picture 2 and 3**, respectively.

The technologies for sustainable agriculture cover the whole spectrum of farming systems. All farming systems, from intensive conventional farming to organic farming, have the potential to be locally sustainable. Whether they are in practice depends on farmers adopting the appropriate technology and management practices in the specific ago-ecological environment within the right policy framework. There is 7 no unique system that can be identified as sustainable, and no single path to sustainability. There can be a co-existence of more-intensive farming system with more-extensive systems that overall provide environmental benefits, while meeting demands for food. However, it is important to recognise that most sustainable farming systems - even extensive systems- require a high level of farmer skills and management to operate.

Farmers have always looked to new technologies as a way to reduce costs. In addition, higher incomes, greater knowledge and improved channels of communication are leading consumers to demand low-cost food of higher quality increasingly produced through organic methods in many countries, with more variety, consistency and year-round availability. At the same time, consumers are increasingly demanding that their food be produced using techniques that conserve natural resources, limit environmental pressures and pay greater attention to rural viability and animal welfare. The process of trade liberalisation is widening the sources of supply and the degree of competition. The changing demands are reflected in policies and are powerfully transmitted to farmers by the media, pressure groups, food retailers and processors.



Picture 2. Components of integrated farming system

Picture 3. Model of Indian integrated farming system

THE ROLE OF EXTENSION

The basic objective of the extension agencies/any knowledge–driven development institute will remain unchanged–the development, expansion and strengthening of the markets and technical back up for its mandated plant nutrients and products. It gives equal weightage to the content (payload) as well as the communication (launch vehicle). The objectives are better achieved by generating, coordinating and dissemination of quality information to meet the needs of diverse target groups (policy makers, researchers, industry, trade, media, extension personnel, service providers such as STLs and the farming community. The fertilizer industry should be visualized as a multi-faceted, multi-nutrient entity to develop, catalyze, coordinate and disseminate knowledge on various issues concerning plant nutrient needs, supply and efficiency. The areas of focus could be productivity, profitability and research based quality information to all the involved target groups. The fertilizer industry should have an up scaled presence, approach and impact as compared to more specialized nutrient focused programs. The fertilizer industry can play an active role in promoting plant nutrients as well as products and brands within the umbrella of balanced crop nutrition. It will also be suitably placed to provide technical back stopping and coordination for specific products through satellite (not core) projects. The challenges before a fertilizer industry will, however, become greater and complex with time going beyond the simple goal of stepping up fertilizer application rates per unit area. The need for increasing crop yield per unit area per unit time will be real and lasting ever green goal which will require enhancement in external plant nutrient supplies and their most efficient use. However, in the process of doing so, the issues concerning policies, agro-economics, farmer profitability, ecology, sustainability and the pressures from alternate farming systems will need to be addressed.

The increasing population pressure in many countries, such as India (17-18 million net annual additions) and the declining land : man ratio will drive the need for more intensive farming. Such cropping at low levels of productivity will be a sheer waste of efforts and resources. A broad–based fertilizer/plant nutrition effort will be better equipped to meet future challenges because it will have greater capability to successfully address the broad-based plant nutrition needs of intensive cropping keeping in mind high productivity and sustainability. In order to maximize the returns from fertilizer and other production inputs, the application of 5 plant nutrients (N, P, K, S, Zn, B) may be required. To promote such plant nutrition strategies with conviction and comfort will be best suited to a program which is not restricted to certain specific nutrients, for example, mostly N and P in north Indian plains. The fertilizer industry should provide the needed critical mass for long-term fertilizer use development to fulfil the present and future challenges of managing multi-nutrient deficiencies.

Reorientation of the Promotional Programs:

The desirable distribution of the promotional programs could consist of collaborative research (new product development and testing to enhance FUE), farmers meetings and group discussions, crop seminars/pre crop season workshops, soil health problems, fertilizer best management practices, improved agricultural practices, SSNM, INM, IPM, benefits of soil test based fertilizer recommendations, importance of biofertilizers, specialty fertilizers, production and use of city compost, climate change, on-farm critical input demonstrations, on-farm maximum economic yield demonstrations, Field days, crop harvest days, success story sessions, T&V programmes, publications and information dissemination, and others - such as liaison, addressing environmental issues, funding special need-based projects (soil nutrient depletion, fertilizer use pattern in relation to soil nutrient status etc). The industry may catalyze activities on the on-farm front by convincing the local institutions to undertake these with minimal direct funding. The fertilizer industry may consider the development and maintenance of a data bank on various aspects of its work plan and drawing upon it to answer enquiries received on any relevant aspect of fertilizer, soil and crop nutrition from various groups (farmers, dealers, extension staff, soil testing laboratories, and even researchers).

Need based Innovative Promotional Programs: Innovative schemes, particularly for the small and marginal farmers, have to be devised and the delivery systems of programs need to be devised and our delivery systems of programs need to be streamlined. There is a host of areas - inputs supply, technology generation and dissemination, rural infrastructure, agro-processing, value addition and marketing, where bold and imaginative steps are needed to ensure the benefits of Government Programs reaching out to the target beneficiaries.

Key Government Policies and Initiatives

Sustainable agriculture focuses on practices that ensure the long-term well-being of the environment, society, and economy. In India, the government has implemented various policies and initiatives to promote sustainable farming practices and increase farmers' income.

Pradhan Mantri Krishi Sinchayee Yojana (PMKSY): Aims to provide irrigation facilities and promote efficient water usage in agriculture, leading to higher crop productivity.

Paramparagat Krishi Vikas Yojana (PKVY): Encourages organic farming practices and sustainable agriculture, minimizing the use of chemicals and promoting soil health.

Rashtriya Krishi Vikas Yojana (RKVY): Enhances public investment in agriculture and allied sectors, supporting sustainable growth and rural development.

Soil Health Card Scheme: Provides farmers with information about soil nutrient status and recommendations for balanced use of fertilizers, leading to improved soil health.

National Mission for Sustainable Agriculture (NMSA): Promotes climate-resilient and sustainable farming practices, focusing on soil health, water use efficiency, and crop diversification.

Pradhan Mantri FasalBima Yojana (PMFBY): Offers insurance coverage and financial support to farmers in case of crop failure due to natural calamities, reducing income risks.

E-NAM (Electronic National Agriculture Market): Facilitates online trading of agricultural produce, ensuring better price realization for farmers by expanding market access.

Kisan Credit Card (KCC) Scheme: Provides farmers with easy and timely credit access for agricultural and allied activities, promoting efficient resource utilization.

***Krishi Vigyan Kendras (KVKs*)**:** Offers extension services, training, and knowledge dissemination to farmers, encouraging the adoption of modern and sustainable agricultural practices.

Agriculture Export Policy: Aims to boost agricultural exports and increase farmers' income by promoting value addition and enhancing market access.

Sustainable Farming Practices and Organic Certification Incentives: Encourages farmers to adopt eco-friendly practices and achieve organic certification, leading to premium prices for produce.

Pradhan Mantri Kisan Samman Nidhi (PM-KISAN): Provides direct income support to small and marginal farmers, improving their financial stability.

Promotion of Agro-Processing Industries: Encourages value addition, reduces post-harvest losses, and creates additional income opportunities for farmers.

National Mission on Oilseeds and Oil Palm (NMOOP): Aims to increase oilseed production and reduce import dependence, benefiting oilseed farmers.

Animal Husbandry Infrastructure Development Fund (AHIDF): Provides financial support to modernize and strengthen animal husbandry infrastructure, benefiting livestock farmers.

Promotion of Nanofertilizers: The government is promoting theuse of IFFCO Nano urea and Nano DAP recently developed by IFFCO to reduce use of chemical fertilizers, enhance their profit and protect environment and reduce the increasing burden of fertilizer subsidy.

Conclusion

The Indian government's policies and initiatives in sustainable agriculture are designed to enhance farmers' income, ensure food security, and promote eco-friendly farming practices. These efforts aim to achieve long-term agricultural sustainability while improving the livelihoods of farmers across the country.

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CHEMOPROFILING OF PLANTS FOR THERAPEUTICAL AND AGRICULTURAL APPLICATIONS

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ABSTRACT

For decades, human have relied on plants for both medicinal purposes, addressing numerous diseases, and safeguarding livestock from infections like mites and parasites. These plants are rich in varieties of bioactive compounds exhibit insecticidal, acaricidal properties, serving multiple roles in traditional remedies and livestock protection. However, using these plants as medicine without sufficient knowledge about their constituents raises safety concerns, as some may be poisonous. To address this, the analysis of these botanicals incorporates evaluations at both macroscopic and microscopic levels, along with chemical profiling, ensuring quality control. Integration of chromatographic techniques along with the identification of marker compounds are crucial in diverse fields like pharmaceuticals and agriculture, contributing to understanding the functional aspects of natural products.

Keywords: Chemoprofiling, botanical plants, bioactive compounds, sustainability.

INTRODUCTION

The Kingdom Plantae encompasses a wealth of herbal sources containing valuable medicinal phytoconstituents. With approximately 500,000 species of land plants, including angiosperms, gymnosperms, ferns, lycophytes, and bryophytes, their diversity is particularly concentrated in the humid tropics. A significant number of these species remain undiscovered by science(Mishra et al.,2018). For centuries, plants have been used as medicine without an understanding of their constituents. Additionally, the use of certain poisonous plants without adequate profiling can lead to fatal consequences. For example, *Lantana camera* which is famous as an insecticidal and also utilized as herbal medicine for ailments like cough, fever, stomach ache. Despite its medicinal properties,, these plants are toxic and poisonous to toddlers and even to dogs and cats(Lauren et al.,2022). Stressing the crucial need for standardization and quality control, it is essential to blend modern scientific techniques with traditional knowledge. Regulatory guidelines and pharmacopoeias support this by endorsing macroscopic and microscopic assessments, coupled with chemical profiling, as measures to guarantee the quality and standardization of botanical materials (Förste et al.,2021).Chemoprofiling is the process of analysing and identifying the chemical constituents within the substance to understand both their makeup and potential biological potential. This process finds applications across various industries, spanning from the therapeutic sector to agriculture.

VARIOUS METHODS EMPLOYED IN CHEMOPROFILING

The techniques listed below(Table 1) are crucial in chemoprofiling as they offer insights into the chemical and bioactive composition of plants. Researchers commonly employ these methods to gain a thorough understanding of the complex mixtures present in biological samples.

Table 1: Techniques used in chemoprofiling and their uses

TECHNIQUES	USES
HPLC (High-Performance Liquid Chromatography)	Employed to identify, separate and quantify constituents within a mixture.
GC (Gas chromatography)	Ideal for volatile compounds. This method separates them by their affinity to the stationary phase.
TLC (Thin-Layer Chromatograph)	Cheap and quick for qualitative analysis. Often employed as an initial step or prelim
MS (Mass spectrometry)	Analyse structural and molecular weight by ionizing compounds and examing their mass-to-charge ratio
NRM (Nuclear Magnetic Resonance)	Offer structural details by examining their nuclear spin character.
IR (Infrared Spectroscopy)	Effective for discerning the functional groups within molecules
UV-Visible Spectroscopy	This process measures absorbance of light to identify and quantify these substances.
X-ray Crystallography	Furnishes intricate three-dimensional(3D) arrangements of crystalline compounds.
CE (Capillary Electrophoresis)	Divides the compound by their sizes and charges in an electric field.
GC-MS (Gas Chromatography-Mass Spectrometry)	Integrates GC for compounds separation and MS for identification.
LC-MS (Liquid Chromatography-Mass Spectrometry)	Pairs LC and MS to separate and identify compounds.

CHEMICAL COMPOUNDS PRESENT IN PLANT

Plant raw materials and their extracts typically comprise a mixture of various components. Plants usually contain four types of constituents: Active principles , Active markers, Analytical marker and Negative marker(Jadhav et al., 2024). Active principles(elements within a substance may possess recognized clinical effects), active markers(the components present in a substance display acknowledged pharmacological activity, playing a role in its effectiveness, for example in green tea, catechins like epigallocatechin gallate (EGCG) serve as active principles), analytical marker(when active principles or markers are not clearly defined, specific components within botanical raw materials and their extracts are chosen for quantitative assessment. These selected constituents serve as markers for the positive identification of the tested substance).Negative marker(Certain elements found in botanical extracts may possess allergenic or toxic properties, rendering their presence undesirable).

Table 2 : Provides an overview of common plants, detailing their associated chemical compounds and respective applications.

PLANT	CHEMICAL COMPOUND	USES
Curcuma longa(Turmeric)	Curcumin, Bisdemethoxycurcumin, Demethoxy curcumin, Turmerones	Anti-cancer, antioxidant, anti-inflammatory, biopesticides

PLANT	CHEMICAL COMPOUND	USES
Zingiber officinale (Ginger)	Gingerol, Zingerone, zingiberene, bisabolene	Anti-inflammatory, Digestive problems ,anti-fungal, biopesticides, soil improvement
Aloe barbadensis miller (Aloe Vera)	Aloin, Aloe-emodin, anthraquinones	Anti-inflammatory, Skin problem, enhance plant growth and improve stress tolerance
Azadirachta indica (Neem)	Azadirachtin, Nimbin, and nimbidol	Skin condition, anti-fungal, anti-bacterial, biopesticides
Allium sativum (Garlic)	Allicin, ajoene, alliin, sulphur compounds.	Heart problems, anti-microbial, anti-inflammatory., biopesticides, plant growth promoter
Mentha spp(Mint)	Menthol	Stomach problems, Cosmetic industry
Rosmarinus officinalis (Rosemary)	Ursolic acid, rosmarinic acid	Anti-oxidant, Cosmetic industry and as a herb,

UTILIZAION OF CHEMOPROFILING

The qualitative and quantitative analysis of plants holds considerable significance across diverse fields, ranging from medicine to agriculture to environment This underscores the importance of the chemoprofiling process**.**

- In the field of medicine, identifying of these secondary metabolites helps in the discovery of the potential drug for various diseases.
- In agriculture, understanding its chemical constituents , we can enhance the plant traits for the plant resistance, nutrition , flavour.
- At the environment level, understanding the chemical composition or chemoprofiling plays a crucial role in identifying and quantifying pollutants within ecosystems.

CONCLUSION

The studies on chemoprofiling of bioactive compound sis one of the best techniques for in-depth knowledge of plants for their applications in pharmaceuticals. By understanding their chemical constituents, we can discover new drugs or improve the plant traits, nutritional concentration or plant growth. Chemoprofiling of the plants may even lead us to new discoveries of antiviral or anti-bacterial properties for curing diseases like HIV(Human Immunodeficiency Virus) or biopesticides effective against some of the resistant strains of insects such as DBM(Diamondback Moth), aphids, BPH (Brown plant hopper), etc.

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WTO AGREEMENT ON AGRICULTURE

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Introduction

The Second World War has played a very significant role in the establishment of the General Agreement on Tariff and Trade. It was signed by 23 nations on 30 October, 1947 and took effect on 1st January, 1948. The ending round with regard to the GATT was the Uruguay Round. Around 124 nations had participated withinside the round. The creation of WTO was negotiated in the Uruguay round. The WTO was set up in the year 1995. Agriculture ruled the continued discussions of the Uruguay Round. Agreement on Agriculture was one of the main agreements which were negotiating in Uruguay round. Agreement on Agriculture enter into force when the WTO came into being on 1st January 1995 with objective to reform agriculture trade.

The General Agreement on Tariffs and Trade (GATT):

- Formed in 1947
- Location - Geneva
- Country involved - 23
- The General Agreement on Tariffs and Trade (GATT) became a multilateral association supposed to modify global trade.

➢ **Main Objectives:**

- Reduction of barriers to international trade.
- Achieved thru discount of Tariff barriers, Quantitative restrictions.

➢ **Key Principles in GATT**

- Non Discrimination
- Transparency
- Tariff binding and reduction
- Promoting development of all countries

World Trade Organization (WTO):

Intergovernmental enterprise which regulates the worldwide change Officially started on 1st Jan 1995 beneath Neath the Marrakesh Agreement Signed with the aid of using 123 countries in 1994. WTO had replaced GATT (General agreement on tariffs and trade). They deal with regulation of trade in goods, service and intellectual properties between member countries.

Objectives of WTO:

- Implement new trade agreement
- Promote multilateral trade
- Promote free trade
- Enhance competitiveness

- Increase the level of production and productivity with employment
- Expand and utilize world resources
- Development of poorest nation
- Improve the level of living and speed up economic development

Major Functions of WTO:

- Administering WTO trade agreements
- Trade negotiations
- Handling trade disputes
- Monitoring national trade policies
- Technical assistance and training for developing nations
- Cooperation with other international organizations

Table 1: Difference Between GATT and WTO

Sr. No.	Particulars	GATT	WTO
1	Commitment	Provisional	Permanent
2	Participating country	Contracting parties	Members
3	Rules	Trade in goods	Trade in goods, service, intellectual properties
4	Efficiency	Dispute settlement mechanism was less efficient	Dispute settlement mechanism is more efficient

WTO Agreement:

GATS
- It was created for service sector.
- The agreement entered into force in January 1995.

TRIPs
- For many forms of intellectual property (IP) regulation.
- It was negotiated at the end of the Uruguay Round of the GATT in 1994.

SPS
- Food safety as well as animal and plant health.
- It was negotiated during the Uruguay round of GATT.

TBT
- It ensures that technical negotiations and standards, testing and certification procedures do not create unnecessary obstacle to trade.
- It was negotiate during 1994.

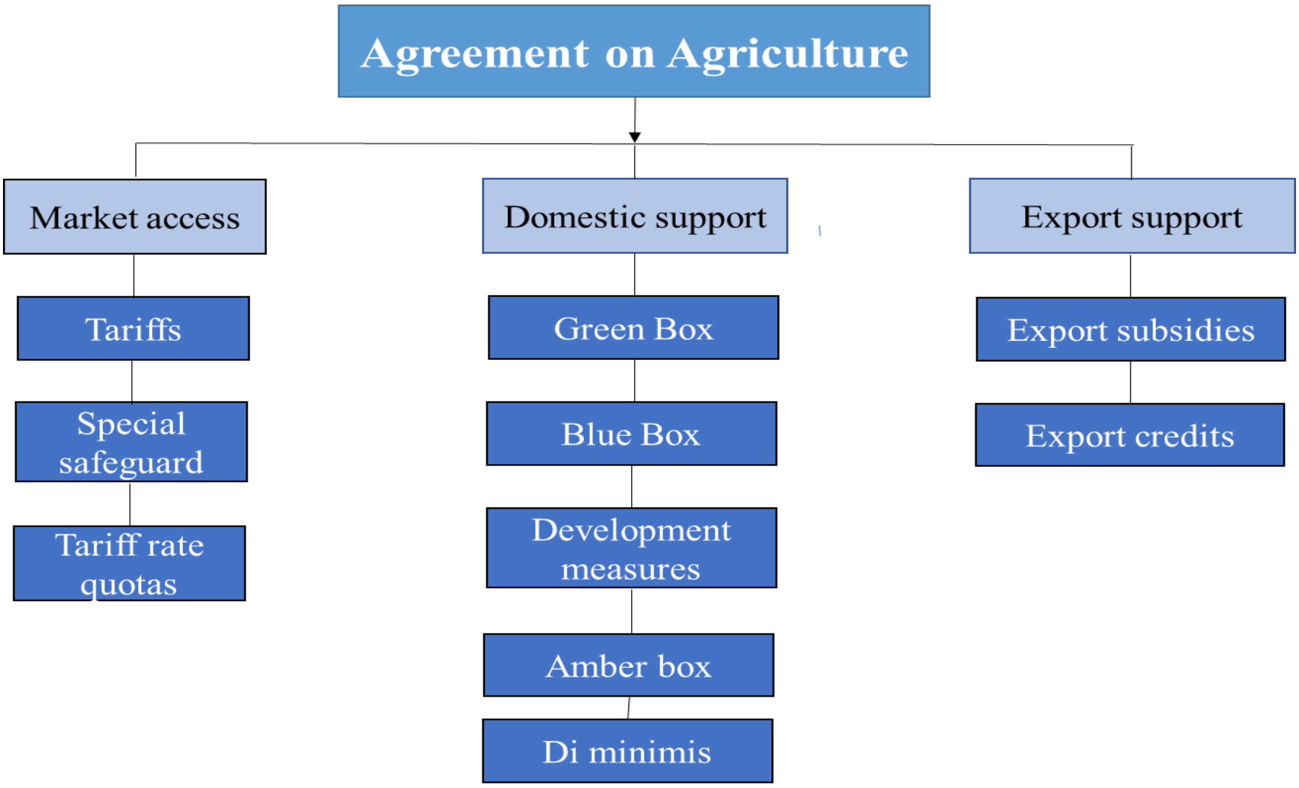
Agreement on Agriculture (AoA):

- Agriculture remains one of the most contentious issues in the ongoing negotiations of the World Trade Organization.
- After over 7 years of negotiations, the Uruguay Round were formally ratified in April 1994 at Marrakesh, Morocco. The WTO Agreement on Agriculture changed into one of the important agreements which had been negotiated at some point of the Uruguay Round.
- The WTO Agreement on Agriculture entered into force on 1 January 1995.
- It was aimed to establish a fair and market oriented agricultural trading system through remove trade barriers and to promote transparent market access.

Objective of Agreement on Agriculture:

- Establish a fair, obvious and marketplace orientated agricultural buying and selling system.
- Reducing distortion in trade by reduction in agricultural support and protection.
- Correct and prevent restriction distortion on world agricultural market.
- Allows a few flexibility withinside the manner commitments are implemented.
- Reduce restriction on trade

Three "Pillars" of the Agreement on Agriculture:



India's Commitment to AoA:

Market access:

- India was maintaining Quantitative Restrictions. It did now no longer should adopt any commitments in regard to marketplace access.
- The most effective dedication India has undertaken is to bind its number one agricultural merchandise at 100%; processed meals at 150% and suitable for eating oils at 300%.
- For a few agricultural products like skimmed milk powder, maize, rice, wheat, millets etc. Which were sure at 0 or at low sure rates
- Though India isn't entitled to apply the Special Safeguard Mechanism of the agreement.

Domestic support:

- India does not provide any product specific support other than market price support.
- For agricultural sector, domestic support up to 10% of total value of agricultural produce is allowed in developing countries, and 5% in developed countries.

- In India, the product specific support is negative, while non product specific support (Subsidies on power, irrigation, fertilizers, etc.) are well below the permissible level of 10% of value of agricultural output.
- So, India beneath neath no responsibility to lessen home guide presently prolonged to the rural sector.

Export subsidies:

- Export subsidies of the type indexed withinside the AOA, which are a magnet for discount commitments aren't prolonged in India.
- In India, exporters of agricultural commodities do now no longer get any direct subsidy.
- The most effective subsidies to be had to them are withinside the shape of (a) exemption of export make the most of profits tax beneath Neath phase 80-HHC of the Income Tax Act. (b) subsidies on fee of freight on export shipments of sure merchandise like fruits, greens and floricultural merchandise.
- India provide product specific subsidies in the form of minimum support price, classified under Green box to maintain food security and non-product specific support to resource poor farmers.

Conclusion

From the foregoing discussion it can be concluded that, after commencement of AoA the, % share of agricultural Imports has increased whereas during the same period % share of agricultural export could comparatively decrease. Therefore, a clean fashion of extra agricultural imports withinside the post-WTO duration arises which indicates that India couldn't advantage the predicted get entry to for its agricultural merchandise with the aid of using joining the WTO's AOA. India is a number of the foremost manufacturers of agricultural commodities and net exporter of them. Presently India's share in agriculture exports is 1.2% which is very minuscule compared to its potential. At the same time after the commencement of World Trade Organization (WTO) GDP of India was increase.

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ENHANCING GLOBAL NUTRITION: BIOFORTIFICATION STRATEGIES AND IMPACTS

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Abstract
This article delves into the pivotal method of biofortification, aiming to enhance the nutritional value of crops crucial for human consumption. Employing plant breeding, agronomic practices, and cutting-edge biotechnology, biofortification addresses the challenge of micronutrient deficiencies in many staple crops. The techniques, including genetic engineering, agronomic practices, and conventional breeding, are explored, each presenting distinct advantages and considerations. The benefits of biofortification extend beyond improved nutritional content, encompassing stable crop yields, disease resistance, and long-term health improvements. Despite its potential, biofortification faces challenges related to public acceptance, awareness, and initial costs. The article emphasizes biofortification's overarching objective of reducing micronutrient-related health issues and enhancing food security in developing nations.

Introduction

The method of biofortification involves improving the dietary value of agricultural crops through a variety of strategies, such as plant breeding, agronomic practices, and cutting-edge biotechnology procedures. An emerging, beneficial, affordable, and effective method of providing micronutrients to people who have few availabilities of varied meals is biofortification. Many agricultural crops, sadly, are poor suppliers of the micronutrients necessary for healthy human growth. The terms "biofortification" describe nutrient-added food crops with improved bioavailability for the human population. The ultimate objective of biofortification is to produce adequate amounts of healthy and secure food. (Saltzman *et al*,2014). When there is little to no genetic diversity in the amount of nutrients present in different plant kinds, the transgenic technique can be a viable choice for the production of biofortified crops. (Welch *et al,* 1999) (Zhu *et al*,2007). One such tactic for combating malnutrition is biofortification. Mineral fertilization or plant breeding are two methods that may be used to biofortify, or enhance the number of micronutrients in the edible sections of plants. The goal of biofortification is to increase the mineral density and bioavailability of certain crops like rice, wheat, beans, and other grains and legumes.

Techniques of Biofortification

The techniques of biofortification are described below-

Genetic engineering/ modification - Redistributing micronutrients across tissues, raising the number of micronutrients in the edible parts of processed crops, boosting the effectiveness of biochemical processes in edible tissues, or even reconstructing specific pathways are all possible through genetic engineering. Contrary to organizational and agronomic biofortification programs that are nutrition-based, the formation of transgenic biofortified crops at first requires a significant amount of energy, time, and expenditure during the research and development stage. However, in the long run, this method is more affordable and environmentally friendly.

Agronomic practices - Agronomic biofortification involves manually applying nutrients to crops in order to improve their nutritional status. Consuming these crops also improves the nutritional condition of humans. Agronomic biofortification is easy and cheap, but it requires specific consideration when it comes to nutrient supply, distribution technique, and environmental impact. These need to be administered often throughout each crop season and are occasionally less cost-effective as a result.

Conventional plant breeding - The most popular kind of biofortification is done through conventional breeding. It provides an affordable, environmentally friendly alternatives to agronomic- and transgenic based techniques. For conventional breeding to be practical, there must be sufficient genotypic diversity in the characteristic of interest. This mutation can be used in breeding programs to raise the mineral and vitamin content of crops. In traditional plant breeding, parent lines with high nutrient content are crossed with recipient lines with desirable agronomic features over a number of generations to generate plants with the desired agronomic and nutritional characteristics. However, the gene pool's restricted genetic diversity is sometimes a need for breeding tactics.

Advantages of Biofortification

1. After the initial expenditure to create fortified seeds, ongoing expenses are minimal, and fortified seeds are distributed globally.
2. The biofortified crop method is very stable once it is established.
3. Helping plants with stand disease and other environmental challenges may have significant indirect impacts on enhancing agricultural yield.
4. In order to combat human malnutrition.
5. An improvement in the nutritional value of daily diets
6. Enhancement of plant or crop quality and growth in genetic diversity.
7. Enhancing biofortification contributes to improving people's general health. These crops yield more and are more resistant to diseases, pests, droughts, and other environmental variables.
8. Biofortification offers a food-based, long-lasting, low-dose alternative to iron supplements technique for customers.
9. Crops that have been bio-fortified have a higher possibility of eradicating the malnutrition issue in the future.

Objective of Biofortification

The primary goals of biofortification are to reduce micronutrient-related mortality and morbidity rates while simultaneously enhancing food security, productivity, and quality of life for the poor in developing countries.

Challenges

It could be difficult to convince people to embrace biofortified foods when they differ in some ways from their non-fortified equivalents. Foods fortified with vitamin A are frequently dark yellow or orange in color in some places where white maize is consumed by humans while yellow maize is associated with animal feed or food aid, or in other regions where white-fleshed sweet potatoes are preferred to their moister, orange-fleshed counterparts. This can be done by making the plant more cultivable. Biofortification may be difficult if rural impoverished people are not properly informed about it. However, during the biofortification process, the food's flavor and color shouldn't be changed. This should be widely used by farmers as well. The initial costs can prevent some individuals from implementing.

Conclusion

It is commonly known that biofortification is a successful and promising agricultural method for raising the nutritional status of undernourished communities all over the world. Human mineral deficiency can be addressed with the use of biofortification techniques based on crop breeding, targeted genetic modification, and/or the use of mineral fertilizers. Insufficient amounts of these and other similar micronutrients, which are typically absent in the diets of the developing and developed worlds, are being provided via the development of biofortified food crops with increased nutritional contents, such as increases in iron, zinc, selenium, and provitamin A content.

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BIOETHANOL IS A RENEWABLE FUEL USED AS A LOW-CARBON ALTERNATIVE TO FOSSIL-DERIVED FUELS

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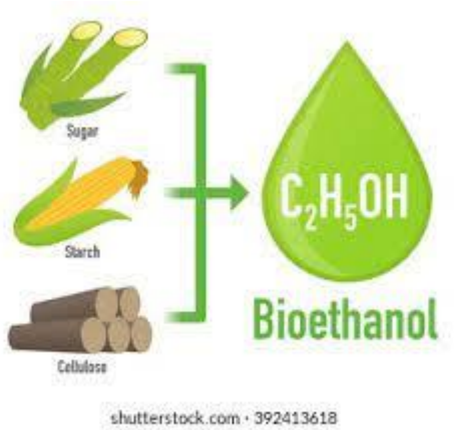
Bioethanol

Bioethanol, also known as ethanol or ethyl alcohol, is a type of alcohol that is produced from renewable resources, typically derived from plant materials, such as crops like corn, sugarcane, wheat, and various types of biomass. It is considered a biofuel because it is produced from organic matter and can serve as a renewable and more environmentally friendly alternative to fossil fuels like gasoline. Here are some key points about bioethanol:



Production: Bioethanol is primarily produced through a process called fermentation. Microorganisms, such as yeast, break down the sugars present in plant materials into ethanol and carbon dioxide. This ethanol can then be separated and purified for various uses.

Feedstock: The choice of feedstock for bioethanol production can vary depending on regional availability and resources. Common sources of feedstock for bioethanol production include corn (maize) in the United States, sugarcane in Brazil, and wheat and barley in some European countries.

Blending with Gasoline: Bioethanol is often blended with gasoline to create ethanol-blended fuels, such as E10 (10% ethanol and 90% gasoline) or E85 (85% ethanol and 15% gasoline). These blends are used as an alternative to pure gasoline and can help reduce greenhouse gas emissions.

Environmental Benefits: Bioethanol is considered more environmentally friendly than fossil fuels because it is derived from renewable sources, and it can help reduce the carbon footprint associated with transportation and other energy-intensive activities.

Challenges: While bioethanol has environmental benefits, its production can raise concerns about land use, deforestation, and competition with food crops. Ethanol production methods can also

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require significant amounts of water, and the energy balance (energy in vs. energy out) can vary depending on the feedstock and production process.

Uses: Besides being used as a fuel additive, bioethanol is also used in various industrial and consumer products, such as alcoholic beverages, perfumes, pharmaceuticals, and as a solvent in chemical processes.

Research and Development: Researchers are continually working on improving bioethanol production processes, exploring new feedstocks, and developing more sustainable methods to enhance its environmental benefits and reduce its drawbacks.

Overall, bioethanol plays a significant role in the transition toward more sustainable and environmentally friendly energy sources, particularly in the context of reducing the carbon footprint in the transportation sector.

Bioethanol offers several benefits, making it an attractive option in the context of renewable and sustainable energy sources. Some of the key advantages of bioethanol include:

Renewable Resource: Bioethanol is produced from renewable resources, such as plants and crops. As long as these resources are managed sustainably, bioethanol production can continue indefinitely unlike finite fossil fuels.

Reduced Greenhouse Gas Emissions: When used as a fuel additive or in ethanol-blended fuels, bioethanol can reduce greenhouse gas emissions compared to traditional gasoline. It is considered a cleaner-burning fuel, as it produces fewer carbon emissions when combusted.

Energy Security: Bioethanol production can enhance energy security by diversifying energy sources. It reduces a country's dependence on imported fossil fuels, which can be subject to price fluctuations and geopolitical tensions.

Job Creation: The bioethanol industry can create jobs, especially in rural areas where feedstock crops are grown and in the production and distribution of ethanol.

Reduced Air Pollution: Ethanol-blended fuels can result in lower levels of air pollutants, such as carbon monoxide and volatile organic compounds, which contribute to smog and air quality problems in urban areas.

Economic Benefits: The production and use of bioethanol can contribute to economic growth, particularly in agricultural regions where bioethanol feedstocks are cultivated.

Reduced Dependency on Oil: Bioethanol can reduce a country's dependency on oil, which is often imported and subject to price fluctuations. This can enhance energy independence and reduce exposure to global oil market volatility.

Technological Advancements: Research and development in bioethanol production methods have led to increased efficiency and reduced environmental impact. New technologies and innovations continue to improve the sustainability of bioethanol production.

Waste Utilization: Bioethanol can be produced from various types of biomass, including agricultural residues and waste materials. This can help reduce waste and provide an additional revenue stream for farmers and waste management facilities.

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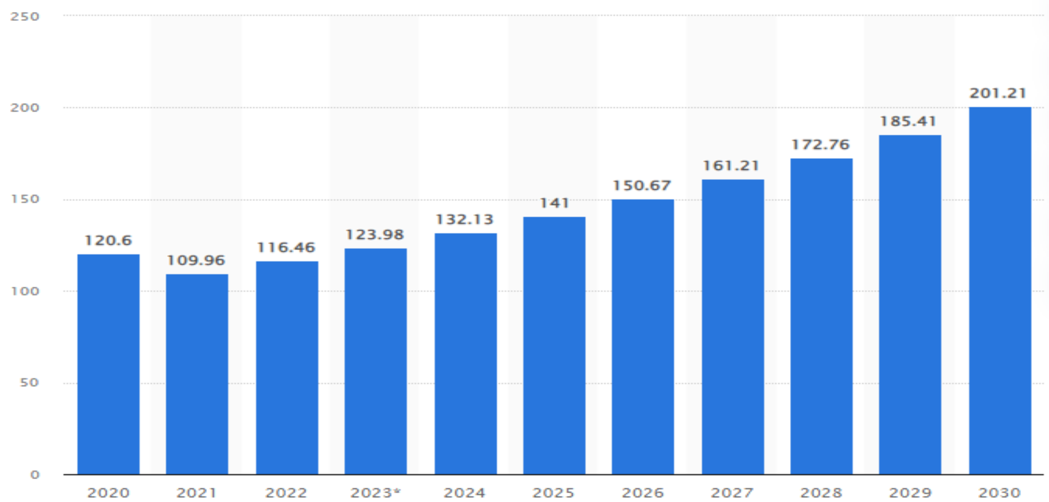
Flex-Fuel Vehicles: Bioethanol can be used in flex-fuel vehicles (FFVs), which are designed to run on a range of ethanol-gasoline blends, making it easier for consumers to adopt this renewable fuel source.

It's important to note that while bioethanol has numerous benefits, it also has some challenges and limitations, such as concerns about land use change, water consumption in the production process, and the energy balance of certain production methods. Nevertheless, as technology and sustainability practices continue to advance, bioethanol is likely to play a growing role in reducing the environmental impact of transportation and other energy-intensive sectors.



Disadvantage of Bioethanol

1. **Land Use and Food Competition**: The production of bioethanol often competes with land and resources that could be used for food production. This competition can lead to rising food prices and concerns about food security, particularly when food crops like corn and sugarcane are used for ethanol production.
2. **Deforestation and Habitat Loss**: In some regions, the expansion of bioethanol feedstock crops has led to deforestation and habitat destruction. This can have negative environmental impacts and contribute to biodiversity loss.
3. **Water Usage**: The production of bioethanol can be water-intensive, especially when large-scale irrigation is required for feedstock crops. This can strain local water resources and lead to water scarcity in certain areas.

4. **Energy Balance**: The energy balance of bioethanol production can vary depending on the feedstock and production methods. In some cases, the energy inputs required for cultivation, processing, and transportation of feedstock may be comparable to or even exceed the energy output from the bioethanol. This can limit the environmental benefits of bioethanol.
5. **Greenhouse Gas Emissions**: While bioethanol can reduce greenhouse gas emissions when used as a fuel, the overall emissions reduction depends on factors like land-use change and the energy sources used in production. If feedstock production results in deforestation or relies on fossil fuels, it can have a negative impact on emissions.
6. **Ethanol Purity and Water Absorption**: Bioethanol can absorb water, which can be problematic for fuel quality and transportation through pipelines. This requires special handling and transportation infrastructure to maintain ethanol purity.
7. **Infrastructure and Distribution Challenges**: Widespread adoption of bioethanol as a fuel requires infrastructure modifications, such as the construction of ethanol blending and distribution facilities. This can be costly and time-consuming.
8. **Limited Energy Density**: Pure ethanol has a lower energy density compared to gasoline, meaning that vehicles fueled by ethanol may experience reduced mileage or require larger fuel tanks for similar driving ranges.
9. **Corrosion and Material Compatibility**: Ethanol is corrosive and can damage certain materials used in vehicle engines and fuel systems. As a result, vehicles and infrastructure need to be designed to handle ethanol-based fuels.
10. **Limited Availability**: In some regions, bioethanol may not be readily available, limiting its accessibility as a fuel option for consumers.
11. **Market and Price Fluctuations**: The bioethanol market can be influenced by factors like government policies, subsidies, and fluctuations in feedstock prices. This can lead to uncertainty for producers and consumers.
12. **Ethical and Social Concerns**: The production of bioethanol can sometimes involve labor practices and land acquisition issues that raise ethical and social concerns, particularly when it affects local communities and indigenous populations.

    Despite these disadvantages, it's important to note that ongoing research and technological advancements aim to mitigate these challenges and make bioethanol production more sustainable and environmentally friendly. Additionally, the choice of feedstock, production methods, and government policies can significantly influence the environmental and social impacts of bioethanol production.

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LAC CULTIVATION: NURTURING RESINOUS WEALTH

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Abstract

Lac cultivation involves the fostering of lac insects primarily on host trees. The process begins by establishing colonies of lac insects on these trees, where they secrete resinous substances to protect themselves. This resin, known as lac, is harvested by scraping it off the branches, processed and used in various industries. The cultivation process typically includes the careful selection of suitable host trees, creating an environment conducive to the growth and reproduction of lac insects. This practice carries significant economic importance, especially in rural areas, providing livelihoods for numerous communities worldwide. The lac resin finds applications in pharmaceuticals, cosmetics, food additives and even in traditional crafts like lacquering.

Key words: Applications, Host trees, Lac cultivation, Resin

INTRODUCTION

Lac is a resinous secretion produced by scale insects, covering their bodies. It stands as the sole resinous secretion originating from animals. These insects excrete a brown, resinous substance, recognized as authentic lac, which serves as the precursor to the production of commercial shellac. Lac insects have a widespread presence in countries like India, Thailand, Burma, Pakistan and Sri Lanka. India specifically contributes 65% to global lac production, with significant cultivation occurring in states such as Bihar (accounting for 40 % of lac production), Madhya Pradesh (MP), West Bengal (WB), Orissa, Assam and Uttar Pradesh (UP). Lac cultivation involves the dispersal of lac insects onto either the same or different host trees. This process entails introducing newly hatched nymphs to establish colonies. Repeated natural inoculation on a single host tree can weaken it. When employing artificial inoculation, meticulous care and precautionary measures are essential.

Cropping calendar of lac insect

Strain	Crop	Time of inoculation	With brood from	Time of harvesting
Rangeeni	Baisakhi	Oct- Nov	Katki crop	June-July
	Katki	June-July	Baisakhi	Oct-Nov
Kusumi	Jethwi	Jan-Feb	Aghani	June-July
	Aghani	June-July	Jethwi	Jan-Feb

Host plants of Lac insect

1. Palas- *Butea monosperma*
2. Ber - *Zizyphus jujuba*
3. Kusum- *Schleichera oleon*
4. Khair- *Acacia catechu*

INOCULATION OF LAC INSECT

- Choose suitable host trees. The process of inoculating crops follows the cropping calendar, utilizing brood lac culture obtained from the previous crop of the specific strain as a guide for inoculation.
- Prepare the host tree by ensuring it has adequate new growth, tender branches and an environment suitable for the insects' colonization.
- Obtain lac insect broods or nymphs from established sources or colonies: Mature and healthy broods, devoid of infestations and containing insects ready to emerge from the parent tree, are carefully cut. The optimal time for branch cutting is typically identified by observing lac cells that exhibit a red hue in the front half and an orange coloration toward the anal region.
- Chosen brood lac sticks or twigs, ranging from 15 to 30 cm in length, are sectioned and bundled together in sets of two or three sticks, secured using banana or jute fiber. These prepared bundles are immediately used to inoculate the host tree by securing them onto the upper branches.
- For the Kusumi strain, the inoculation of a tree typically requires around 1 to 2 kilograms of brood lac sticks, the quantity vary based on the tree's size. Conversely, for the Rangeeni strain, the amount needed ranges between 0.40 to 5 kilograms for the inoculation of a single tree, again contingent upon the tree's size.
- Within one or two days following inoculation, the crawlers begin to emerge. The brood lac sticks must be removed within three weeks of inoculation.

HARVESTING

- A mature crop is the one from which nymphs will emerge in 7 to 10 days. The harvesting is made prior to emergence of nymphs.
- The general symptoms of emergence (swarming) are dried appearance of cracks on the encrustation. However, appearance of an orange yellow area near anal tubercle is the clear indication of swarming.
- The harvested lac sticks are spread out on the clean floor without allowing them to stick together.

Yield- 2.5 to 3 times the weight of brood lac.

CONCLUSION

Lac cultivation holds immense importance for farmers, providing them with a significant source of income and livelihood. The products derived from lac, especially shellac, have wide-ranging uses in industries like cosmetics, pharmaceuticals, food coatings, and even in traditional crafts like wood finishing and polish. These products not only cater to domestic markets but also contribute significantly to global trade, enhancing economic prospects for lac-producing regions. Lac cultivation serves as a reliable income stream, often supplementing agricultural earnings. It requires relatively low investment and utilizes trees that are not primarily for food, making it a valuable addition to farming practices.

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BALANCING THE SCALES: UNRAVELING THE ENVIRONMENTAL DILEMMA OF INDUSTRIAL AGRICULTURE

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Abstract

This article delves into the historical trajectory of industrial agriculture, initially hailed as a solution to global food scarcity. Despite its success in boosting food production and lowering costs, the environmental toll has been significant. From the rise of industrial farming methods to the consolidation of multinational corporations, the narrative unfolds the pros and cons of this agricultural model. While industrial agriculture has increased food production, lowered consumer costs, and spurred technological innovation, it has also led to issues such as animal mistreatment, environmental degradation, health concerns, and subpar food quality. The discussion extends to the concept of agricultural pollution and its multifaceted effects on the environment, including soil erosion, water contamination, and biodiversity loss. The article concludes by advocating for a shift towards sustainable farming practices to address the challenges posed by industrial agriculture and ensure a healthier, more environmentally conscious future.

Introduction

Industrial agriculture once appeared like the answer to a planet that was expanding too quickly. High yield hybrids of cereals, chemical pesticides, and synthetic fertilizers all made claims to decrease hunger, feed expanding populations, and boost the economy. Agriculture's output more than quadrupled between 1960 and 2015, resulting in an abundance of affordable food and preventing a worldwide food emergency. However, not everything happened as planned. The ecology has suffered greatly as a result of decades of industrial farming, and there are significant worries about the future of food supply.

What is Industrial Agriculture?

Industrial agriculture is the large-scale, intensive production of both crops and animals, sometimes involving the risky routine use of antibiotics on animals or chemical fertilizers on crops (as a means to make up for filthy surroundings, even when the animals are healthy). There is also a chance of growing crops that have been genetically altered, using a lot of pesticides, and engaging in other practices that harm animals, the environment, or aggravate pollution.

Over the last several decades, industry consolidation has increased as a result of "vertical integration," or the transition from small, diversified farms producing a range of crops and livestock to an industrialized system controlled by giant multinational corporations. These companies make money even as the expenses of industrial operations' impact on health climb, while farmers, producers, and their staff watch their incomes decline.

Pros of Industrial Agriculture

Food production has increased: Industrial farms that operate on a huge scale have an advantage over traditional farms when it comes to producing food more rapidly and in larger quantities. This may be advantageous given that the world's population is steadily growing.

Consumer costs are decreased: Industrial farms help to reduce food costs and provide access to food for all consumers, especially those with little financial resources. Industrial agriculture decreases food prices by boosting revenue and profits while decreasing overhead expenses. Modern technology and machinery are used in industrial agriculture to swiftly and effectively prepare meat, eggs, milk, crops, and other food commodities.

Encourages innovation and technological development: These farms heavily rely on modern technology; therefore, engineers and scientists must continue to create new and improved machinery to boost food production's speed and efficiency. Both industries and industrial farms businesses benefit from this.

Creates new employment opportunities: Industrial agriculture still needs workers despite its reliance on automation. The local economy of the area gains once these powerful weapons are constructed, creating job opportunities.

Extends the food supply: Industrial agriculture has helped to advance innovative techniques for handling, storing, and transporting food, increasing its shelf life. As a result, there is now more food accessible and less food waste.

Cons of Industrial Agriculture

It increases the likelihood of animal mistreatment: since animals confined in factory farms are not given enough space to walk about freely and behave as they would in the wild. On rare occasions, animals are housed in cramped cages. They usually live in unsanitary circumstances and are compelled to consume vitamins, minerals, and other things that speed up their growth. Animals are more often treated as disposable objects than as living beings.

It negatively impacts ag-related small companies: Industrial farms are often run by large corporations with the financial ability to use state-of-the-art equipment, larger structures, and expensive chemicals to produce more food more efficiently.

Since they can produce these goods in bulk at a reduced cost, they can also sell them to grocery stores and supermarkets for far less than smaller farms can. Smaller farms sometimes lack the funds to purchase cutting-edge equipment.

It prompts environmental concerns: Thousands or perhaps hundreds of animals are reared on industrial farms. These animals create a lot of waste products, which are usually dumped into nearby water bodies where they pollute them. The waste produced might contaminate adjacent lands, rivers, and streams, as well as damage the ozone layer and the air quality.

It exacerbates health problems: Industrial agriculture may harm our health in a variety of ways. One method is by the pollution it generates, which is harmful to individuals who live nearby and increases their susceptibility to sickness. The regular use of herbicides and pesticides on food crops, which are connected to sickness and poisoning, is another issue.

In addition to chemical poisoning and animal-transmitted illnesses, the stressful conditions in which animals are kept have a negative impact on the quality of the food that is produced.

It could produce subpar quality food: As we discussed earlier, pesticides that are dangerous to ingest are often sprayed on food crops. Antibiotic injections are administered to farm animals at factory farms in an effort to keep them healthy considering the unclean conditions they are housed in. However, bacterial illnesses that are resistant to antibiotics can evolve and flourish, and they can then transmit to those who consume the germs. In addition to chemical poisoning and animal-transmitted illnesses, the stressful conditions in which animals are kept have a negative impact on the quality of the food that is produced.

What is Agricultural Pollution?

Agricultural pollution is the contaminant that is released into the environment as a result of raising livestock, food crops, animal feed, and biofuel crops.

Effects of Agricultural Practices on the Environment

Industrial agriculture causes severe animal suffering and an increase in greenhouse gas emissions since it uses a tremendous amount of land, energy, and water to raise animals for food. Regularly applied agricultural fertilisers, pesticides, herbicides, and insecticides have been found to be associated with acute poisoning, toxicity, and long-term chronic diseases. Given the risks to human health and the environment posed by the improper use of chemical insecticides, pesticides, fertilisers, and herbicides, it is imperative for the agricultural industry that the public be made aware of alternative strategies.

It is becoming common to utilize integrated pest management programmes, which incorporate pest population monitoring, mechanical and biological control methods, traditional preventative measures, and appropriate pesticide usage.

In addition to reducing soil fertility, soil erosion causes sediment contamination downstream. The land, water, and air are contaminated by herbicides, insecticides, and fertilisers used in industry and agriculture. Inefficient agricultural practices result in higher silt loads, fertiliser concentrations, and faecal contaminants. Increased animal faeces induced nutrient loads cause eutrophication in water bodies, which can be detrimental to aquatic ecosystems. The transfer of land to agricultural use is the main factor in the degradation of forestland. Poor farming practices including land clearance and deforestation, excessive animal grazing, inappropriate irrigation, and over-drafting are to blame for the agricultural depletion of soil nutrients. Environmental difficulties including deforestation, climate change, irrigation problems, pollution, soil degradation, and waste management are all associated with industrial agriculture.

The ecosystem is negatively impacted by industrial agricultural practices, which have a range of environmental implications on biodiversity preservation, water quality, carbon sequestration, and soil retention. Landscape management should optimize adaptability, variety, and biodiversity for increased resilience rather than concentrating on achieving the maximum levels of economic stability and efficiency. Farmers must use effective soil and land management techniques in order to decrease the negative impacts on the environment.

Conclusion

Food production in the current climate has been considerably impacted by industrial agriculture, improving food accessibility on a worldwide scale. The increased affordability of food is one of these significant breakthroughs. Regardless of the season, farmers are now permitted to engage in their profession year-round. However, due to the devastation that industrial agriculture has caused to the environment, it must be avoided. Farmers must embrace urban agricultural practices in order to avoid the drawbacks of industrial agriculture.

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DRUMSTICK: A RESERVOIR OF NUTRIENTS FOR GOOD HEALTH

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Introduction

Drumstick (*Moringa oleifera*L.), emerges as a nutritional powerhouse, offering a reservoir of essential nutrients that contribute to the overall well-being of humankind. It is frequently seen dangling in our bowl of sambhar. It belongs to the family Moringaceae. It is an evergreen tree that thrives well in tropical and subtropical areas and adapts well to different soil and even harsh conditions. Its rapid growth enables it to attain a height of approximately 9 meters (30 feet).It can be found in the Himalayan regions of Pakistan, Afghanistan, Bangladesh, and India. In addition to being called drumstick in English, *Subhanjana* (in Sanskrit), *Haritashaaka* or *Akshiva* in Ayurveda, and *Sainjna* or *Saguna* in Hindi. The drumstick is also known as the horseradish tree in other languages. The drumstick may be one of the most important nutritious trees because it may include vital qualities for human health in every aspect. The drumstick has been utilized in traditional medicine for a long time. Drumsticks may be beneficial for treating various disorders, according to the Ayurvedic medical system, because of their high nutritional value, ability to retain water, and purification capacity.

Nutritional Value of Drumstick

Different types of essential minerals and nutrients are present in drumsticks. It's pods, leaves, flowers, barks, roots, and seeds also contain bioactive substances. A hundred grams of drumstick contains 2.1 g protein, 0.2 g fat, 8.53 g carbohydrate, 3.2 g fiber, 30 mg Calcium, 0.36 mg iron, 45 mg magnesium, 50 mg phosphorus, 461 mg potassium, 42 mg sodium, 0.45 mg zinc, 0.084 mg copper, 0.259 mg manganese, 141 mg vitamin C, 0.053 mg Thiamin, 0.074 mg riboflavin, 0.12 mg vitamin B6, 44 µg folateand4 µg vitamin A.

Properties of Drumstick

The primary ingredients of this crop have biological properties that may contribute to its potential use as several medicines, including ayurveda, homeopathy, unani, yoga, naturopathy, and Siddha. Drumstick has excellent anti-diabetic, anti-cancer, anti-seizure, anti-oxidant, anti-asthmatic, anti-bacterial, anti-fungal, anti-pyretic, anti-ulcer, anti-spasmodic, anti-allergic, hepato-protective, laxative and diuretic properties. It also helps in lowering cholesterols and reduces the risk of the formation of kidney stones as well.

Uses of drumstick for diabetes

Drumstick leaf extract may include anti-diabetic effects that could help decrease blood sugar levels. According to an animal study (Gupta, 2012), the extract of drumstick leaves may slow the progression of diabetes and cause a drop in serum glucose levels by boosting the production of proteins such as insulin and globulin. According to Ndong's, study in 2007, the extract from drumstick leaves may help regulate blood sugar levels, urine protein and sugar levels, hemoglobin levels, and total protein levels. To verify the aforementioned statements, more research is needed.

Drumstick for wound healing

According to several animal studies (Rathi *et al.,* 2006; Hukkeri *et al.,* 2006), dried drumstick leaf extracts may have the ability to cure wounds in animal models of granuloma (dead space), excision, and incision. Additionally, it dramatically reduces scarring, may aid in accelerating wound healing, and may even reinforce skin tearing. The prospective use of drumsticks for wound healing, however, still needs further human investigations to be established.

Drumstick for kidney health

The barks, leaves, seeds, flowers, and roots of drumstick plants, may have diuretic properties that can help patients with renal disease to produce urine. It reduces kidney stone formation from oxalate salt buildup may also be beneficial. From animal studies, it has been established that the extract of drumstick root reduces salt retention in the kidneys and urine excretion. Additionally, these extracts lower high levels of serum creatinine and uric acid. Extensive research from medical view point is necessary to support this assertion.

Drumstick for healing of cancer

Drumstick seeds and leaves may possess anti-tumor properties. They contain specific substances that could function as inhibitors and could stop the activity of chemicals that support cancer growth. Studies conducted in vitro on human cancer cells revealed that drumstick leaf extracts may be toxic to cancer cells at the maximum dose, resulting in the least amount of viable cancer cells.

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HOMA FARMING: A TRADITIONAL FARMING APPROACH FOR SUSTAINABILITY IN AGRICULTURE

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Introduction

Homa farming, sometimes referred to as Agnihotra farming, is a traditional agricultural method with Indian origins that is founded on Vedic ideas. It entails carrying out fire rituals known as 'homa' to foster an encouraging and energizing environment for agricultural work. 'Agnihotra', the main ritual in homa farming, is carried out at sunrise and sunset using a properly constructed fire. It is mostly practiced in Maharashtra, Karnataka, Tamil Nadu, Kerala, Andhra Pradesh, Goa etc. Its key components are as follows:

- **Vedic principles:** Homa farming is based on Vedic ideas that were found in the early Indian literature. The Vedas are a group of holy books that impart knowledge and wisdom on many facets of life, including farming. Homa rituals are regarded as sacred ceremonies that link the participant to cosmic energy. During the Agnihotra ritual, particular organic elements are offered into a copper pyramid-shaped jar at specific sunrise and sunset times, including dried cow dung, ghee (clarified butter), and rice grains. During the procedure, Vedic mantras are recited to clear the air and balance the energies of the surroundings.
- **Homa Pyre:** A "homa pyre" is the name for the copper, pyramid-shaped pot used in the Agnihotra ritual. It is made to maximize the fire's energetic effects and burning process.
- **Timing of rituals:** The Agnihotra ritual is conducted precisely at sunrise and dusk since it is thought that these times have a significant impact on the environment and human consciousness.
- **Impact on atmosphere:** Proponents of homa farming believe that the Agnihotra fire creates a special energy field that cleanses the atmosphere, improving the quality of the air and soil and promoting plant development.
- **Homa ash:** The ash that is gathered during each Agnihotra ritual is revered and powerful. This ash is said to be a strong, all-natural fertilizer. It is thought to contain the nourishing and healing qualities of the fire, promoting plant development and soil fertility.A solution made of the collected homa ash and water is sprayed or applied to crops, plants, and soil. Ash is said to promote plant development, increase soil fertility, and guard against pests and diseases.
- **Field preparation:** To establish a favourable and conducive environment for the ceremony, farmers frequently carry out various preparatory practices before the Agnihotra ritual, such as chanting mantras, meditation, and purification rites.
- **Use of cow products:** Dried cow dung and ghee are emphasized in homa farming. Indian culture accords the cow tremendous value and regards it as sacred. In the Agnihotra rite,

cow dung and ghee are employed, and it is said that these substances help the fire's cleaning and healing properties.

- ❖ **Spiritual connection:** Homa farming emphasizes the spiritual and energetic qualities of farming, going beyond standard agricultural practices. By fostering a deeper comprehension of how closely connected people, plants, animals, and the environment are to one another, it seeks to foster a sense of oneness with nature.
- ❖ **Community participation:** In some areas, homa farming is carried out as a collective endeavour in which farmers and families gather to perform the Agnihotra ceremony, promoting a sense of cohesion and shared accountability for the land and its health.
- ❖ **Organic and sustainable farming techniques:** Homa farming encourages farmers to use fewer chemicals and more environmentally friendly techniques. It also supports organic and sustainable farming techniques.

Scientific basis of homa farming:

Chanting in Homa farming has been linked to higher agricultural yields, however this is mostly due to cultural norms and traditional beliefs. Although some cultures use homa farming and think it enhances agriculture, there is not enough solid evidence to support or explain the benefits from a traditional scientific perspective. However, exploring the homa farming, certain scientific explanations are speculated which are as follows:

- ❖ **Use of organic inputs:** Homa farming can promote soil fertility and microbial activity, leading to better soil health and increased plant nutrient availability. Synthetic chemicals should be avoided, and organic inputs like cow dung and compost should be used instead.
- ❖ **Compost and nutrient recycling:** When organic items are burned as part of the Agnihotra ceremony, nutrient-rich ash may result, which, when spread on the ground, may have the ability to act as a natural fertilizer. Improved nutrient cycling and recycling in the ecosystem may result from this method.
- ❖ **Microbial activity:** The ash and smoke generated during the Agnihotra ritual may have an impact on the local microbial populations. Certain microbial communities may flourish in reaction to the ritual's byproducts because microorganisms play a critical role in the cycling of nutrients and the health of the soil.

Possible benefits of chanting mantra:

Strong scientific data on the effect of mantra chanting on crop growth is lacking, and the precise methods through which it might alter crops are still up for debate. But advocates of mantra chanting in agriculture, including methods like Homa farming, think that the advantageous impacts on crops are connected to a number of things:

1. Vibration and sound energy: Chanting mantras causes certain sound vibrations to be created. Mantra chanters contend that these vibrations can reverberate with the surroundings, affecting energy levels and fostering favourable consequences. It has been proposed that such uplifting energy can enhance plant development.

2. Stress reduction: According to some advocates, the meditative and repeated nature of mantra chanting can have a relaxing influence on the surroundings. Stress reduction may have a favourable effect on the health and development of plants.

3. Enhanced awareness and concentrate: Chanting mantras while engaging in agricultural work may enhance awareness and concentrate on the current task. Mantra chanting by farmers may cause them to pay greater attention to crop management and plant care, improving agricultural practices and crop growth.

4. Spiritual and cultural beliefs: Chanting mantras while agricultural work is seen as a crucial component of traditional rituals in several cultures. The cultural importance of these behaviours can foster a sense of awe and respect for the environment, which will result in better crop care and attention.

5. Community cohesion: Mantra chanting during agricultural tasks occasionally can be a community affair, involving farmers gathering to perform rituals. This encourages a sense of cohesion, collaboration, and shared ownership of the land, which might have a favourable impact on crop development.

Constraints of homa farming:

1. Absence of thorough studies: To assess the precise effects of Homa farming on crop growth and agricultural output, rigorous scientific studies with proper control groups and unbiased methodology are scarce.

2. Subjectivity and cultural beliefs: Cultural and spiritual beliefs are closely related to homa farming. In the framework of conventional scientific study, measuring and quantifying the spiritual or energetic qualities related to Homa rites involves substantial obstacles.

3. Potential confounding factors: Numerous factors, including soil type, climate, crop variety, and management techniques, must be considered when evaluating the benefits of Homa farming. In agricultural studies, separating the precise effects of Homa rituals from other aspects becomes difficult.

4. Limited research funding: Compared to other agricultural approaches, homa farming may not attract significant research funding or attention, which restricts the availability of trustworthy scientific data. The efficacy of homo farming and its real impacts on crop yields and total agricultural output have not been well studied or validated by research.

5. Labor-intensive and time-consuming: The Agnihotra ritual necessitates focus, consistency, and exact timing. Farmers with limited time and finances may find it challenging to adhere to the ritual's schedule and criteria.

6. Potential yield variability: Although proponents have touted increased crop yields, actual yield improvements could differ depending on a range of factors, such as the type of crop cultivated, the properties of the soil, the environment, and certain farming techniques.

Steps involved in Homa farming:

1. Time and place: Dawn and dusk are the precise times of the Agnihotra ceremony. It is usually carried out in a public space, preferably outside where the energy of the ritual could benefit the surroundings.

2. Constructing the homa pyre: A little copper jar in the shape of a pyramid is the homa pyre. It should be pure and unclouded. Often filled to the brim with dried cakes of cow dung, the vase is positioned to allow for enough ventilation throughout the ceremony.

3. Organic materials: Certain organic materials are used in the Agnihotra process. Dried cow dung, ghee (clarified butter), and raw rice are the key ingredients. These parts are carefully measured out and put away.

4. Mantra chanting: The Agnihotra procedure involves the practitioner or another selected individual chanting specific Vedic mantras. The mantras are considered sacred and are believed to disperse positive energy over the region.

5. Lighting the fire: At precisely sunrise or sunset, a small piece of cow dung cake and ghee are used to light the fire in the homa pyre. There must be constant fire throughout the entire procedure.
6. Offering of ingredients: The practitioner places little amounts of rice grains, ghee, and dried cow dung into the fire at specific times during the ceremony, following the sequence and order described by the Vedic texts.
7. Intention and focus: Throughout the Agnihotra ceremony, the practitioner stays intent and meditative, sending positive energy towards the wellbeing of the land, the crops, and all living creatures.
8. Homa ash collection: The remaining ashes from the homa pyre are collected after the ceremony. The healing properties and positive energy generated during the rite are said to be contained in this cherished ash.
9. Application of homa ash: Typically, water is added to the gathered homa ash to create a solution. This solution is then sprayed or applied to the soil, plants, and agricultural crops as a natural fertiliser and soil conditioner.
10. Repeated practice: Agnihotra must be performed often, ideally twice a day at dawn and dusk, in order to practice homo farming.

Benefits of homa farming:

- **Use of organic inputs:** Homa farming can promote soil fertility and microbial activity, leading to better soil health and increased plant nutrient availability. Synthetic chemicals should be avoided, and organic inputs like cow dung and compost should be used instead.
- **Compost and nutrient recycling:** When organic items are burned as part of the Agnihotra ceremony, nutrient-rich ash may result, which, when spread on the ground, may have the ability to act as a natural fertilizer. Improved nutrient cycling and recycling in the ecosystem may result from this method.
- **Microbial activity:** The ash and smoke generated during the Agnihotra ritual may have an impact on the local microbial populations. Certain microbial communities may flourish in reaction to the ritual's byproducts because microorganisms play a critical role in the cycling of nutrients and the health of the soil.
- **Lessening of soil pathogens:** Homa farming is supposed to lessen the number of dangerous soil pathogens. A healthier soil environment can result from the removal of some pests and diseases by the heat produced during the fire rites.
- **Greater soil structure:** Regular application of homa ashes can improve the physical characteristics of the soil, including as structure and water-holding capacity, resulting in greater root growth and nutrient uptake by plants.
- **Positive energy:** Supporters of homa farming think that the good vibes produced during the fire ceremonies have a positive effect on the general health of the plants, soil, and surroundings.

Future prospects of homa farming

The prospects for Homa farming in the future are uncertain and dependent on several variables. Homa farming has become more well-known and well-liked within some communities, but its widespread adoption and potential effects on conventional agriculture are still unknown. Homa farming may have the following prospects:

1. Continued scientific research and scientific validation: Homa farming's prospects may depend on ongoing scientific research to substantiate its alleged advantages and comprehend its possible applications in contemporary agriculture. Through the provision of evidence-based insights regarding its effects on crop yields, soil health, and overall agricultural sustainability, rigorous research could assist assess the efficacy of Homa farming techniques.

2. Adoption in niche markets: Eco-conscious consumers who appreciate organic and sustainable agricultural practices may find a niche market for homa farming. Homa farming could become more popular as consumers demand more items that are socially and environmentally friendly to create. This is because it is a distinctive and culturally meaningful method of farming.

3. Homa farming approaches could be used with more general sustainable farming techniques like agroecology, permaculture, and organic farming. Homa farming may provide a comprehensive strategy for agricultural sustainability by fusing conventional wisdom with contemporary ecological concepts.

4. Preserving traditional knowledge: Homa farming helps to safeguard cultural assets and traditional knowledge. Homa farming may continue to be practiced as an integral component of communities' agricultural traditions as they work to preserve their ancestors' knowledge and stay connected to their cultural roots.

5. Limitations and challenges: Homa farming may encounter difficulties with respect to scalability, viability, and the requirement for widespread acceptance and understanding. Its chances for the future will depend on how well it handles these difficulties.

Conclusion

It is critical to note that there is little empirical scientific data to support the positive effects of mantra chanting on agricultural productivity. Numerous variables, such as soil quality, climate, water availability, nutrient levels, and management techniques, have an impact on crop development. In scientific investigations, it is difficult to separate the precise effect of mantra chanting from these intricate interconnections. There is still a lot of research gap which prevents the adoption and spread of this traditional approach widely. Adequate in-depth analysis and research is therefore highly required for this traditional farming approach to sustain in future.

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TECH IN THE FIELDS: TOP MOBILE APPS DRIVING A REVOLUTION IN AGRICULTURE FOR FARMERS

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Introduction

In recent years, the agricultural landscape in India has witnessed a significant transformation, driven by the integration of technology into traditional farming practices. The initiation of mobile applications has played an important role in empowering farmers, providing them with essential tools, information to enhance productivity, make informed decisions and navigate the challenges of modern agriculture. This collection of agricultural apps stands as an evidence to the synergy between technology and agriculture, addressing various aspects such as crop management, market access, information dissemination and community building. From comprehensive agri-solutions to niche applications focusing on specific needs, these apps collectively contribute to the sustainable and prosperous future of Indian agriculture. In this exploration, we explore the features and significance of diverse agricultural mobile applications, each catering to the unique requirements of the farming community.

Agricultural Applications:

1. AgriApp : Transforming Agriculture with Digital Solutions

AgriApp stands as a versatile solution for farmers, offering a myriad of features such as Crop and Agro Advisory, Smart Farming insights, and the convenience of purchasing Agri-inputs directly through the app. This Android-based mobile application serves as a holistic platform for crop production and management, providing farmers with valuable information on Crop Production, Crop Protection, and allied services. Beyond being an information portal, AgriApp acts as an online marketplace, bringing together farmers, Agri input providers, retailers, and fulfilment services on a unified digital platform. With services like Crop Advisory, Soil Testing, Drone Services, and more, AgriApp emerges as a valuable asset for the agricultural community, driven by a commitment to make agriculture more sustainable both ecologically and economically.

2. Plantix App: Revolutionizing Crop Health with Smart Agriculture

Plantix, a leading digital khetibadi platform, takes center stage in the agricultural landscape as a revolutionary mobile application designed to transform crop health management. Boasting a user-friendly and straightforward interface, Plantix has become an indispensable tool for farmers, offering swift and accurate detection of crop diseases within seconds through advanced image recognition technology. This app serves as the perfect solution for crop diagnosis, providing farmers with actionable insights to boost yields. However, Plantix is not just a diagnostic tool; it fosters a strong farmer community, encouraging knowledge-sharing on seeds, fertilizers, and pesticides. With a commitment to empowering farmers, Plantix emerges as a pivotal asset, combining cutting-edge technology with a collaborative community to address the complex challenges in agriculture and elevate farming practices.

3. IFFCO Kisan Agriculture: A Holistic Agri-Solution at Your Fingertips

IFFCO Kisan Agriculture, a commendable mobile application managed by IFFCO Kisan, stands as a comprehensive agri-solution designed to empower Indian farmers. Launched in 2015, this user-friendly app aims to assist farmers in making informed decisions by providing customized information tailored to their specific needs. Encompassing a variety of informative modules, including agricultural advisory, weather updates, market prices, and an agriculture information library, IFFCO Kisan Agriculture ensures that users receive a diverse range of insights through text, imagery, audio, and videos in their chosen language. The app also offers helpline numbers, facilitating direct communication with Kisan Call Centre Services. By seamlessly integrating technology with agricultural expertise, IFFCO Kisan Agriculture contributes significantly to enhancing the knowledge and decision-making capabilities of farmers, ultimately fostering sustainable and prosperous agriculture practices across the nation.

4. Krishi Jagran: Empowering Farmers with Agricultural Insights

Krishi Jagran, a recently launched agricultural mobile application, is making waves in the farming community by providing a comprehensive platform for farmers to access vital agricultural insights. This app serves as an information hub, delivering the latest in agricultural news, cultivation guides, crop calendars, and detailed information on crop protection, pest management, subsidies, and farm mechanization. With a mission to connect farmers to a wealth of resources, Krishi Jagran plays a pivotal role in facilitating knowledge-sharing within the agricultural community. Its user-friendly interface ensures easy navigation, making it accessible to farmers with varying levels of technological proficiency. By offering a one-stop solution for diverse agricultural needs, Krishi Jagran emerges as a key player in advancing and sustaining agriculture in India, empowering farmers with the tools they need for success.

5. Pusa Krishi: Bridging Farmers to Agricultural Innovation

Pusa Krishi, a government-launched mobile application in 2016, serves as a technological companion for farmers, aiming to enhance their knowledge about cutting-edge technologies developed by the Indian Agriculture Research Institute (IARI). This app provides valuable insights into new crop varieties developed by the Indian Council of Agriculture Research (ICAR), along with resource-conserving cultivation practices and information about farm machinery. By offering farmers information about the latest advancements in agriculture, Pusa Krishi becomes a catalyst for increasing returns to farmers. With a focus on knowledge dissemination and the adoption of innovative practices, this app contributes to the modernization of Indian agriculture, helping farmers stay abreast of technological developments for improved productivity and sustainability.

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Figure: Top agricultural Apps

6. Kheti-Badi: Empowering Farmers towards Organic Agriculture

Kheti-Badi, a pioneering mobile application, is a social initiative aimed at promoting and supporting organic farming practices in India. Launched with the vision of providing essential information and addressing issues pertinent to farmers, Kheti-Badi serves as a catalyst for the transition from chemical to organic farming. Currently available in Hindi, English, Marathi, and Gujarati, the app offers farmers a valuable resource to facilitate the shift towards more sustainable agricultural practices. By encouraging the adoption of organic farming techniques, Kheti-Badi aims to contribute to the ecological well-being of farmlands and the overall health of the farming community.

7. Kisan Suvidha: Nurturing Agricultural Empowerment

Kisan Suvidha, a mobile application launched by Prime Minister Narendra Modi in 2016, stands as a beacon of empowerment for farmers in India. With a neat and user-friendly interface, this app provides essential information on current weather conditions and forecasts for the next five days, ensuring farmers are well-prepared for their agricultural activities. Beyond weather updates, Kisan Suvidha offers valuable insights into market prices of commodities and crops in the nearest towns, along with knowledge on fertilizers, seeds, machinery, and more. The app's accessibility in multiple languages enhances its reach, making it a versatile tool for farmers across different regions. By amalgamating technology and agricultural wisdom, Kisan Suvidha actively contributes to the overall development and empowerment of farmers and rural communities.

8. Shetkari Mitra: Empowering Farmers with Comprehensive Agricultural Support

Shetkari Mitra, a versatile mobile application, is tailor-made for farmers in India, providing a wealth of information and knowledge to enhance their agricultural practices and increase their incomes. This multifunctional app serves as a hub for government schemes, crop management insights, agri-business guidelines, market rates, and success stories in agriculture. By consolidating diverse agricultural resources into one accessible platform, Shetkari Mitra assists farmers in staying informed about the latest advancements and best practices in the field. With its user-friendly interface and a commitment to supporting farmers, the app plays a crucial role in fostering sustainable and profitable agriculture across India.

9. e-NAM: Revolutionizing Agricultural Marketing for Farmers

e-NAM, short for Electronic National Agriculture Market, is a transformative initiative launched by the Government of India to modernize and streamline the agricultural marketing sector. This digital platform serves as a unified online marketplace, connecting agricultural produce sellers (farmers) with buyers, including traders, processors, and retailers. Through e-NAM, farmers gain access to a wider market reach beyond their local mandis (markets), leading to better price discovery for their produce. The platform facilitates transparent and efficient trading by providing real-time information on market prices, reducing intermediaries, and ensuring prompt online payments. By leveraging technology, e-NAM aims to create a seamless, pan-India market network, empowering farmers and fostering a more competitive and fair agricultural marketing ecosystem. The platform plays a crucial role in enhancing farmers' income and boosting overall agricultural productivity.

10. Agri-Market: Bridging Farmers to Market Prices

Agri-Market is a dedicated mobile application designed to empower farmers by providing real-time information on crop prices. The app's primary objective is to discourage distress sales among farmers by offering insights into the prevailing market rates for various crops within a 50-kilometer radius of the user's device location. Farmers can use Agri-Market to stay informed about crop prices, enabling them to make strategic decisions about when and where to sell their produce. By facilitating access to timely and accurate market information, Agri-Market plays a vital role in supporting farmers and promoting fair agricultural practices. This app contributes to a more transparent and efficient agricultural ecosystem, aligning with the broader goal of improving farmers' income and overall well-being.

11. Crop Insurance: Nurturing Agricultural Security

The Crop Insurance mobile application emerges as a pivotal tool for farmers, ensuring a shield of financial security for their agricultural pursuits. This app offers farmers the ability to calculate insurance premiums for notified crops, providing crucial information on cut-off dates and company contacts relevant to their specific crops and locations. Serving as a reminder and calculator, the app proves invaluable in helping farmers stay informed about insurance details, including normal and extended sum insured, premium details, and subsidy information for any notified crop in any designated area. Linked to a web portal that caters to various stakeholders, including farmers, states, insurance companies, and banks, Crop Insurance acts as a comprehensive resource, streamlining and enhancing the insurance process for the benefit of the farming community.

12. AgriSetu: Cultivating Empowerment through Knowledge Sharing

AgriSetu emerges as a transformative platform, redefining the agricultural landscape by offering a comprehensive mobile application. This app serves as a beacon for farmers, experts, suppliers, and buyers, providing a dynamic space for knowledge and experience sharing. With a commitment to empower farming journeys, AgriSetu delivers real-time satellite-based services, fostering vibrant farming communities, and unlocking business opportunities. Stay updated with live mandi rates, delve into insightful agriculture blogs, and explore the world of agriculture magazines—all conveniently accessible in the palm of your hand. At AgriSetu, our dedication lies in revolutionizing the farming experience, ensuring that farmers, agribusinesses, and enthusiasts are equipped with the necessary tools and knowledge to thrive in the dynamic realm of agriculture.

Conclusion

As we conclude our exploration of these agricultural mobile applications, it becomes evident that technology is not just a tool but a catalyst for positive change in the farming sector. These apps have successfully bridged the gap between traditional farming practices and modern innovations, offering farmers a suite of solutions at their fingertips. From real-time market information to smart farming insights, crop diagnosis, and community-building platforms, these applications contribute significantly to the well-being of farmers and the overall growth of the agricultural sector in India. The commitment to sustainability, empowerment, and knowledge-sharing embedded in these apps reflects a shared vision to create a resilient and thriving future for Indian agriculture. As these digital tools continue to evolve, they hold the promise of transforming the lives of farmers, fostering innovation, and steering agriculture towards a more sustainable and prosperous path.

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EUTROPHICATION OF AQUATIC ECOSYSTEMS: CAUSES, IMPACTS, AND SUSTAINABLE SOLUTIONS

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Abstract

Aquatic ecosystems face the challenge of eutrophication, a process characterized by accelerated nutrient accumulation, primarily nitrogen and phosphorus, leading to adverse impacts on water quality and biodiversity. While natural eutrophication occurs over extended periods, anthropogenic eutrophication, driven by human activities like agriculture and industrial discharge, poses a more immediate threat. This article explores the causes of eutrophication, including fertilizer use, concentrated animal feeding operations, and sewage discharge. It delves into the environmental factors influencing the process and discusses the consequences, such as algal blooms, reduced oxygen levels, and dead zones. Highlighting the implications for water resources, the article concludes by advocating improved pollution management and sustainable practices to mitigate eutrophication's detrimental effects.

Introduction

Aquatic ecosystems like a lake eventually become increasingly concentrated in nitrogen, phosphorus, and other plant nutrients. Naturally, the productivity or fertility of such an ecosystem rises as the amount of organic matter that can be transformed into nutrients increases. This material enters the environment mostly by runoff from the land, which carries waste and by products of terrestrial organisms' reproduction and decomposition. Large blooms of algae or other tiny organisms commonly develop on the water's surface, obstructing light and oxygen absorption, which are vital for undersea life. Waterways that are eutrophic tend to be murkier and have fewer large species, such fish and birds, than those that are not eutrophic. Due to runoff from fertilizers and soil erosion, agriculture is a major contributor to the phosphorus in streams and lakes. Significant problems with nitrogen from sewage treatment facilities for municipalities and direct runoff from feedlots exist in several places. With improved pollution management and municipal, industrial, and agricultural practices, the eutrophication of inland and coastal waterways due to human activity may be greatly decreased. In a body of water over hundreds or thousands of years, sediments and nutrients accumulate, causing natural eutrophication to occur. Numerous human activities, including as aquaculture, sewage discharge into the environment directly, and the use of agricultural fertilizers, have contributed to the eutrophication of numerous water bodies.

Classification

Natural eutrophication: The gradual build of nutrients and organic debris in water sources causes a process known as natural eutrophication, which happens over a very long time. Since organic matter deposits need time to organically build up and disintegrate, natural eutrophication can take up to 100 years. The process of natural eutrophication is sped up by natural occurrences like floods and landslides, which sweep organic debris from the soil into water supplies.

Natural eutrophication is also greatly influenced by environmental factors as temperature, carbon dioxide concentrations, and light exposure. Natural eutrophication begins in an oligotrophic water resource, where productivity increases as nutrients accumulate to a steady level of eutrophication. As the process of nutrient build up and consumption continues, the condition might evolve towards eutrophication, although it takes hundreds of years. The length depends on the kind of water resource, the surrounding geographic locations, and the climate.

Anthropogenic Eutrophication

The process through which too many nutrients accumulate in aquatic environments as a result of human activity is known as anthropogenic eutrophication, often referred to as cultural eutrophication. Natural eutrophication is accelerated by cultural eutrophication, resulting in the rapid emergence of severe circumstances. Although it takes hundreds of years, as the process of nutrient build up and consumption continues, the condition may begin to eutrophication. How long it will survive depends on the kind of water resource, the surrounding geographic locations, and the climate. Eutrophication restricts the use of these water resources for a number of purposes, including drinking, aquatic life, and industrial usage, as a result of the proliferation of undesirable algae.

Causes of Eutrophication

Natural eutrophication is a long-term process that happens naturally as part of the ecosystem's cycle. However, human actions have improved the process, causing it to happen much more quickly and with immediate effects. The main cause of eutrophication is the introduction of a significant amount of readily available nutrients into the water resources, which boosts the fertility and promotes the uncontrollable growth of different plants and algae. Some elements that speed up the eutrophication process by raising the nutrient content of water supplies include:

Fertilizers: The application of fertilizers that include phosphates and nitrates to increase agricultural output is one of the primary contributors to cultural eutrophication. The fertilizers put to the region adjacent to water resources eventually find their way into the water sources due to rain and other natural processes. Fertilizers provide easily available nutrients, which planktons, algae, and aquatic plants in the aquatic environment take up, increasing the availability of nutrients in the water resources. Eventually, runoff from various sites enters lakes, rivers, and seas, increasing the amount of organic matter in the environment.

Concentrated animal feeding operations: Agriculture practices known as concentrated animal feeding operations keep a large number of animals in one location for a predetermined period of time in order to increase the animals' output and quality. Most of the manure is composed of nitrogen and phosphorus, two elements that are essential to algal blooms. Millions of tonnes of manure are produced annually by operations like these, and all of it eventually finds its way into water systems. Nitrogen and phosphorus operate as limiting variables in algal blooms since they are the elements that make up the least amount of an algae molecular structure. Thus, in many ecosystems, the low supply of phosphorus and nitrogen limits the biomass of phytoplankton. However, releasing nitrogen and phosphorus-rich animal manure into these ecosystems leads to eutrophication by increasing phytoplankton production.

Sewage and industrial waste discharge: Domestic sewage and industrial garbage are frequently discharged into lakes, ponds, and rivers in developing countries. The wastewater from different sources frequently contains large concentrations of chemical fertilizers, which encourages the fast growth of algal blooms in such resources. Even after treatment, small levels of a number of contaminants are still present in industrial waste. The health of ecosystems is directly impacted by wastewater with high nitrogen and phosphorus contents from homes and communities. Because they increase the amount of nutrients available in the water supply over time, these substances eventually promote eutrophication.

Environmental factors: Although environmental factors are crucial in eutrophication, the precise process by which they operate is still not fully known. Algal blooms commonly happen when the temperature is between 23°C and 28°C, and the salt content is between 23% and 28%. Variations in these factors have an effect on how quickly algae develop, especially when salinity and temperature are rising and lowering, respectively.

The pH of the water resource is also impacted by the free carbon dioxide concentrations in the water, which has an impact on the development of different bacteria. Cyanobacteria may use low concentrations of carbon dioxide to become buoyant and stay on the water's surface so they can absorb sunlight, which has an impact on their ability to develop. Growing plants benefit from increased light levels, with 4000 lux being the most advantageous.

Consequences

Related high rates of photosynthesis can reduce dissolved inorganic carbon and raise pH to extraordinarily high levels throughout the day. Elevated pH can "blind" animals that depend on detecting dissolved chemical signals for their survival by reducing chemosensory abilities. Microbial breakdown substantially reduces dissolved oxygen when these dense algal blooms ultimately die, the growth of dense blooms of poisonous, foul-smelling phytoplankton that reduce water quality and clarity is the most evident effect of anthropogenic eutrophication. Algal blooms hinder plant development and cause die-offs in littoral zones by reducing light penetration. Additionally, they make it harder for predators to pursue and capture prey. Additionally, eutrophication resulting in a hypoxic or anoxic "dead zone" with insufficient oxygen to support most organisms Some algal blooms are more dangerous than others because they produce toxic by product. Harmful algal blooms have been associated with three negative effects on public health over the past century are:

1. Water quality degradation
2. The extinction of commercially significant fisheries.
3. Hazards to human health.

Conclusion

Eutrophication poses a significant threat to aquatic ecosystems, affecting water quality, biodiversity, and human health. Addressing this issue requires a comprehensive approach involving improved pollution management and sustainable agricultural, industrial, and municipal practices. Reducing nutrient inputs from fertilizers and animal feeding operations, as well as enhancing wastewater treatment, are crucial steps. Additionally, understanding and mitigating the impact of environmental factors on eutrophication are essential. By adopting sustainable strategies, we can safeguard water resources, prevent harmful algal blooms, and ensure the long-term health of aquatic ecosystems, benefitting both the environment and human well-being.

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NANOENCAPSULATION IN FOOD PROCESSING

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Introduction

Nario Taniguchi first introduced the term "nanotechnology" in 1974 to refer to the manipulation of particles smaller than one micrometre. Richard Feynman, a physicist, popularized the idea of atomic engineering in 1959 (INN, 2009). Nowadays, nanotechnology is used for developing structures with unique characteristics that are highly dependent on size and structure, such as super paramagnetism in magnetic materials, surface plasmon resonance in certain metal particles, and quantum confinement in semiconductor particles. The process of forming nano-sized materials can be done in two ways: either by "bottom-up" approaches that induce the organization of atoms, molecules, or single particles, or by "top-down" approaches that reduce the size of macrostructures to the nanoscale. The importance of conserving food quality and health benefits without disturbing nutritional value in industrial processes has been a challenge (Figueiredo *et al* 2022). The practice of nanoencapsulation entails the placement of solid, liquid, or gaseous constituents into tiny containers called capsules. These may be produced at nanoscales (less than 100 nm) using a range of materials to create the membrane of the capsule; bio-based components, including polysaccharides, gums, proteins, lipids, and combinations of these, are particularly noteworthy (Hosseini *et al.*, 2020; Samborska *et al.*, 2021 and Maqsoudlou *et al.*, 2022). Numerous advantages come with using nanoencapsulation in food products: it can increase the stability and solubility of bioactive compounds, shield them from deterioration during production, transportation, and storage, hide unpleasant tastes, increase the activity levels of the ingredients that are nano encapsulated, and regulate release (Maqsoudlou *et al.*, 2022 and Awuchi *et al.*, 2022). Food may include nanocapsules throughout the manufacturing, processing, packing, and security stages (Momin *et al.*, 2015) Recent studies have emphasized the possible applications of natural component nanoencapsulation, including food additives (Choudhary *et al.*, 2023), antioxidants (Maqsoudlou *et al.*, 2022 and Soni *et al.*, 2022), antimicrobials (Oprea *et al.*, 2022), and longer food shelf lives (Lim *et al.*, 2023 and Choudhary *et al.*, 2023). There are several technologies available for creating nanoencapsulation systems. The most common processes for developing nanoencapsulation systems include emulsification, coacervation, inclusion complexation, solvent evaporation, nanoprecipitation, andextraction (Cruz-Lopes *et al.*, 2021 and Awuchi et al., 2022).A brief list of these few commonly utilized nanomaterials is provided in Figure 1 based on how big they are about biomolecules or microorganisms, which are roughly the size of a nanomaterial sample.

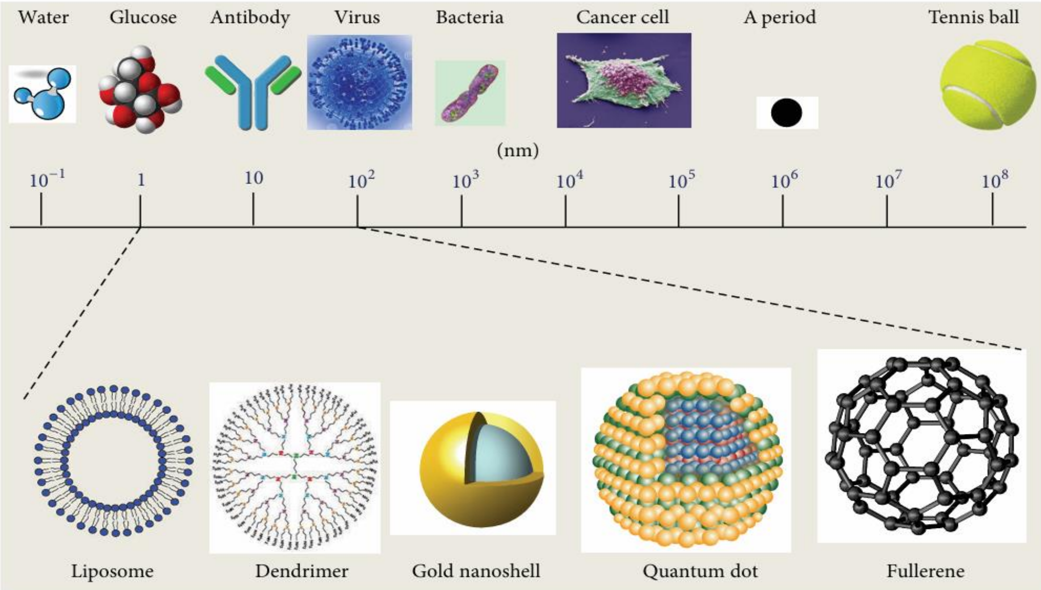

Fig. 1 There are many nanomaterials apparent, with sizes varying from 1 to 100 nm. These nanoparticles are effective in serving as scaffolds and assisting in the distribution of drugs because of their smaller size. However, as nanotechnology gradually permeates the food industry, its uses for nanomaterials have expanded beyond the delivery of pharmaceuticals to include the delivery of dietary supplements and nutraceuticals (source: Neethirajan, S., and Jayas, D. S. *et al*., 2011and Pradhan *et al*., 2015)

1. Classification of Nanoencapsulations

The processes of absorption, integration, dispersion, or chemical interaction are capable of encapsulating substances. These days, various materials are used to enclose natural compounds, allowing for the development of several nanocapsule types. We will utilise this context to classify the nanoencapsulation family system and list the materials often employed in each family.

1.1 Lipids Structures

1.1.1 Liposome

In the 1960s, Bangham et al. developed aliposome, a colloidal unit of phospholipid bilayer vesicles.Natural phospholipids with a range of lipid chains are used to make liposomes. Liposomes have polar phospholipid sections on their surface, and a bilayer hydrophobic nucleus keeps the fatty acid chain portions of the phospholipids isolated from the water.Smaller liposomes with hydrophilic and lipophilic regions that may ensnare substances in lipid bilayers with a range of lipotropic characteristics are known as nanoliposomes. Stable compounds including medications, vitamins, antioxidants, and antibacterial agents can be encapsulated in nanoliposomes. Liposomes can be characterized structurally into various categories based on the quantity and size of their bilayers.

1.1.2 SLNs (Solid Lipid Nanoparticles)

Solid nanoparticles in colloidal dispersions consist of particles with a hardened lipid core encased in a coating of emulsifying molecules. Except for the fact that the droplets in SLNs are completely crystalline as opposed to liquid, they are therefore structurally similar to conventional emulsions. A temperature over the lipids' melting point is typically used to homogenize an oil phase and a water phase containing a hydrophilic emulsifier to create SLNs. Afterwards, the produced nanoemulsion is cooled below the temperature at which the lipid phase crystallizes to solidify it. Edible lipids used to make SLNs should be crystalline at the temperature at which they are meant to operate, but they also need to be able to melt to include the bioactive ingredient. Biodegradable lipids that include glyceryl palmitostearate, glyceryl monostearate, glycerol behenate, tripalmitin, steric acid, tristearin, and waxes are utilized for producing SLNs (Meetoo *et al*., 2011; Sozer *et al*., 2009 and Vidhyalakshmi *et al*., 2009).

1.2 Polymer Structures

1.2.1 Protein

The 20 natural amino acids are joined by amide bonds to form proteins, which are polymers. Certain amino acids, such as L-3,4-dihydroxyphenylalanine (DOPA), hydroxyproline (Hyp)and selenomethionine, are not produced by ribosomes; instead, they are produced via posttranslational modifications. Proteins molecularly self-assemble in a variety of nanoarchitectures with the encouragement of noncovalent and weak interactions such as hydrogen bonding, electrostatic contacts, hydrophobic interactions, van der Waals interactions, and metal coordination.

1.2.2 Pectin

Pectinis a polymolecular and polydisperse complex mix of polysaccharides obtained from plant cell walls. Furthermore, depending on the source and the problems encountered in isolation, its composition may alter (Moraru *et al*., 2003).

1.2.3 Polylactic Acid

The hydrophobic polymer polylactic acid is also known as poly-hydroxy acids, polyesters, or aliphatic polyesters [-(C3H4O2) n]. Lactic acid (LA; 2-hydroxypropanoic acid), a water-soluble monomer that is available in two enantiomeric forms, L-(+)-LA and D-(-)-LA, serves as the basis for its synthesis. When poly-L-lactic acid (PLLA) and poly-D-lactic acid (PDLA) homopolymers are created from pure L- and D-lactic isomers, respectively, PLA can be generated. On the other hand, poly-D, L-lactic acid (PDLLA) copolymer is generated with a racemic mixture of L- and D-monomers (Veronique *et al*., 2008)

1.2.4 PEG (Polyethylene Glycol)

Polyethene glycol (PEG) is a hydrophilic polymer composed of repeated ethylene glycol units [-(CH2CH2O)n]. It may be produced via the ionic polymerization of ethylene oxide and a hydroxyl group (from water, ethylene glycol, or any diols). Epoxy-ethane ring-opening polymerization is a method for producing PEG.

1.3 Metallic Structures

In light of its potential application in the development of antimicrobial therapies that might prolong food shelf life by inhibiting the growth of bacteria, metallic nanoparticles (MNPs) have garnered a lot of attention. In applications requiring food technology, these characteristics are essential. In this context, sensors, hydrogels, and films based on MNP are becoming more and more useful as instruments in the food science domain. Various research has proved the application of MNPs in food as an intelligent system for food preservation. Furthermore, food pollutants—that is, microorganisms—are detected using MNP-based sensors (Bouwmeester *et al*., 2009).

1.4 Methods of Production

In general, both the "top-down" and the "bottom-up" approaches may be used to produce nanoparticles, and nanocapsules are nota concession. In the former method, energy is applied to accomplish nanononization, whereas in the latter, physicochemical processes govern the aggregation of molecules, monomers, ions, or even atoms to create the nanocapsules (Fig. 2).

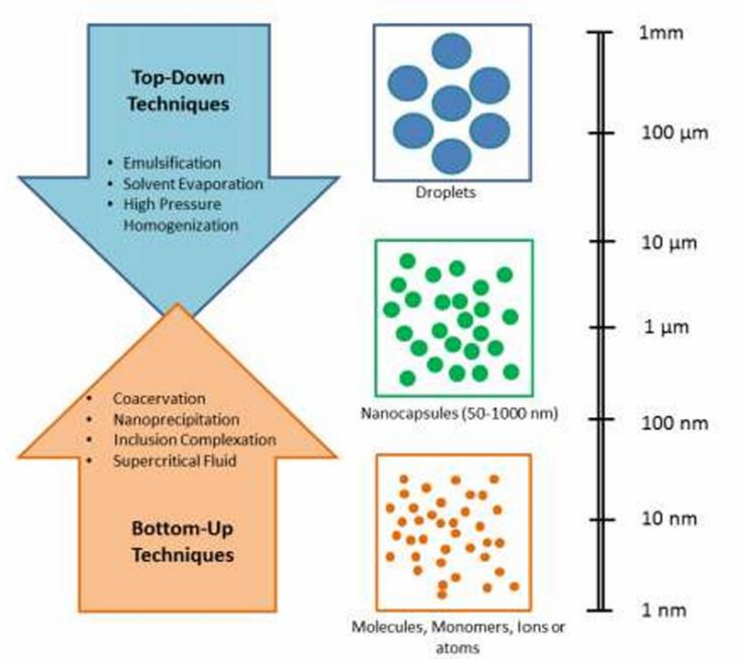

Fig. 2. Top-down and bottom-up techniques for the production of nanocapsules (source: Paredes *et al*., 2016)

1.4.1 Emulsification

The process of emulsification is the dispersion of one immiscible liquid into another immiscible liquid. An emulsion is a combination of two liquids, such as water and oil, that are often insoluble or unbendable. One liquid is distributed throughout the other liquid as an emulsion in the form of small droplets. Emulsifying agents, or surfactants, are used to keep the emulsion stable. Several factors, including the types of emulsion and their constituent parts, can affect the droplet size. The terms mini-emulsions, nanoemulsions, ultrafine emulsions, submicron emulsions, etc. are frequently used in the literature to describe emulsions with droplet sizes in the nanometric scale, which are usually in the range of 20 to 200 nm. Although most of the publications on either oil-in-water (O/W) or water-in-oil (W/O) nanoemulsions report their formation by dispersion or high-energy emulsification methods, Nanoemulsions, being non-equilibrium systems, cannot be formed spontaneously.

1.5 Elimination of Solvent

It is commonly recognized that the use of solvents has several drawbacks, including a higher chance of microbiological contamination, higher expenses, and physicochemical instability. Moreover, there is a danger of toxicity and explosion with organic solvents (for consumers and operators).In this case, the solvent may need to be removed to make room for a powdered form that is redispersible. The most often used methods for this are lyophilization and spray drying. Table 1 compares the results of spray drying, freeze drying, and nano spray drying.

Table 1. Comparison between laboratory scale equipment commonly used for solvent elimination. (Paredes *et al*., 2016)

	Freeze Drying	Spray Drying	Nano-spray Drying
Particle size	NA	2-5µm	0.3 -5µm
Re-dispersed particle size	No restriction by deagglomeration	No restriction by deagglomeration	< 1µm
Process Yield	100%	Up to 70%	Up to 90%
Process Speed	Low	High	Low
Operating Temperature	Up to -50 ºC	Up to 220 ºC	Up to 120 ºC
Viscosity	No restrictions	< 300 cP	< 10 cP
Sample volume	Max. 1 L	30 ml – 1 L	1 – 200 ml
Ease of operation	Simple operation	Trained staff	Trained staff
Operation cost	+++	+	+
Process Time	+++	+	++
Scalability	+++	+	+++

1.6 Application in Food Processing

Nanoencapsulation in food processing involves enclosing active ingredients, such as flavours, colours, nutrients, or bioactive compounds, within nanoscale carriers. In terms of improving these substances' stability, bioavailability, and controlled release, this method offers several advantages. The following are some uses of nanoencapsulation in the food sector: Improved Bioavailability, Flavor and Aroma Enhancement, Nutrient Delivery, Functional Ingredients in Beverages, Fat Replacement, Preservation of Food Quality and Targeted Delivery in Functional Foods.

Conclusion

Nanoencapsulation of natural composites is thought to be one of the areas where nanotechnology would play a significant role. A number of procedures and systems have been developed with varying degrees of complexity and rigidity, with the physicochemical properties of the bioactive material being a factor in the expression technique. Natural composites have been nano-encapsulated, a technique that is now widely used in colored food preparation. It is analogous to objectification in food matrices, packaging, and beneficial supplements and nutraceuticals.

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NANOFILTRATION IN FOOD INDUSTRY

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Introduction

As a separation technology, membrane technology has been widely used for decades because of its inherent advantages, including simple operational procedure, low chemical consumption, scalability, compact design, easy maintenance, consistent permeate quality, and relatively low energy consumption. Generally, membrane separation processes can be classified based on the average pore diameter of the membrane, such as microfiltration (MF), ultrafiltration (UF), nanofiltration (NF), and reverse osmosis (RO).

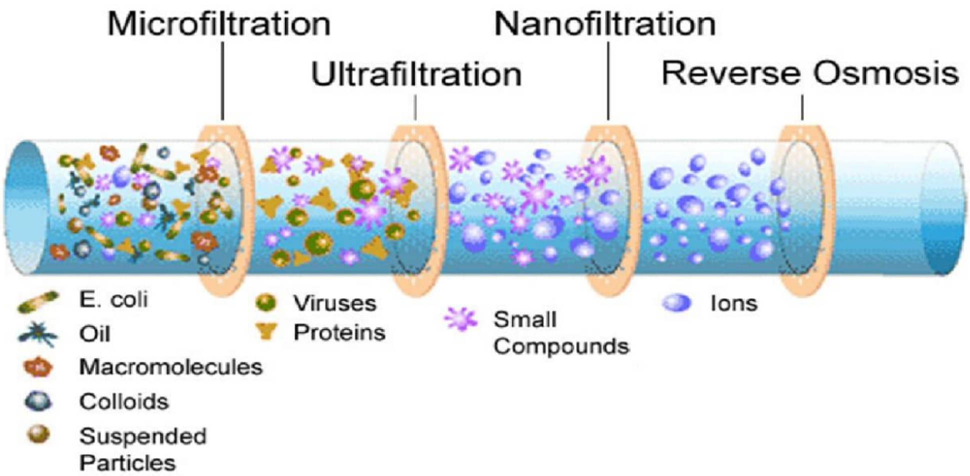

Fig.1 Different Membrane Separation

There are numerous pressure driven membrane separation technologies, but nanofiltration (NF) is a relatively new and complex one. A membrane's ability to function depends on various interfacial events occurring at its surface as well as within its nanopores. Nanofiltration (NF) membranes are usually composed of polymer materials, featuring an asymmetric structure with a low-resistance support layer and a functionally active porous top layer. The nominal molecular weight cut-off for an NF membrane falls within the 100–1000 Da range, suggesting that the active layer of the NF membrane possesses pores of approximately one nanometer in size.

The separation of solutes within the nanofiltration (NF) range relies on the micro-hydrodynamics and interfacial occurrences taking place both at the membrane surface and within the membrane itself. The effectiveness and productivity of NF processes are the result of a combination of various effects, including transport, Donnan, steric, and dielectric properties. NF is capable of eliminating smaller solutes compared to ultrafiltration (UF), and it achieves higher permeate flow rates than reverse osmosis (RO) under equivalent pressure conditions. This results in more compact systems with comparable production capacities. Applications of nanofiltration (NF) in agro-food processing are growing, including process like fractionation, water softening, wastewater treatment, vegetable oil processing, and the treatment of products from the dairy, beverage, and sugar industries.

Mechanism of Nanofiltration

The separation mechanisms of NF membranes can be categorized into three types: (1) sieve mechanism or size-based exclusion (steric), (2) electrical (Donnan) exclusion, and (3) dielectric effects. These membranes exhibit rejection rates ranging from 30% to 80% for monovalent ions and 70% to 95% for divalent ions. NF membranes demonstrate significantly higher rejection rates for divalent ions while allowing the partial passage of monovalent ions. Consequently, they find application in fractionating electrolyte mixtures, separating heavy metal ions, and isolating divalent anions from wastewater. The predominant factor influencing the separation performance of the NF membrane for uncharged solutes is the size exclusion effect. This mechanism essentially means that larger molecules are constrained by the membrane pore size, while smaller molecules can freely pass through the membrane, with the separation determined solely by their molecular size. Polyether sulfone membranes can reject trace organic compounds based on their molecular weight cut off (MWCO). The uncharged organic compounds were more likely to be rejected by sieving with decreasing MWCO.

NanoFiltration membranes

NF membranes may be classified according to their materials and can be further divided into two categories such as Polymeric membranes and Inorganic membranes Polymeric membranes. The majority of commercially accessible NF membranes are of a polymeric nature. They can be made by phase inversion (integrally skinned membranes like polyether sulfone or cellulose acetate membranes), coating of a UF support (sulfonated polyether sulfone TFC membranes), or interfacial polymerization (thin film composite (TFC) polyamide membranes, for example). The active top layer of a polymer membrane swells due to interaction with water, resulting in the acquisition of certain properties. Membrane characterisation requires taking into account the fact that the wet membrane is a swollen polymeric network that acts differently than in a dry environment. The distinct nanopores are present in inorganic NF membranes, such as those made of alumina or titanium dioxide. Moreover, their morphology does not change whether they are wet or dry because they do not swell in water.

A sieving mechanism works in the case of nanoporous membranes, whereas a solution-diffusion mechanism will determine the state of a swelling network. Donnan exclusion, or the electrostatic repulsion between ions with an electrical charge of the same sign as the wet membrane, is a commonly used mechanism of rejection when ions, or more broadly charged solutes, are involved. This is especially true at low to moderate concentrations of charged solutes, where the membrane charge is gradually screened as ionic strength increases. However, steric hindrance and non-Donnan electrostatic effects, such as dielectric exclusion, may also be significant.

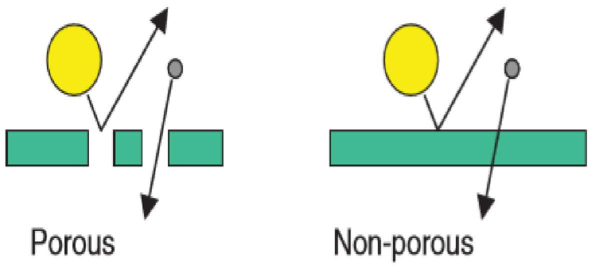

Fig. 2: Diagrammatic representation of the porous and nonporous (swollen\) NF membranes separation for uncharged molecules

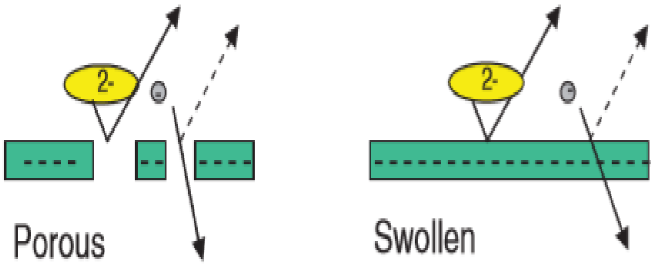

Fig. 3: Diagrammatic representation of the Donnan exclusion, porous and nonporous (swollen) NF membranes electrostatically repel charged species (such as ions) that bear the same electrical charge as the membrane material.

Polymers Used for the development of Nanofiltration Membranes

- Cellulose acetate
- Poly(dimethylsiloxane)
- Polyvinyl alcohol
- Poly(vinylidene fluoride)
- Chitosan
- Acrylic acid
- Poly(styrene sulfonate)
- Polyacronitrile
- Polyamide
- Trimesoyl chloride
- Polysolfone
- Polyethersulfone
- Piperazine
- Polyethyleneimine
- Polyimide

Application of nano filtration in food industry

The food industry employs membrane separation techniques like nanofiltration extensively. NF membranes have unique properties that make them appropriate for ion and molecular separation.

Dairy industry:

The dairy industry's favorable encounters with membrane filtration led to the rapid integration of nanofiltration (NF) in concentration and environmentally relevant processes. NF's primary use in the dairy sector involves creating partially demineralized whey concentrate and producing lactose. The production of lactose from whey permeate currently involves combining NF with other membrane techniques like microfiltration (MF) and ultrafiltration (UF).

Beverage Processing:
Fruit juices are concentrated using NF, which removes water from the mixture while keeping important ingredients and desired flavorings. The concentrated juice's overall flavor and quality are improved by this procedure. Fruit juice concentration is done to extend the shelf life of the juices and lower the cost of shipping and storage. Wine can be effectively de-alcoholized with NF without significantly losing any of its sensory qualities. NF membranes have the potential to be used in the concentration of numerous other food sector fluids in addition to fruit juice. NF is also used in the coffee processing to concentrate the extract of coffee prior to drying.

Softening of water:
In food processing sector, NF is used to soften water by removing hardness ions while preserving other vital minerals. This is particularly critical for circumstances where consistent product quality depends on the quality of the water used.

Colour and flavour removal:
Fruit and vegetable juices can have unwanted color and flavor components removed with NF, guaranteeing that the finished product satisfies consumer preferences and quality standards.

Sugar syrup production:
NF is used to concentrate and purify sugar solutions during the manufacturing of syrup and sugar. It aids in the elimination of water and contaminants, increasing the concentration of sugar for use in a wide range of food applications.

Advantages of Nanofiltration
Regarding the size of particles it can efficiently filter, nanofiltration is a membrane filtration technique that lies between reverse osmosis and ultrafiltration. Ions, molecules, and particles are separated from water according to their size and charge using a semi-permeable membrane. The advantage of nanofiltrations are;

Selective filtration: Ions and molecules can be removed selectively using nanofiltration according to their size and charge. When divalent ions are removed and monovalent ions are allowed to pass through, it performs very effectively. Because of its selectivity, nanofiltration can be used for a number of processes, such as desalination and water softening. In nanofiltration techniques, hardness, heavy metals, particles, natural organic matter, and a variety of other organic and inorganic contaminants can all be successfully removed in a single treatment step.

Low energy consumption: Nanofiltration usually requires less energy input and operating pressure than reverse osmosis. In certain applications, this can lead to cost savings and make nanofiltration a more energy-efficient choice.

Environmental benefits:
Through the elimination of some chemical treatments and the reduction of brine or concentrate discharge related to certain water treatment procedures, nanofiltration can support environmental sustainability.

Conclusion
In the food business, nanofiltration has become a useful technology that offers many advantages in a variety of procedures. Applications including concentration, fractionation, and purification of food and beverage products are particularly well-suited for the ability of nanofiltration

membranes to selectively separate components based on size and molecular weight. The versatility of nanofiltration to preserve beneficial elements like flavors, colors, and nutrients while eliminating unwanted elements like pollutants and impurities is a key benefit for the food sector. This process of selective separation enhances the nutritional value and sensory appeal of the finished product in addition to improving its overall quality. In food processing, nanofiltration reduces waste and energy consumption, making it a sustainable solution. Because of the effectiveness of nanofiltration membranes in concentrating solutions, valuable byproducts can be retrieved, enabling the food production process more sustainable both financially and environmentally. In the food sector, nanofiltration is a promising and adaptable tool which offers a sustainable and selective way to improve the efficiency, safety, and quality of food and beverage processing.

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MILLETS IN INDIA: NOURISHING THE PAST FOR A SUSTAINABLE FUTURE

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Abstract

This article explores the resurgence of millets in India, once considered "poor man's food" but now recognized as superfoods with remarkable nutritional benefits. Examining the state of millets in India as of 2023, the article addresses their role in promoting food security, sustainability, and better nutrition. Millets, such as finger millet, sorghum, pearl millet, and foxtail millet, thrive in diverse agro-climatic conditions, offering vital minerals, gluten-free options, and dietary fiber. With their climate resilience, health benefits, and government support, millets contribute to food security, sustainable farming, and market growth, presenting a promising path for a healthier and more prosperous future.

Introduction

As people in India rediscover the rich history and nutritional benefits of these ancient grains, millets have recently attracted a lot of attention and respect. Millets, often regarded as "poor man's food," are now acknowledged as superfoods with enormous health advantages. In order to promote food security, sustainability, and better nutrition for a healthy future, this article examines the state and relevance of millets in India as of 2023.

With a range of 6 to 11 percent protein and 1.5 to 5 percent fat, millet grains are strong in carbs. They have a moderately strong flavour and are typically eaten in flatbreads and porridges, or cooked and eaten similarly to rice. The majority of millets are grown in tropical and subtropical areas at an altitude of altitude up to 2100m. Requires 60-80cms of rainfall annually. Temperature requirements are from 18-27 degrees Celsius. Grows well in sandy loam to loamy soil having a sufficient amount of organic matter having pH from 5.5-7.5.

Reviving Millets

There are a number of reasons why millets are becoming more popular, including growing interest in health and nutrition, environmental issues, and the efforts of farmers, NGOs, and government programmes. A wide range of millets, including ragi (finger millet), jowar (sorghum), bajra (pearl millet), and foxtail millet, are found in India due to the country's unique agro-climatic conditions. These grains are loaded with vital minerals like iron, calcium, and magnesium and are gluten-free, high in dietary fibre, and filled with these grains.

Food Security and Climate Resilience

Particularly in areas with difficult agricultural conditions, millets are essential for guaranteeing food security. In comparison to other crops, they are drought-resistant, need less water and fertiliser, and can grow in nutrient-poor soil. Due to their suitability for rainfed agriculture and marginal terrain, small-scale farmers can now more easily support themselves. Millets boost soil health and promote sustainable farming methods by diversifying crops and decreasing reliance on monocropping.

Health Benefits

Millets have propelled themselves to the forefront of the health food movement due to their nutritious profile. Millets provide a solution to the growing problems of malnutrition and lifestyle disorders. Their high fibre content promotes healthy blood sugar levels, decreases cholesterol, and helps with digestion. Millets are suitable for people with celiac disease or gluten intolerance because they are also gluten-free. Because of their low glycemic index, these grains help people maintain their energy levels and control their weight.

Government Initiatives and Market Potential

The Indian government has made substantial efforts to encourage millets' cultivation, consumption, and marketing because it recognises their enormous potential. Several states have millet-focused policies in place as of 2023, offering farmers training, financial incentives, and subsidies. The Public Distribution System and mid-day meal programmes' inclusion of millets has increased demand for and supply of the grain.

Additionally, the market for items made from millet has grown as more people look for healthier alternatives. In metropolitan areas, millet flour, ready-to-cook morning cereals, snacks, and bakery goods have become more popular. This has given farmers and businesspeople new options, generated jobs and fostering rural development.

Conclusion

The revival of millets in India signifies a transformative shift from overlooked staples to essential superfoods, contributing to food security, climate resilience, and improved health. Millets' ability to thrive in challenging agricultural conditions, coupled with their low water and fertilizer requirements, empowers small-scale farmers and promotes sustainable practices. The government's initiatives, including policies and incentives, highlight the recognition of millets' potential. The burgeoning market for millet-based products not only meets consumer demands for healthier alternatives but also fosters rural development. As millets gain momentum in both fields and kitchens, they emerge as a key player in ensuring a sustainable and nutritious future for India.

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NANOSENSORS IN THE FOOD INDUSTRY

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Introduction

Nanotechnology is one of the emerging technologies that has the potential to disrupt and revolutionize many traditional sectors, and it has grown in prominence significantly in recent years. Nanotechnology has found extensive uses in several areas of the economy, including cancer therapy, phosgene detection, energy harvesting for self-powered nanosystems, chip manufacturing, aerospace materials, and so on. Carbon nanotubes, nano-polymers, nanoparticles, nanofibers, nanoclays, nanotubes, nanowires, nanosprings, nanorods, and many more materials are being developed by recent researchers. Food products are highly nutritious, which makes it simple for microbes to contaminate them. The most important thing in life is the safety of food. The globalization of food production and consumer concerns about food quality and safety have resulted in linked and worldwide production and distribution networks and significant improvements in food standards.One of the main approaches to creating new devices is integrating analytical tools with nanotechnology features. Food safety standards are now comprehensively adopted in the worldwide food industry, such as BRC, FSSC22000, IFS, and HACCP(Aung *et al.,* 2014). Therefore far, several methods have been developed for the detection of food safety, including gas chromatography (GC), enzyme-linked immunosorbent assay (ELISA), GC mass spectrometer (GCMS), high-performance liquid chromatography(HPLC), and LC-MS(Esteki *et al.,* 2018; Malik et al., 2010; Stachniuk *et al.,* 2016; Cháfer-Pericás *et al.,* 2010; Rodroguez-Lazaro *et al.,* 2007 and Wu L *et al.,* 2019).These techniques are widely used and highly sensitive, but they have several drawbacks, including lengthy operation times and complex sample pretreatments. Biosensors using nanomaterials offer the promised benefit of improving response time, sensitivity, and selectivity to address the demand for contamination detection in complex food samples because of the unique physical and chemical features of nanomaterials (Rotariu *et al.,* 2016; L. Reverte *et al.,* 2016 and Warriner *et al.,* 2014). Food products that are packaged properly are shielded from moisture, contamination, and spoiling. Conventional passive packaging techniques serve as a moisture, dust, and air barrier. However, according to Vermeiren *et al.,* (1999), passive packaging systems fall short of addressing the growing concerns about food safety and bioterrorism. In contrast, intelligent packaging systems can detect the quality of food items and safeguard the packaged food's shelf life and brand name. Various smart packaging devices, including biosensors, gas indicators, time-temperature indicators, and barcodes, are used in intelligent packaging. In the future, invisible and smart tags based on nanoparticles might be used to verify the uniqueness of food items, as barcode-based protection tags are currently quite manipulable (Banu *et al.,* 2006 and Birtwell *et al.,* 2008).

Nanosensors

A sensor is a device that, for a given system, senses or measures changes in the physical and chemical qualities of the environment. When compared to conventional sensors, nanosensors provide several advantages in terms of sensitivity and specificity that make them highly useful in the food sector. Because the nanoparticles utilized in their manufacture have a high surface-to-volume ratio, they offer excellent sensitivity of detection. One-dimensional nanomaterials like nanotubes and nanowires have demonstrated significant promise for the creation of nanosensors. Nanosensors have several potential uses in a variety of fields, including research, medicine, agriculture, and food technology. With remarkable accuracy, nanosensors can track changes in a wide range of physical parameters, including gravity, velocity, temperature, volume, concentration, pressure, and electric and magnetic signals. Three types of nanosensors employ molecularly imprinted polymers: spectroscopic, piezoelectric, and electrochemical. The electrochemical characteristics of sensing materials, such as charge, conductivity, capacitance, and electric potential, constitute the foundation of electrochemical sensors (Fig. 1.1). Using a piezoelectric sensor, mechanical force may be converted into electrical force or vice versa. The three light-based signals that spectroscopic sensors use are surface Plasmon resonance, fluorescence, and chemiluminescence.

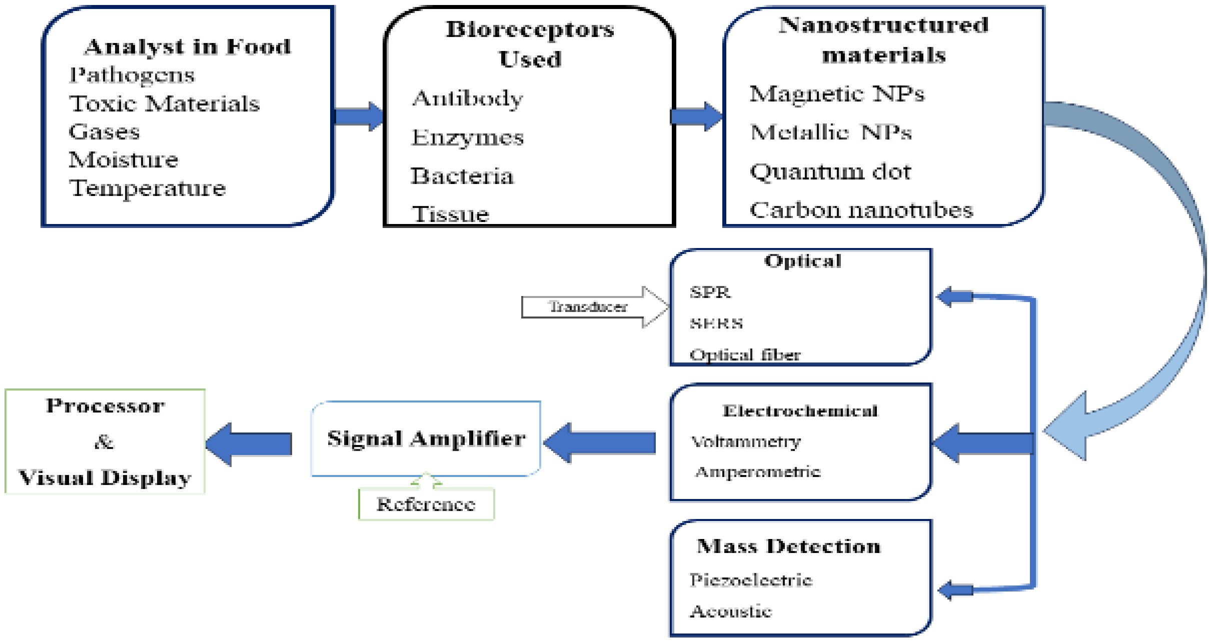

Fig. 1.1Schematic to illustrate the various nanosensors components

Optical Nanosensors

Biological or chemical sequences can be transduced using optical signals using optical nanosensors, which can analyze any particle smaller than 1000 nm in size. These consist of the ability to measure in tiny volumes, high specificity, low toxicity, and additional interferences on the characteristics of the sensor that are comparable to water. Fluorescein trapped in a polyacrylamide nanoparticle served as the basis for the first optical nanosensor, which was used to detect pH (Sasaki *et al.,* 1996). The fluorescent molecules were made up of a minimum of one photoactive element and a substrate unit. Throughout the process, a certain wavelength of light was absorbed; as a result, luminescencethe emission of light quanta with an energy equal to the difference between the excited and ground states was produced. This phenomenon is desirable for applications in biology or the environment, as well as for nanoscale chemical analysis (Aylott *et al.,* 2003). The optical nanosensor incorporates an optical receptor, also known as a sensing element, which is comprised of an inert matrix and is utilized to detect the characteristics of the designated analyte. Because of its great sensitivity and relative simplicity of measurement, fluorescence is currently the only transduction technique (Lobnik *et al.,* 2011).

Fiber-Optic Nanosensors

A chemically or biologically sensitive layer, often composed of chemical or biological recognition components covalently bonded to the optical transducer, makes up optical nanosensors. This transduction process offers an extremely appealing platform for chemical sensing applications, the most significant of which is minimum invasiveness for cell monitoring(Vo-Dinh *et al.,* 2005).The inherent optical characteristics of the target analytes are assessed using a direct technique, which forms the basis of the sensing strategy for fiber optic nanosensors. The first fiber-optic sensor in the field of food science was designed for detection of E. *coli* O157:H7 from the complex matrix of assigned food material (DeMarco *et al.,* 1999). Analyte 2000 is a core type fiber-optic sensor designed by Research International (Monroe, WA, USA) and is widely used for the detection of various pathogens in a sandwich form using fluorophore-labeled antibody including E. coli O157:H7 (Geng *et al.,* 2006), L. monocytogenes (Nanduri *et al.,* 2006), Salmonella enteritidis (Valadez *et al.,* 2009), and staphylococcal enterotoxin B (Tempealman *et al.,* 1996).While the primary issue with optic detectors iscross-sensitivity to ionic strength, pH sensing is still of significant significance. Because pH seeing inside depressions may be applied without coming into touch with food, microbial impurity in food can be averted by using bias like microtiter plates and micro-bioreactors. Similarly, benzo(a) pyrene, which is displayed to be kindly advanced in well-cooked barbecued dishes, especially steaks, flesh with skin, and hamburgers, may also be detected using these nanosensors inside a single cell (Sinha *et al.,* 2005). A silver nanoparticle with a gold-silica core nanoparticle is used in the development of the pH sensor based on SERS approach. A characteristic SERS spectrum that depends on the pH of the adjacent solution is displayed by the sensor, which is composed of 50–80 nm diameter silver nanoparticles combined with para-mercaptobenzoic acid. As a non-pathogenic stand-in for B. anthracis, the B. subtilis spore has been effectively detected using this method, which is sensitive to pH fluctuations in the range of 6.0 to 8.0 (Talley *et al.,* 2004 and Goodacre *et al.,* 2000).

Surface Plasmon Resonance (SPR)

SPR sensors use free electron oscillation when stimulated light of a certain wavelength is coupled to a metal surface with dielectric constants of opposing charges. This phenomenon was initially exploited in biological sensors and gas detection in 1982 (Liedberg *et al.,* 1983 and Cusano *et al.,* 2012). Since then, the technique has been widely used in the detection of chemical and biological analytes in solutions (Shankaran *et al.,* 2007). SPR nanosensors are comprised of an electronic database, an optical system, and a transducing medium that connects chemical (or biological) qualities with optical outputs. The optoelectronic parts of this sensor enable data processing via the transducing medium. These two elements, which entirely rely on the characteristics of the optical and transducing systems, help determine the sensor's capabilities, including sensor stability, sensitivity, and resolution (Homola *et al.,* 1999).It has been observed that this sensor, which uses phage-displayed single-chain fragment variable antibodies or rabbit antibodies, can distinguish between living and injured L. monocytogenes cells at 10^6cells mL^{-1}(Leonard *et al.,* 2004).

Chemical Nanosensors

These nanosensors convert data obtained from chemical analytes (varying from the concentration of a single specific component to a mixed component) into a detectable signal through a wide range of transducing processes carried out optically, calorimetrically, gravimetrically, or in numerous other ways. These nanosensors rely on the transduction process and the interaction of chemical recognition components with the physical part of the sensor to achieve chemical selectivity and analytical performance. Another common method for comparing chemical sensors based on nanomaterials and used in the food industry to colourimetric or fluorimetric methods is available for electrochemical-based nanosensors. This method is more beneficial for food matrices because it prevents light absorption and scattering from the food's various surfaces(Das *et al.,* 2014).The primary mechanism by which these nanosensors work is the binding of certain antibodies to conductive nanomaterials, such as carbon nanotubes (CNTs), and the subsequent modification of the material conductivity upon the binding of the target analyte to the antibodies (Wang *et al.,* 2009). Other nanomaterial-based electrochemical devices include an immunosensor that uses a CeO_2 nanoparticle and chitosan (chitosan that has been partly or completely deacetylated) nanocomposite to identify ochratoxin-A, a crucial foodborne fungus contaminant. Additionally, it might use silicon nanowire transistors (Mishra *et al.,* 2008) to detect staphylococcal enterotoxin B and carbon nanotubes (Viswanathan *et al.,* 2006) to detect cholera toxin. Nanomaterials help in the electrochemical detection of microbes in addition to chemical analytes. To screen for L. *monocytogenes*, a conductive TiO_2 nanowire covered with antibodies has been created. In approximately one hour, this technique identified 4.7×10^2 CFU mL^{-1} of the L. *monocytogenes* pathogen without any noteworthy interference from other foodborne pathogens. Changes in resistance or conductance across these nanosensors' circuits have also been made to detect viruses (De La Rica *et al.,* 2008), *Bacillus* (Pal *et al.,* 2007), *Salmonella* (Villamizar *et al.,* 2008 and De la Rica *et al.,* 2008), and *E. coli* (Lin *et al.,* 2008 and So *et al.,* 2008).

Biosensors and Biological Nanosensors

The development of biosensors has shown to be a useful tool in several disciplines, including medicine, environmental protection, and food safety. Biosensors are among the most effective instruments accessible to the food business because of their high selectivity, specificity, fast response, and low cost. A biological sensing element of a receptor combined with one or more transducers that may transmit selected or semiquantitative data to an output device is called a biosensor (Terry *et al.,* 2005). Biosensors are the most adaptable analytical instruments ever utilized since they combine a wide range of cross-disciplinary skills from fields like biochemistry, physical science, molecular engineering, biotechnology, and material sciences. This allows for the potential of detecting changes at the nanoscale. Toxins, pesticides, and viruses found in different food samples and packaging materials are among the main uses of biosensors in the food industry. Biosensors use a variety of sensing components, including entire cells, nucleic acids, enzymes, microorganisms, antibodies, and biocatalysts (Castillo *et al.,* 2004). The organic component gives the sensors their discriminating capacity by preferentially interacting with the target analytes (pesticides, microorganisms, poisons, or diseases). For biosensors, the most significant and vital features are biorecognition components' speed and selectivity. In biological recognition, enzymes and antibodies are the most commonly utilized components.A transducer is the second essential part; it transforms the chemical reaction between the bioanalyte and bioreceptor into an electrical signal. Since the words "trans" and "ducer" denote change and energy, respectively, the name itself describes the capacity to transform one type of energy into another. Electrical energy may be produced from biological energy by the transducers. Certain interactions involve heat production that is dependent on temperature, or electrochemical processes with an electrical output. Other methods of transduction of signals might include light output or light absorbance between reactant and product, which are dependent on reactant mass; electromagnetic radiation absorption or emission; modification of wave propagation by mass and microviscosity, etc. (Thakur *et al.,* 2013).The detector, the third part, is responsible for processing the electrical energy that it receives. The primary components of the detector are an optical or electrical processing instrument or a microcontroller. Biorecognition elements ensure the specificity of the sensor for a certain target analyte, while the type of transducer used affects accuracy and sensitivity. Apart from these discrete elements, the conjugation chemistry controlling the immobilization of the bio receptor on the sensor platform is a crucial structural characteristic of biosensors. It is crucial to properly immobilize the biosensor to guarantee its accuracy and speed. Temperature, pH, different kinds of pollutants, and other physiochemical variables, however, have an impact on the process (Malik *et al.,* 2013).

Other sensors with nanomaterials at the nanoscale

Electronic nose

The electronic nose is a tool comprised of clusters of chemical sensors with exceptional selectivity, sensitivity, and the capacity to identify and evaluate both basic and complicated smells emanating from test specimens (Fig. 2). The human olfactory system should ideally be replaced with this sensor. The electronic nose is a highly sought-after instrument in the culinary, healthcare, and biomedical industries due to its ability to accurately distinguish and identify various types of odour. The term "an intelligent system of chemical-array sensors that mimics the human olfactory system" (Ramgir *et al.,* 2013) is used to describe electronic noses. Food quality inspection, shelf-life research, freshness assessment, and process monitoring have all benefited from the introduction of the electronic nose idea (Peris *et al.,* 2009). When creating an electronic nose, large aspect ratio structures can be employed as a single film or in several films, whereas lower aspect ratio structures, such as those of nanoparticles, nanospheres, and nanocubes, are usually used as a film for sensing elements (Ramgir *et al.,* 2013). The fabrication of electronic nose devices for detection and discrimination between food samples and odour consists of an array of broadly tuned sensors that are treated with odour-sensitive biological or chemical materials (Peris *et al.,* 2009). The chemical sensors that are the key components of the system comprise inorganic crystalline materials like semiconductors, organic materials, polymers, and biologically derived materials. The sensing element depends on the type of analyte to be detected.

Electronic noses have several applications in food processing and quality assurance of raw and manufactured food products. The usage of an electronic nose system is one example of determining the quality of harvested fruits and vegetables. Monitoring and controlling the quality fluctuation of fresh harvest fruits and vegetables is presently one of the food industry's top priorities (Brezmes *et al.,* 2016).Electronic noses are precise and particular enough to distinguish between a wide variety of fruits, as well as measure the amount of damage (like rotting) and how long the fruit should be stored (Di Natale *et al.,* 2001).The measurement is done by aroma transformation, changes in defects caused by skin cuts or over-ripening, changes in starch or sugar composition, etc. (Brezmes *et al.,* 2016). The extent to which the electronic nose can aid in food analysis depends on the type of sensor array used. Electronic noses consisting of quartz crystal microbalance coated in modified metal porphyrins and related compounds may detect the level of spoilage in red wine and pulped tomato (Baietto *et al.,* 2015).

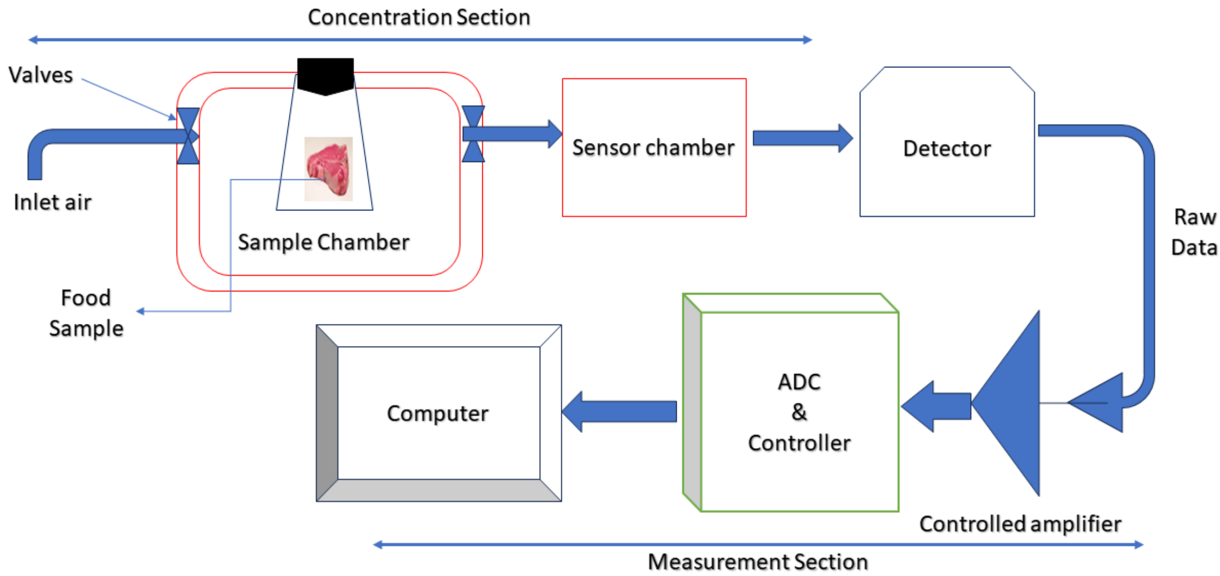

Fig 2.1: Schematic layout of a typical e-Nose Setup

There are two sections to the system. To allow the volatile compound-containing scent to build up in the headspace, the food sample is placed in a closed chamber and left for a certain amount of time in the concentration section. The intensified taste is transported to the sensor chamber using synthetic gas that comes from the inlet valves. The sensor generates a unique fingerprint for fragrance in the measurement portion, which is picked up by the detector and sent for amplification. Ultimately, the amplified analogue signal is transformed into a digital format and utilized for more examination.

Electric tongue

Sweetness, sourness, bitterness, saltiness, and umami are the five primary flavours that make up Human taste perception. To evaluate the flavour of various food items, trained or untrained human sensory panels have been used (Jiang *et al.,* 2018). It does take a lot of money and effort to operate and train a sensory panel, though. When panellists lack proper training, biases may occasionally be introduced into sensory panels. For this reason, numerous studies used e-tongue, a cheap, impartial, and fast-sensing substitute for the human tongue (Schlossareck and Ross, 2019). According to Jiang *et al.,* (2018), the chemical sensors that are frequently used for an e-tongue include electrochemical sensors, biosensors, and optical mass sensors. Like e-nose's gas sensors, e-tongue's chemical sensors react with analytes to produce reversible electrical property changes. Pattern recognition and categorization are then performed using measurable electrical signals. An electronic tongue system typically consists of the following components: transducers, measuring tools, chemical sensor array, reaction tank, data collection devices, data processing, and pattern recognition algorithms (Fig. 3).A person can alter an e-tongue system's functionality by utilizing various sensor kinds, data processing methods, and pattern recognition algorithms.

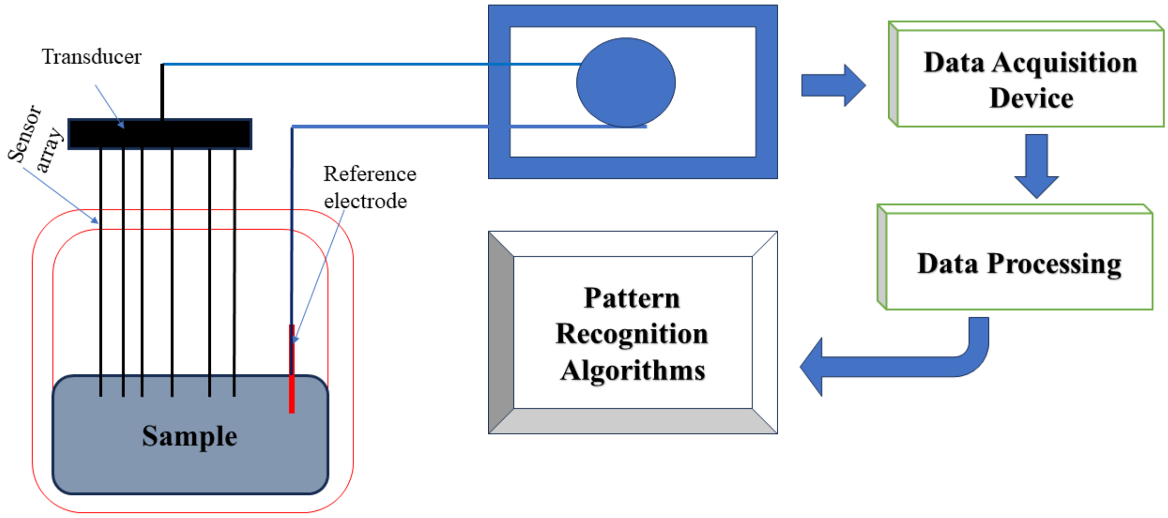

Fig 2.2: Schematic layout of a typical e-Tongue Setup

An e-tongue's sensor responds differently to the intended analyte. However, when working with actual food samples, the majority of the chemical sensors used by e-tongue experience notable matrix effects (Ceto *et al.,* 2016). To ensure that the sensors are made to target certain analytes in particular kinds of samples, a sample pre-treatment step is usually implemented. When analyzing several analytes at once, this pretreatment procedure takes a long time. The very brief lifetime of the sensors' detecting materials, particularly biomaterials, is another drawback of e-tongue. Users must regularly review the tongue's performances. Additionally, for training and validation, a large number of sample sizes (usually N10) are needed for each type of sample. There are various situations where a larger sample size is required. The use of biosensors with high selectivity, which lessen the effect of complex and interferents, is one e-tongue trend. Additional biomaterials will be employed as recognition components for those sensors, such as aptamers and nucleic acids, antibodies, cells, phages, and, specifically, enzymes. Food processors will find it quite helpful to assess the quality of their goods with the creation of standardized universal functionality e-tongues.

Conclusion

The basic ideas behind popular pattern recognition algorithms which is called nanosensors and their classification techniques as optical nanosensors, fiber-optic nanosensors, surface plasmon resonance, chemical nanosensors and Biological nanosensors are presented and covered, and their functioning principle elaborated briefly. Electronic gadgets that used sensors, such as e-noses and e-tongues, were also covered in this study. The functioning principles of different sensors are briefly described. All things considered, e-nose and e-tongue combing pattern recognition algorithms are incredibly potent analytical instruments that are quick, accurate, and reasonably inexpensive. Both in-line and off-line measurements which are crucial for tracking the processing of food and determining the quality of the final product can be performed using e-nose and e-tongue. The sample preparation, sampling, and data processing must all be closely regulated by the e-nose and e-tongue user. Two issues that still need to be properly addressed are the relatively low reproducibility and comparability of e-nose and e-tongue measurement and data processing.

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PLANT PROTECTION MEASURES IN PAPAYA

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Introduction

Papaya holds a significant position as a crucial fruit crop in India, covering an extensive area of one lakh and sixty thousand hectares with a production of 57 metric tons. Our country leads globally in both cultivation area and production. Important papaya growing states are Telangana, Andhra Pradesh, Uttar Pradesh, Bihar, Assam, Tamil Nadu, Karnataka, Maharashtra, West Bengal and Orissa. Due to the high nutritional value of papaya, its consumption is increasing day by day. With this, the cultivation is promising for the farmers who are cultivating it. Cultivation is favored in large area during recent years. The fruit has gained widespread popularity due to its exceptional availability, consistent productivity, and year-round fruiting capability, making it a profitable short-duration crop. Further, its uses extend to medicinal, nutritional, and industrial purposes. Raw papayas find consumption as a vegetable, while ripe ones are consumed as fresh fruits. However, the production of papaya faces challenges in both biotic and abiotic factors. Papaya production is constrained by several biotic & abiotic factors and among the biotic factors, diseases and insect pest are the most significant constraints. In recent years papaya cultivation has not become profitable to the farmers due to infestations of insects and diseases. Proper management should be adopted by the farmers to earn more profits by increasing the yields.

Management in nursery stages

If proper management measures are not taken at right time in nursery stages the plants will suffer a lot and plants mortality will increase. Damping off is a serious disease in nursery stage. A number of fungi like *Pythium ultimum, Phytophthora parasitica, Fusarium solani* & *Rhizoctonia* species can cause damping off disease of papaya seedlings. Initially the roots become soft and brown discoloration takes place on collar region. One week old plants are more susceptible to this disease than one year old trees and the disease spread rapidly when seedlings are placed crowded. Water soaked lesions are seen on the stem at or just above soil level. Affected stem tissues weakens, shrink and finally die. To manage this disease, seeds should be treated with 5 gram *Trichoderma viride* or 3 gram captan per kg seed before sowing. Drench the seedlings with COC @ 3 g per lit of water at weekly intervals to avoid infestation.

Management in main orchards

Anthracnose: Brown to black depressed spots appeared on the fruits which are initially water-soaked and sunken. The centers of these spots later turn black and then pink. The flesh beneath the spots becomes soft and watery, which spreads to the entire fruit. Irregular water soaked small spots may be seen on leaves also which turn brown finally. On the fruits, the symptoms appear only upon ripening and may not be apparent at the time of harvest. To manage the disease, spray carbendazim @ 1 gram per liter of water at 15 days interval.

Leaf curl: It is a viral disease transmitted by white fly. Symptoms appeared on leaves as curling and crinkling with reduction in leaf lamina. The veins become thick with leaf margins rolling inwards and downwards. Later leaves become leathery, brittle and distorted with stunted growth. To manage this disease, rogue out affected plants after noticing the symptoms. The vectors can be controlled by spraying acetamiprid @ 0.3 g per liter of water.

Ring spot: This is a viral disease and is transmitted by aphids. Young leaves show cholorotic spots initially and later show vein clearing, rugosity and prominent mottling of laminae with elongated dark green streaks on petioles. On fruits circular concentric rings are produced. If the infestation is earlier, fruit formation is arrested. To manage this disease, rogue out affected plants after noticing the symptoms. The vectors can be controlled by spraying acetamiprid @ 0.3 g per liter of water.

Root rot/ stem rot: Initially the roots become soft and then water soaked patches on the stem near ground level appeared on lower portions of the stem. These patches enlarge rapidly and girdle the stem, causing rotting of the internal tissues give a black to brown honey comb like appearance. The disease can be expected at any stage of the crop and is more in trees having fruits. To manage this, makes sure that water should not be logged near the basin of the plant. When the symptoms appeared on trees, drench the basins with metalaxyl or chlorothalanil @ two grams per liter of water twice a week. If the infestation is high, spray Ridomil MZ @ 2 g per liter of water on the stems.

Mosaic: It is a viral disease transmitted by aphids. In plants infected with virus, the leaves will shrivel and are having yellow and green mosaic spots. Fruiting is significantly reduced. This can be controlled removing the virus infected trees from field to reduce further infestation. The vectors can be controlled by spraying acetamiprid @ 0.3 g per liter of water.

Fruit fly: Adult female fruit flies lay eggs inside the matured fruits. The larvae which are hatched from eggs feed on the pulp of the fruit and causes damage at the time of ripening. To manage the flies keep the orchard clean and fallen fruits should be removed from time to time. Install methyl eugenol traps here and there around orchad @ 10 per acre.

Mealy bugs: Mealy bugs infest the fruits and suck the sap. These bugs excrete honey dew and as a result infested portion becomes shiny and moist and to this, secondary infection of sooty mould occurs results in black covering of the fruits. To manage this pest, alkathene banding to the tree stem at one feet height should be adopted. In case of severe infestation spray profenophos @ 2 ml per liter of water.

White fly: Both nymphs and white color adults found clusters on lower portions of leaves and suck the sap. Affected leaves become curled and wrinkled. The pest is responsible for economic damage. Severe infestation leads to stunted plant growth. They can be managed by encouraging parasitoids like *Encarsia formosa*, *Eretmocerus* spp., predators like *Chrysocoris, Dicyphus hesperus*, green lacewing, ladybird beetle, big-eyed bugs (*Geocoris* sp), mirid bug, spider, reduvid bug, robber fly, dragon fly, *Orius* sp. Install yellow colored glue sticky traps @ 10 per acre. In severe infestation spray systemic insecticides like thiamethoxam @ 0.4 g per liter of water.

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NATURAL FARMING IN INDIA: A SUSTAINABLE REVOLUTION FOR AGRICULTURE AND ENVIRONMENT

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Abstract

This article investigates the adverse environmental impacts of modern agricultural practices, including climate change, deforestation, and the excessive use of fertilizers and pesticides. It delves into the concept of Natural Farming, also known as Do-nothing farming, popularized by Masanobu Fukuoka in Japan. Examining the case of Japan and its successful application, the article explores the philosophy and principles of Natural Farming and its potential to revolutionize agriculture in India. Highlighting the Bhartiya Prakritik Krishi Paddhati Programme (BPKP) under the Paramparagat Krishi Vikas Yojana (PKVY), the article discusses the Indian scenario, its adoption, and its positive impact on production, water use, soil health, and rural employment.

Introduction

Modern agriculture practices have a major impact on the environment. Climate change, deforestation, genetic engineering, irrigation problems, pollutants, soil degradation and wastes are some of the concerns that relate to agriculture. Excessive use of fertilizers such as urea, nitrate, phosphorus along with many other pesticides have affected air, water, and soil quality. Genetically engineered crops are herbicide tolerant, and their overuse has a major impact on the environment. Non-target plants, birds, fish and other wildlife have also been killed because of pesticide application. Soil degradation has affected the microbial community of the soil disturbing the nutrient cycle, pest control and chemical transformation properties of soil. Natural Farming in India is an ideal solution to reducing all these hazards. This sustainable way of farming is also known as Do-nothing farming or No -tillage farming. It was first popularized by 'Masanobu Fukuoka' way back in 1940s in Japan. The idea is to let nature play a dominant role to the maximum extent possible. Masanobu Fukuoka a Japanese farmer and philosopher introducing the Natural Farming term in his book 'The One -Straw Revolution'. The title refers not to lack of effort, but to the avoidance of manufacturing inputs and machinery.

What is natural farming?

Natural Farming is related to fertility, farming, organic farming, sustainable agriculture, agroecology, agroforestry. The systems along with the natural biodiversity of each farmed area, encourage the complexity of living organisms- both plants and animals that shape each ecosystem to thrive along with food plants. Natural Farming is a closed system that demands no human supplied inputs and mimics nature. One of the main objectives of natural farming is to ask why we would apply modern technology to the process of growing food if nature could achieve similar yields without the negative side- effects of these technologies. Such ideas radically challenged conventions that are covered to modern technologies agriculture - industries instead of promoting importation of nutrients and chemicals, he suggested an approach that take advantage of the local environment. When chemical fertilizers began to spread in Japan several decades ago, many farmers and agricultural scientist blindly believe in chemical fertilizers and pesticides that pests would become extinct, and hunger would be extreme by chemicals. At this moment, Mokichi Okada an orient philosopher warned people with an opinion contrary to others and proposed his philosophy of Nature Farming, an agricultural system like organic farming in agriculture.

Case of Japan

The suggestion of Okada's Nature Farming philosophy has been proved with modern scientific theories and experiments. For example- experiment results show that the accumulation of nitrogen immediate metabolites in the tissue make the plant susceptible to diseases and pest insects. As discussed in accordance with many research achievements, fertilizer, poisons exist at the medicinal industries or molecular level as nitrate- Cancers and other health problems such as Blue baby Syndrome at the macroecological level is caused by excessive nitrogen and phosphorus from fertilizations, and at macroclimatic level as global warming by the greenhouse gases from excessive fertilization. Now Mokichi Okada's followers are promoting Nature Farming in Japan in collaboration with the recent organic movement. The principle and technologies of Nature Farming have undergone development, and adaptation to today 's sustainable food production. Natural Farming is a chemical free traditional farming method. It is considered as an agroecology based diversified farming system which integrates crops, trees, and livestock with functional biodiversity.

Indian scenario

In India, Natural Farming is promoting as Bhartiya Prakritik Krishi Paddhati Programme BPKP under centrally sponsored scheme -Paramparagat Krishi Vikas Yojana PKVY. BPKP is a programme aims at promoting traditional indigenous practices which reduces extremally purchased inputs. It is largely based on farm biomass mulching, use of cow dung urine formulation, periodic soil aeration and exclusion of all synthetic chemical inputs. According to HLPE reports Natural Farming will reduce dependency on purchased inputs and will help to ease small holder farmers from credits burden. The BPKP programs havebeen adopted in states A.P, H.P, U.P. Several studies have reported the effectiveness of natural farming BPKP in terms of increase in production, sustainability, saving of water use, improvement in soil health and farmland ecosystem. It is considered as a cost- effective farming practice with scope for raising employment and rural employment. NITI Ayog along with the ministry of agriculture and farmers welfare had converted several high-level discussions with global experts as Natural Farming practices. Around 2.5 million farmers in India are already practicing 'Regenerative Agriculture'. National level consultation on BPKP- Natural Farming held on 29th and 30th Sep2020 NITI Ayog held a two-day national level consultation on the principles and practices of BPKP- Natural Farming, chaired by hon'ble Vice Chairman, NITI Ayog from 29th - 30th Sep to poster an exchange of information on the potential and challenges in the adoption of Natural Farming in India. More than 600 participants were key officials from Central and State Agriculture ministries, scientists from SAU subject matter experts from ICAR faculty of agriculture universities and institutions. KVK, IARI, NGO/TRUSTS associations with BPKP, farmers associations progressive farmers representative from FAO, UN and ICRAF and agriculture- entrepreneurs attended the virtual consultation.

The meeting on natural farming : A follow up meeting to the National level consultation on BPKP- Natural Farming 9th Sep 2020 was held on 9th Oct 2020 under the chairmanship of vice- chairman NITI Ayog through virtual network. The purpose of the meeting was to discuss the next steps in taking Natural Farming forward, including the collection of empirical evidence, scientific validations, preparations of success stories related to the states of A.P, H.P, Gujarat. The participants included member agriculture NITI Ayog, DG-ICA, DDG-ICAR, official from ministry of Agriculture and farmers welfare by Director General ICRAF, representatives of states, KVK's is involved in upscaling of Natural Farming.

Lecture series on natural farming : The agriculture vertical organized a virtual lecture by Dr. Bruno Dorin Senior Researcher and Head, Economics and development, Centre de Sciences Humans - on sustainable agroecological systems on 18th Nov 2020 chained by NITI Ayog Vice Chairman Dr. Rajiv Kumar, the lecture was attended by 71 participants including professor Ramesh Chand, NITI Ayog member and additional secretary Dr. Rakesh Sarwal, State agriculture secretaries deputy director generals, ICAR and representative of FAO, scientist from State agriculture universities and KVK officials involved in scaling up of Natural Farming.

Conclusion

Natural Farming emerges as a sustainable and chemical-free solution to address the environmental challenges posed by conventional agriculture. With its roots in traditional indigenous practices, as demonstrated by the success in Japan, Natural Farming gains prominence in India through initiatives like BPKP. The program showcases increased production, improved sustainability, water conservation, and enhanced soil health. NITI Ayog's active involvement, national consultations, and virtual lecture series underscore the commitment to promoting Natural Farming as a way forward. As more farmers adopt regenerative agriculture practices, the movement towards Natural Farming offers hope for a greener and more resilient agricultural future in India.

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NUTRIENT-RICH NOURISHMENT:SILAGE MAKING FOR LIVESTOCK WELL-BEING

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Abstract

This study explores the critical conditions for successful silage making, emphasizing the importance of maintaining optimal moisture content (65-75%) in plant material, ensuring an airtight silo pit, and promoting a temperature rise to 30-38°C during ensiling. In cases where ideal conditions are challenging, the incorporation of preservatives such as molasses, salt, and citrus pulp, as well as modifiers like sodium metabisulphite, proves beneficial. Silage color varies with temperature, ranging from yellowish to brownish-green under moderate conditions and becoming dark brown or black at higher temperatures. The research also highlights potential nutrient losses, including dry matter, vitamins, and minerals, offering insights for improved silage quality and preservation.

Introduction

During periods of abundant green fodder, farmers often preserve it as silage to sustain animals through summer or lean seasons. Silage can be defined as the preservation of green, succulent roughage through controlled anaerobic fermentation, minimizing quality deterioration and nutrient loss. The method of preserving green fodder as silage is referred to as ensiling.

Silage preparation under field conditions:

Silo: A silo is an air tight structure designed for storing and preserving high moisture feed in the form of silage. Various types of silos exist, such as Tower silos, Bunker silos, Bag silos, and Pit silos, with the latter being more prevalent in India.

Requisites of pit silos:

a) The walls must be impermeable to prevent water infiltration into the silo pit and it is made up of cement, brick or mortar.
b) Adequate depth is crucial, dependent on the water table in the area, and a shallow silo is to be avoided.
c) Optimal placement involves locating the silo on an elevated area.
d) The silo's size should be determined based on the number of animals to be fed and the length of the feeding period. Pit dimensions typically range from 2.4 to 3.0 meters in

depth, with variable sizes. Approximately one cubic meter of space is required for every 400 kilograms of fodder.

Crops suitable for making good quality silage:

a) Green fodder should be rich in soluble sugars/carbohydrate i.e., maize, jowar, bajra are ideal for silage making.
b) Cultivated and natural grasses typically have lower levels of soluble sugars/carbohydrates. To enhance their silage quality, molasses is added at a rate of 3-5%.
c) Legume fodders have high levels of protein and minerals which leads to poor quality silage. Hence, legume green fodders are mixed in the ratio of 1:3 with grasses/cereal fodders and unwilted leguminous leafy fodders and dry forage in the ratio of 4:1.

Stage of harvesting and dry matter content: Harvesting crops for silage production should occur between the flowering and milk stages, avoiding the harvest of immature crops rich in proteins and low in sugars. The chosen crops for silage should not exceed 35% dry matter. If the fodder is too succulent with higher moisture content, field wilting is recommended until the dry matter content reaches approximately 35%. Optimal cutting time is late in the day, as sugar content tends to increase throughout the day. Harvesting during rainy conditions or very early in the morning with dew is discouraged.

Chopping: For effective ensiling, it is advisable to chop the green fodder into small pieces, approximately 1-2 inches in length.

Rapid filling and compaction in the silo pit: Efficiently filling the silo pit with fodder is essential for minimizing air entrapment, as excessive air can lead to rapid oxidation of fermentable sugars, generating heat. The heat, in turn, attracts more air from the surroundings, promoting aerobic conditions in the pit. This aerobic environment is unfavorable for the proliferation of lactobacilli, the key bacteria responsible for bacterial fermentation. It's crucial to establish a robust lactobacilli population quickly to facilitate the rapid breakdown of fermentable carbohydrates into lactic acid.

Steps in making silage:

a) Choose crops for ensiling when their dry matter ranges between 30-35%. If the dry matter is below 30%, allow the crop to air-dry in the field for 3-4 hours to reach the desired range.
b) Typically, harvest and ensile crops when the ears begin to emerge.
c) Opt for fair, non-rainy days of the week for the ensiling process.
d) It is advisable to initially chop the fodder, as it improves packing efficiency, minimizing nutrient loss in chaffed fodder. This also facilitates easier filling and removal of silage.
e) After chopping, ensure that the dry matter content reaches approximately 35% before filling the silo.
f) Distribute the fodder evenly within the pit, ensuring proper trampling. At the silo's top, pack the fodder 3-4 feet above ground level.
g) Cover the silo from all sides with long paddy straw or low-quality grasses, sealing it with wet mud and dung to prevent air and water entry. The layer of straw/grasses over the green fodder should be around 4 to 5 inches. The silage should be ready in two months after covering.
h) Enhance palatability and nitrogen content in cereals and grasses by adding 0.5% salt and 1% urea.

i) Improve sugar content and silage quality for preserving grasses by adding molasses at a rate of 3 to 5%.

Changes in the silo pit during fermentation: When green crops are harvested, cut into pieces, and tightly packed into silo pits or towers, a fermentation process takes place, transforming the material into silage. Following the packing of the material into the silo pit, plant respiration continues briefly. During this period, enzymes, aerobic bacteria, yeast, and molds become active until all the oxygen in the packed material is depleted. This respiration process also consumes some carbohydrates in the plant material, releasing CO_2 and causing a temperature increase, particularly in the initial stages of fermentation (approximately 27 to 38°C).

As the temperature rises, bacteria naturally present on the material's surface become active, utilizing carbohydrates and producing CO_2 along with organic acids such as lactic, acetic, and butyric acids, along with small amounts of alcohol.

Types of fermentation: Two main types – Lactic acid type and Butyric acid type.
The fermentation process of silage is as follows:

1) **First stage:** Plant respiration - After chopping, the packed raw materials continue to undergo respiration, consuming oxygen. This leads to a temperature increase of approximately 32°C.
2) **Second stage:** Acetic acid production - Acetic acid production commences through fermentation with acetic acid bacteria during the respiration phase. The silage pH gradually transitions from around 6.0 to 4.0.
3) **Third stage:** Initiation of lactic acid production - About three days after packing the chopped materials, lactic acid fermentation begins with lactic acid bacteria. Acetic acid fermentation by acetic acid bacteria diminishes, leading to a decline in acetic acid production.
4) **Fourth stage:** Peak lactic acid production and storage – lactic acid production continues for about 2 weeks and the temperature gradually decreases to normal atmospheric temperature. The pH decreases to about 4.0, and the activity of the various bacteria ceases. If the process progresses smoothly to this stage, it enters a stable phase characterized by low pH, resulting in high-quality silage. The lactic acid fermentation completes in about 20 days, marking the conclusion of the silage production.
5) **Fifth stage:** when the concentration of lactic acid is not properly reached due to reasons such as high moisture and high protein content or low sugar content in the green fodder, the proliferation of other bacteria like Clostridia occurs. These bacteria consume plant proteins, remaining carbohydrates, sugars, as well as acetic, lactic, and other organic acids formed in previous fermentation stages. This results in the production of butyric acid. Additionally, these bacteria break down proteins into amines and ammonia, leading to silage decomposition and the development of poor-quality silage with an unpleasant odour.

Important conditions for success in silage making:

- ✓ The plant material selected for ensiling should have a moisture content of 65 to 75%.
- ✓ Excluding air in the silo pit.
- ✓ Encouraging a rise of temperature to 30 to 38^{0}C.

In instances where achieving these optimal conditions is challenging, the addition of preservatives or silage conditioners becomes beneficial. Preservatives like molasses, salt, cereal grains and citrus pulp not only act as preservatives but also enhance the feeding value. Sodium metabisulphite can modify the fermentation process and reduces undesirable odours.

Colour of the silage: Silage tends to exhibit a yellowish, brownish green or even golden colour when the temperature in the silo is moderate. This coloration is due to the action of the organic acids on the chlorophyll, converting it into the brown magnesium free pigment, phaeophytin. Silage assumes a dark brown or black colour, when the silo temperature is high.

Nutrient loss in silage making:

- Shattering of leaves causes a loss of dry matter.
- Poor quality silages may result in loss of vit-C and carotene.
- Some minerals may leach out and be lost during the ensiling process.

Table: 1 Grading of silage

Quality of silage	pH	Ammonical nitrogen	Lactic acid	Other qualities
Very good silage	3.5-4.2	Less than 10%	1-2%	Free from butyric acid, moulds sliminess
Good silage	4.2-4.5	10-15%	0.5-1.0%	Traces of butyric acid (<0.2%)
Fair silage	4.8 and above	20%	0.5%	Some butyric acid, slight proteolysis and some moulds

Conclusion

In conclusion, maintaining optimal moisture levels, ensuring airtight silo conditions and promoting controlled temperature dynamics are crucial for successful silage making. The incorporation of preservatives further contribute to the production of high-quality silage for efficient livestock feed.

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THE ROLE OF NANOTECHNOLOGY IN CROP PRODUCTION

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Abstract
Nanotechnology, a science focused on incredibly small things, has a significant role in increasing crop production. With the world's population steadily growing, the challenge of producing enough food is becoming more pressing. Nanotechnology aids in this by enhancing the resilience of plants and ensuring they receive the right nutrients for optimal growth. Think of it as giving plants a boost to produce more food. In the coming years, nanotechnology could become a crucial element in our efforts to ensure there's an ample food supply for everyone, helping us tackle one of the planet's most important challenges.

Keywords: Nanotechnology, Crop Production, Food Security, Plant Resilience

Introduction
The world's population is on an unstoppable trajectory, expected to reach 9.7 billion by 2050. This unprecedented population growth poses a significant challenge: how do we ensure food security for all while dealing with limited arable land, changing climate patterns, and diminishing natural resources. Enter nanotechnology a field that holds the promise of revolutionizing crop production and addressing these pressing challenges. In this article, we'll delve into the fascinating world of nanotechnology in agriculture and explore how it's shaping the future of food production.

Understanding Nanotechnology
Nanotechnology involves manipulating and engineering materials at the nanoscale, which is on the order of one billionth of a meter. At this scale, materials exhibit unique physical, chemical, and biological properties that differ from their bulk counterparts. Scientists and researchers have harnessed these properties to design innovative solutions across various fields, and agriculture is no exception.

Nanotechnology Meets Agriculture
1. Precision Agriculture: One of the key contributions of nanotechnology to crop production is its role in precision agriculture. Traditional farming methods often involve blanket treatments of fertilizers and pesticides across entire fields. This approach is not only wasteful but also harmful to the environment. Nanotechnology enables the development of "smart" delivery systems for nutrients and chemicals. Nanoparticles can be engineered to release nutrients slowly based on the plant's needs, reducing waste and minimizing environmental contamination (Madzokere *et al.*, 2021). It encourages the development of novel, effective agrochemicals for plants, such as nanofertilizers and nanopesticides, which help sustainably smart agriculture by inhibiting plant diseases and preventing crop failure (Samreen *et al.*, 2022).

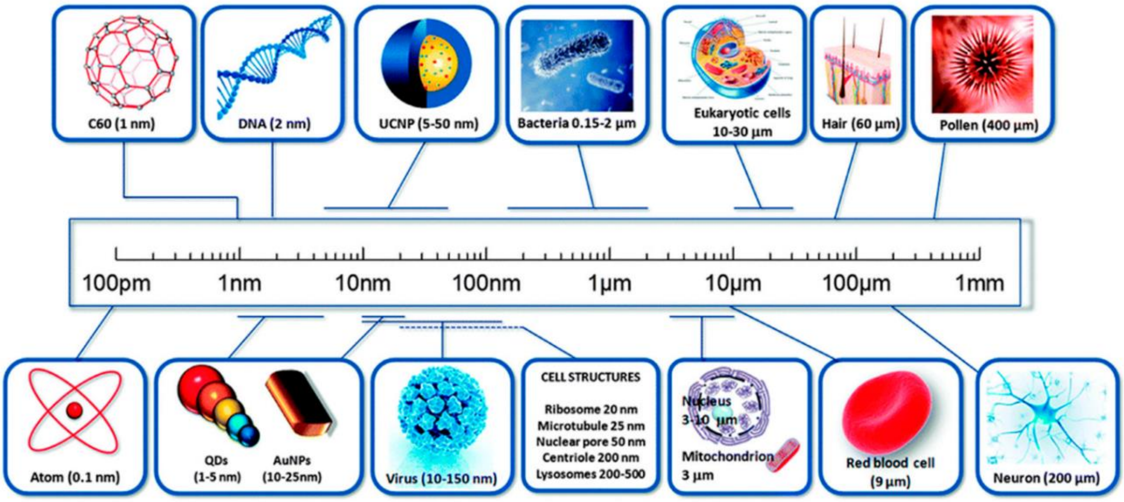

Figure 1. Comparison of sizes of nanomaterial (Gnach *et al*., 2015).

2. Enhanced Plant Nutrient Uptake: Plants require various nutrients for healthy growth. However, a significant portion of applied fertilizers is lost due to leaching or being bound in forms unavailable to plants. Nanoparticles can be designed to encapsulate these nutrients, protecting them from degradation and delivering them directly to the plant's root zone. This targeted approach enhances nutrient uptake efficiency and reduces the need for excessive fertilizer application.

Here are some ways in which nanotechnology can enhance plant nutrient uptake:

a. **Nano-fertilizers**: Nanoscale nutrient particles, such as nanoparticles of nitrogen, phosphorus, and potassium, can be engineered to release nutrients slowly over time. This controlled release ensures that plants receive a steady supply of nutrients, reducing wastage and improving nutrient uptake efficiency.

b. **Nanoencapsulation**: Nutrients can be encapsulated within nanoscale carriers, protecting them from environmental factors like leaching or volatilization. This approach ensures that a higher proportion of applied nutrients reaches the plants' roots.

c. **Nanoscale delivery systems**: Nanoparticles can be designed to carry nutrients directly to plant roots, increasing the efficiency of nutrient uptake. These nanoparticles can be coated with materials that enhance their adhesion to root surfaces or penetrate cell membranes to deliver nutrients more effectively.

d. **Enhanced nutrient solubility**: Nanotechnology can be used to increase the solubility of less soluble nutrients. This means that nutrients that were previously unavailable to plants due to poor solubility can now be absorbed more easily by plant roots.

e. **Smart nutrient release**: Nanoscale sensors and responsive nanomaterials can be used to develop "smart" nutrient delivery systems. These systems can release nutrients in response to specific environmental cues, such as soil moisture levels or plant nutrient demands, ensuring that nutrients are supplied when and where they are needed most.

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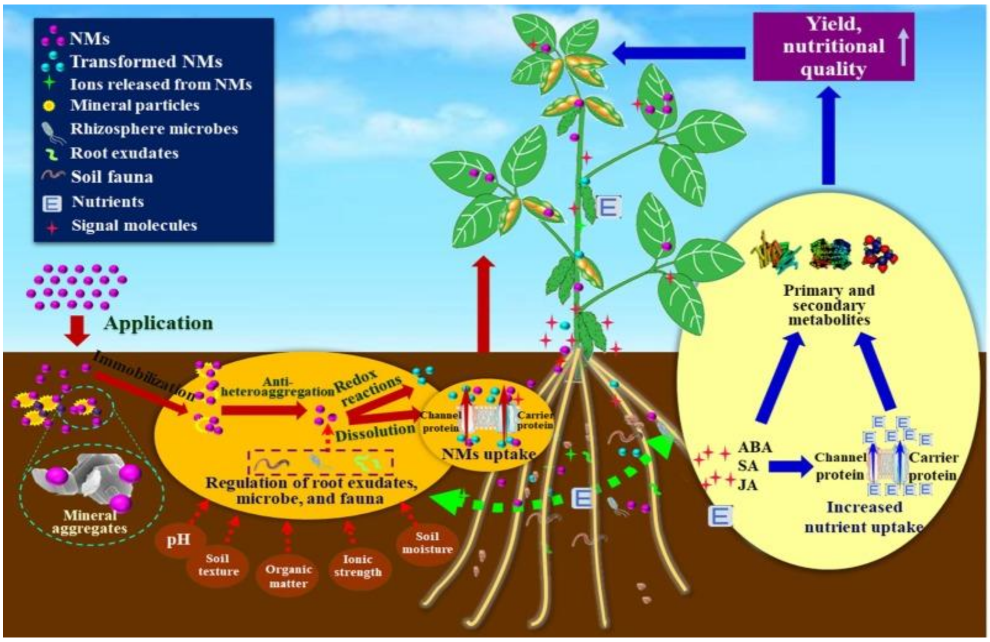

Figure 2. Key environmental geochemical processes (left) and biological response mechanisms (right) of nano materials in agroecological systems (Wang *et al*., 2020)

f. **Improved nutrient management**: Nanosensors can be employed to monitor nutrient levels in soil and plants in real-time. This data can then be used to optimize nutrient application, ensuring that plants receive the right nutrients at the right time.
g. **Reduced environmental impact**: Nano-fertilizers and delivery systems can minimize nutrient runoff and leaching, which can lead to water pollution and soil degradation. This reduction in nutrient losses benefits both the environment and agricultural sustainability.
h. **Biological interactions**: Nanotechnology can also be used to enhance beneficial interactions between plants and microorganisms in the soil. Engineered nanoparticles can facilitate nutrient uptake by promoting the growth of beneficial soil microorganisms that aid in nutrient mobilization and uptake.

3. Disease and Pest Management: Nanotechnology offers novel methods for pest and disease management. Nanoparticles can be loaded with pesticides or antimicrobial agents and delivered directly to the site of infection. This not only reduces the quantity of chemicals required but also minimizes their impact on non-target organisms. Additionally, nanomaterials can be engineered to stimulate the plant's natural defense mechanisms, making them more resistant to diseases and pests.

4. Improving Water Management: Water scarcity is a significant concern in agriculture. Nanotechnology has paved the way for the development of nanosensors that can detect soil moisture levels in real-time. These sensors provide valuable data that help farmers optimize irrigation practices, preventing water wastage and promoting water-efficient crop production.

5. Nanogenetics: Nanotechnology is revolutionizing crop breeding through nanogenetics. This approach involves manipulating and modifying plant genes at the nanoscale, enabling precise control over desirable traits. Nanoparticles can deliver gene-editing tools like CRISPR-Cas9 to specific plant cells, accelerating the development of crops with enhanced yield, resilience, and nutritional content.

Challenges and Considerations

While the potential of nanotechnology in crop production is exciting, it's important to address potential challenges and ethical considerations. The release of nanoparticles into the environment raises questions about their long-term impact on ecosystems and human health. Rigorous research is needed to assess the safety of nanomaterials used in agriculture and to develop guidelines for their responsible application.

Conclusion

As the global population continues to surge, harnessing innovative technologies becomes imperative to ensure food security and sustainable agricultural practices. Nanotechnology's marriage with agriculture offers a beacon of hope, promising more efficient resource utilization, reduced environmental impact, and higher crop yields. While challenges exist, ongoing research and collaboration between scientists, policymakers, and farmers pave the way for a future where nanotechnology plays a pivotal role in feeding the world. So, as we peer into the future of farming, it's clear that the small world of nanotechnology is making a big impact on crop production.

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HARNESSING THE THERAPEUTIC POTENTIAL OF POSTBIOTICS: A COMPREHENSIVE REVIEW ON IMMUNOMODULATION, DISEASE PREVENTION, AND FUTURE CLINICAL APPLICATIONS

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Abstract

This article explores the profound impact of postbiotics on human health by examining their role in immunomodulation, disease prevention, and future clinical applications. Beginning with an overview of the human microbiota, particularly in the gastrointestinal tract, the discussion encompasses the definitions of various biotics, challenging traditional notions about the criticality of cell viability in probiotics. Focusing on postbiotics, the article delves into their therapeutic potential in diverse populations, from infants to adults, highlighting their pleiotropic effects. The review also discusses the clinical significance of postbiotics, emphasizing production technology, safety of use, and their potential incorporation into functional foods. Ultimately, the article underscores the promising future of postbiotics in treating or preventing various diseases, with ongoing clinical trials exhibiting encouraging initial results.

Introduction

The micro-biota is an assemblage of microorganisms that inhabit the human body, their genomes and metabolites, as well as the environment in which they reside. Microorganisms from the microbiome can be isolated from all places that are constantly in contact with the outside environment (e.g., the skin, upper respiratory tract, or urogenital tract).

However, they are particularly common in the gastrointestinal tract. The human body provides a stable, nutrient-rich habitat for the microbes that dwell it in exchange for a variety of benefits. These advantages include immune system stimulation, increased digestion and absorption of food, reduced proliferation of harmful flora, and preservation of intestinal barrier integrity.

Because of the systemic distribution of substances and cells produced in the intestine, the beneficial effects of the interaction between the microbiota and the gastrointestinal tract can be noticed not only locally, but also in distant organs. This is known as the gut-organ axis, from which we can separate the gut-brain, gut skin, gut-lung, and so on.

Definition of Biotics

Probiotics: Live microorganisms that, when administered in adequate amounts, confer a health benefit on host or Live microbes that are beneficial for the host health. Eg.- *Bifidobacterium animalis subsp. lactis* BB-12.

Prebiotics: A substrate that is selectively utilized by host microorganisms conferring a health benefit on the host or “Food” for beneficial microbes residing in or on the host that provide a health benefit. Eg.- Inulin, FOS (Fructo-oligosaccharides) , or GOS (Galacto-oligosaccharides)

Synbiotics: A mixture comprising live microorganisms and substrate(s) selectively utilized by host microorganisms that confers a health benefit on the host. Probiotic + Prebiotic, defined as a complementary symbiotic. Eg.-*B. lactis* BB-12 + inulin.

Postbiotics: Preparation of inanimate microorganisms and/or their components that confers a health benefit on the host or Intact non-viable microbes or cell fragments, with or without metabolites that provide a health benefit. Eg.- Heat-killed Akkermansiamucinophila ATCC BAA-835.

Cell viability has long been thought to be critical for a probiotic to provide a health benefit. On the other hand non-viable microorganisms, their cell components, and their metabolites, have long been recognised as having an impact on health. Particularly in the perinatal period, several factors can influence the genetic makeup of the microbiota, including the composition of the maternal gut microbiota, their method of delivery and the type of food consumed by the mother, antibiotic medication, and stress. As a result, treatment techniques and preparations that influence the composition of the microbiota and hence the patient's well-being are gaining in popularity.

Many studies have shown that an imbalance in the intestinal microbiota—dysbiosis—can lead to the development of allergic or autoimmune diseases (e.g., inflammatory bowel disease, type 1 diabetes, among others), cancer, and psychiatric disorders. There are currently three main ways in which the microbiota can be modulated, i.e., through the use of prebiotics, probiotics, postbiotics.

Postbiotics in Healthy Population

Infant feeds with postbiotics: Infant formulas with postbiotics are those fermented with lactic acid– producing bacteria during the production process but not containing significant numbers of viable bacteria in the final product. Most studies evaluated infant formulas fermented with *Bifidobacterium breve C50* and *Streptococcus thermophilus 065*. As previously reported, such formulas, compared with non-supplemented infant formula, were safe and well tolerated. Fermented formulas with B. breve C50 and S. thermophilus 065 reduced fecal pH values and increased fecal IgA levels, IgA plays an essential role in mucosal immunity; thus, it may impact the overall immunity of infants.

Postbiotics in Adults: A small randomized, controlled trial performed in healthy individuals (aged 20– 70 years) with a tendency toward constipation (n = 20) or frequent bowel movements (n = 19) found that the consumption for 3 weeks of *Lactobacillus gasseri*CP2305-fermented heat-treated milk compared with artificially acidified milk-based placebo beverage significantly improved Bristol stool scale scores ($p < 0.05$). Output and color tone were also improved, especially in subjects with a tendency toward constipation.

A large random control trial involving almost 2,200 healthy adults, aged between 20 and 59 years, found that the consumption for 12 weeks of heat-killed *Levilactobacillus brevis* KB290 in combination with βcarotene did not significantly reduce influenza incidence, fever incidence, or incidence/degree of clinical symptoms. However, the study product significantly reduced influenza incidence in the subjects aged < 40 years (n = 1,077).

Therapeutic Potential of Postbiotic Activity

Postbiotics will likely have pleiotropic effects on the human body. Postbiotics display pleiotropic properties Due to the induction of differentiation of T regulatory lymphocytes and synthesis of anti-inflammatory cytokines, postbiotics restore the imbalance between two major arms of immune system represented by Th1 and cytokines, postbiotics restore the imbalance between two major arms of immune system represented by Th1 and Th2 lymphocytes. The balance between Th1 and Th2 lymphocytes is vital for immune-regulation, and its disturbance causes various immune diseases, including atopic disorders. Antibacterial activity is probably mediated by postbiotics' impact on the molecular structure of enterocytes, which results in sealing the intestinal barrier.

Infection Prevention: Some postbiotics can have direct antimicrobial effects by sealing the intestinal barrier, competitively binding to receptors required by some pathogenic bacteria, changing the expression of host genes, or modulating the local environment. Indeed, combining postbiotics and probiotics effectively prevented rotavirus-associated diarrhoea in a preclinical model. Furthermore, randomized clinical trials conducted in a group of children aged 12–48 months showed that daily intake of products containing *L. paracasei* postbiotic led to a reduction in the incidence of diarrhea, acute gastroenteritis, pharyngitis, laryngitis, and tracheitis.

Antitumor Effects: As inflammation is inextricably linked to carcinogenesis, any substance that inhibits inflammation may also have anti-cancer potential. Indeed, the SCFA (Short Chain fatty acid) propionate (produced by *Propionibacterium freudenreichii*) was shown to selectively induce apoptosis in gastric cancer cells [83]. SCFAs also influence the regulation of oncogenes and suppressor genes through epigenetic modifications.

Antiatherosclerotic Effects: Postbiotics may also play a role in lipid metabolism and could reduce the risk of cardiovascular incidents. For example, the SCFA propionate can inhibit condensation of cholesterol precursors, leading to statin-like effects. *Kefiran* also has antiatherogenic properties, which may result from the reduction of inflammation, prevention of cholesterol accumulation in macrophages, and reduction of lipid concentration. Moreover, *Lactobacillus BLs (Bacterial lysate)* were found to reduce the levels of triglycerides and LDL cholesterol while increasing the level of beneficial HDL cholesterol in an obese mouse model.

Accelerated Wound Healing: Oxytocin is a multidirectional neuropeptide that plays a dominant role in stimulating uterine contractions during labor, modulating behavior, and creating an emotional bond. In addition, oxytocin can stimulate and accelerate wound healing. The administration of BLs obtained by sonication of *Lactobacillus reuteri* increased the number of oxytocin-producing cells in the hypothalamic periventricular nuclei, resulting in an elevated oxytocin concentration in blood serum in animal models. Comparable results were obtained by the administration of L. reuteri probiotics in both animal and human models, suggesting that the use of BLs is sufficient to achieve satisfactory results, with a significantly improved safety profile.

Autophagy: Autophagy is a homeostatic mechanism through which damaged organelles and proteins are cleaned out. This self-degradative process can act as a response to various stress stimuli, including nutrient stress.

Intracellular receptor NOD1 detects bacterial peptidoglycan and promotes autophagy and inflammatory signaling. Postbiotic-obtained *Lactobacillus fermentum* triggers autophagy in hepatic cells HepG2. Autophagy inductive potential of *L. fermentum* displayed protective effects in pharmacologically induced liver toxicity.

Clinical Significance

Production Technology: Probiotic synthesis and bacterial culture are somewhat unexpected processes. Postbiotics do not have the dose standardisation issue, which is a key concern in the production of probiotics. The advantages of postbiotics in terms of economics as comparison to probiotics, a longer shelf life, simpler storage and transport, and a decreased requirement to maintain a low temperature.

Safety of Use: It is important to note that postbiotics are preferable to probiotics in terms of safety when addressing the therapeutic advantages. The undeniable benefit of postbiotics is avoiding the issue of acquiring virulence factors and antibiotic resistance genes, which may occur in vivo when probiotics are utilised.

Functional foods: Functional foods can be defined as dietary items with additional health benefits besides their nutritional value. Physiologic profits of functional foods are provided by adding new (e.g., probiotics or postbiotics) or already present ingredients.

The favourable safety profile of postbiotics makes them rational candidates for use in functional foods. In addition, functional foods could be enriched with postbiotics to increase the host's immune activity.

Future Clinical Applications

Postbiotics play a vital role in the maturation of the immune system, affect barrier tightness and the intestinal ecosystem, and indirectly shape the structure of the microbiota. As such, postbiotics may be useful in treating or preventing many disease entities, including those for which effective causal therapy has not yet been found (e.g., Alzheimer's disease, inflammatory bowel disease, or multiple sclerosis). Indeed, clinical trials aimed at modifying the microbiota of patients suffering from the abovementioned diseases are currently underway, and the first results are promising.

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PRODUCTION TECHNOLOGY OF VERMICOMPOSTING FOR BETTER FOOD AND NUTRITION SECURITY

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INTODUCTION

The process of converting organic waste into worm castings is known as vermicomposting. Worm castings are extremely beneficial to soil fertility. Nitrogen, potassium, phosphorus, calcium, and magnesium is all present in the castings. Vermicompost is an excellent organic source of plant nutrients. It contains a high concentration of nitrogen (1.6%), phosphorus (0.54%), potassium (0.80%), calcium (0.44%), magnesium (0.15%), sulphur (0.45%), zinc (24.43ppm), iron (175.2ppm), vitamins, and growth hormone, all of which promote plant growth and microbial population increase. Unlike synthetic fertilisers, vermicompost reduces soil toxicity by buffering action, prevents soil degradation, and improves soil fertility.

Vermicomposting has been practised intermittently in India for more than three decades. The deteriorating soil conditions caused by chemical fertiliser use, as well as the harmful foods connected with pesticide use, have popularised organic farming, of which vermicompost is a key part. Many research institutes and non-governmental organisations (NGOs) have been investigating possible vermicompost production methods ranging from small backyard units to large-scale production units over the last decade. Farmers are also using it on an individual basis to meet their own demands. Commercial production, on the other hand, has yet to take off.

Farmers that adopt the practise can seek for government subsidies and financial aid to build up vermicomposting units. The National Mission for Sustainable Agriculture (NMSA), the National Food Security Mission (NFSM), the Mission for Integrated Development of Horticulture (MIDH), and RKVY - Remunerative Approaches for Agriculture and Allied Sector Rejuvenation (RKVY-RAFTAAR) are among these. For example, the NMSA covers half of the entire cost of establishing vermicomposting units, up to a maximum of INR 5000 (USD 70) per hectare and INR 10,000 (USD 140) per beneficiary.

Chhattisgarh State introduced a new initiative, Godhan Nyay Yojana, in July 2020, with an emphasis on rural livelihood and organic farming. Under the plan, the state government buys cattle manure from farmers for INR 2 per kg (3 cents/kg), which is gathered in cowsheds (Gothan Samiti) and used to create vermicompost by women self-help groups (SHGs). It is then sold at INR 8 per kg (12 cents/kg) through local cooperative groups. Furthermore, the plan has been combined with other larger schemes such as PKVY, RKVY, and MGNREGS. As of 20" August 2020, the plan had registered around 4,419 Gothans (livestock day-care centres) and acquired 63,500 tonnes of total cow manure.

Vermicompost is practiced in many states, particularly in the southern and central parts of the country. According to the NCOF, Assam, Maharashtra, Madhya Pradesh, and Karnataka are the states with the highest levels of production. Vermicompost is used to grow a variety of crops, although it is most cost-effective in high-value horticultural crops (vegetables, fruits, ornamental crops, spices, medicinal).

Human well-being - other than those that suggest human and environmental health advantages from lowering chemical use in food production, relevant literature on the health impact of vermicompost is rare. This research, however, did not delve farther into the matter. Vermicompost is seen as an alternative to industrial farming practises that utilise a lot of fertiliser and pesticides, although there hasn't been much research done on it.

MATERIALS REQUIRED FOR PREPARATION OF VERMICOMPOST

- ✓ Cow dung and litter
- ✓ Water
- ✓ wood dust
- ✓ Gunny bags.
- ✓ Earthworms
- ✓ plastic or cement tank
- ✓ Crop residues and leaves collected from fields
- ✓ Biodegradable wastes collected from fields and kitchen

PRODUCTION TECHNOLOGY OF VERMICOMPOST

- ✓ The vermibed layer is a 15 to 20 cm thick layer of moist saw dust laid at the bottom.
- ✓ Earthworms are put into the saw dust that the worms will call home.
- ✓ 150 earthworms can be placed into a 2m x 1m x 0.75m compost pit with a vermibed thickness of 15 to 20 cm.
- ✓ The vermibed is then covered with a handful of fresh cattle manure.
- ✓ The compost pit is subsequently layered to a depth of roughly 5 cm with dry leaves, hay/straw, or agricultural waste biomass.
- ✓ The pit is kept wet for the next 30 days by watering it as needed.
- ✓ The bed should not be either dry or wet.
- ✓ To cover the pit with an old jute (gunny) bag.
- ✓ Plastic bed sheets should be avoided since they trap heat.
- ✓ After the first 30 days, predigested moist organic waste of animal and/or plant origin from the kitchen or farm is placed over it to a thickness of around 5 cm. This should be done twice a week.
- ✓ All of these organic wastes can be turn over or mixed with a shovel on a regular basis.
- ✓ Watering should be done on a regular basis to maintain the pits moist.
- ✓ If the weather is extremely dry, it should be examined on a regular basis.

ADVANTAGES OF VERMICOMPOST

- ✓ Improves the physical structure of the soil.
- ✓ Increase water holding capacity of the soil
- ✓ Helps in germination, plant growth, and crop yield.
- ✓ Vermicompost contains all of the needed plant nutrients.
- ✓ It enhances soil structure, texture, aeration as well as preventing soil erosion.

- ✓ Vermicompost is rich in all essential plant nutrients.
- ✓ Vermicompost is positive impact on overall plant growth, encouraging the growth of new shoots and leaves, and improving the quality and shelf life of produce.
- ✓ Vermicompost is free flowing, easy to apply, handle, and store, and has no foul odour.
- ✓ Vermicompost contains helpful micro-flora such as fixers, P-solubilizers, cellulose degrading micro-flora, and so on, in addition to improving the soil environment.
- ✓ Vermicompost includes earthworm cocoons, increasing earthworm population and activity in the soil.
- ✓ It neutralizes the soil protection.
- ✓ It reduces nutrient losses and increases the use efficiency of chemical fertilizers.
- ✓ Vermicompost is free from diseases, harmful substances, weed seeds, and other contaminants.
- ✓ Vermicompost minimizes the incidence of pest and diseases.
- ✓ It enhances the decomposition of organic matter in soil.
- ✓ It contains valuable vitamins, enzymes and hormones such as auxins, gibberellins etc.

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REVOLUTIONIZING IRRIGATION WATER MANAGEMENT WITH EFFICIENT WIRELESS SENSOR NETWORKS

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ABSTRACT
Water scarcity and sustainable resource management have become pressing concerns in today's world. Agricultural practices, which account for a significant portion of water consumption, need innovative solutions to ensure efficient utilization of this precious resource. Wireless Sensor Networks (WSNs) have emerged as a game-changing technology in the realm of irrigation water management, enabling farmers to monitor and control their water usage with unprecedented precision. With the global water crisis intensifying, adopting such advanced technologies becomes essential for sustainable agriculture and environmental conservation. As technology continues to evolve, the potential for WSNs to transform irrigation practices holds great promise for a more water-efficient future. This article delves into the significance of WSNs in revolutionizing irrigation practices and highlights their benefits and applications.

INTRODUCTION
Agricultural irrigation plays a pivotal role in food production (Ringler *et al.,* 2022). Furthermore, climate change lead to rising temperatures, variation in seasonal rainfall, runoff, and evapotranspiration resulting in water flux imbalances and groundwater issues (Rank et al., 2016; 2023; Kumar and Rank, 2023). Parmar *et al.* (2016) and Pandya *et al.* (2019) also assessed rainfall variation and its correlation with *Kharif* groundnut productivity and found a strong positive correlation (0.79) between seasonal rainfall and groundnut yield with varying correlations at the monthly and weekly levels. However, traditional irrigation methods are often inefficient and lead to overuse of precious water resources, resulting in increased costs and environmental degradation (Yang *et al.,* 2023). Now a days new concept on canopy air temperature difference (CATD) and the crop water stress index (CWSI) based irrigation scheduling might achieving significantly higher crop yield, water savings, and water use efficiency compared to traditional border irrigation with implications for food and water security (Patel *et. al.,* 2014; 2023a). Furthermore, Patel *et al*., (2020; 2023b); Sadatiya *et al.,* (2019); Vadar *et al.,* (2016) found that high-discharge drip irrigation at 40% of the maximum allowable depletion of available soil water (ASW) resulted in significantly higher wheat grain yield, water use efficiency and water savings compared to traditional border irrigation practices which highlighting the suitability of this regime for optimizing wheat cultivation in clay loam soils. Furthermore, design and development of micro irrigation system depends on different weather condition and types of crops like operating pressure influenced discharge rates and throw radius, with wind drift and evaporation losses to recommend as a cost-effective and efficient choice for micro sprinkler irrigation (Patel, 2019; Patel

et al., 2021).Vadar *et al.,* (2019) observed that no-stress condition during development and flowering stages and irrigating at a 0.6 PE ratio during grain setting stage resulted in the highest grain yield, biological yield, and water use efficiency. That could be only possible through the development of efficient water management system (Modhavadia *et al*., 2023; Rathod *et al.,* 2023a; 2023b; Rank and Satasiya, 2022; Rank *et al.,* 2022a; 2022b; 2022c ;2023). As climate change exacerbates water scarcity in many regions, adopting intelligent water management practices becomes imperative. Wireless Sensor Networks (WSNs) have emerged as a game-changing technology in the realm of irrigation water management (Rank and Vishnu, 2019; 2021). WSNs consist of a multitude of small, battery-powered devices called sensors, which are spread across a designated area. These sensors are equipped with various types of detectors such as soil moisture, canopy temperature, humidity, temperature, light sensors, etc. The data collected by these sensors are wirelessly transmitted to a central node, which processes and analyzes the information. This real-time data allows farmers to make informed decisions about irrigation scheduling, optimizing water distribution and usage.

WSNs offer farmers granular insights into soil moisture levels, enabling them to water their fields only when necessary. This precision irrigation approach reduces water wastage and promotes healthier plant growth. Efficient water usage reduces the strain on local water resources and minimizes the negative environmental impact of excessive water extraction. By eliminating guesswork and allowing targeted irrigation, WSNs significantly reduce water consumption. This translates to lower operational costs for farmers. WSNs provide real-time data on soil conditions, weather patterns, and crop health. This allows farmers to respond promptly to changing conditions and implement necessary adjustments. WSNs enable remote control of irrigation systems, allowing farmers to manage water distribution without being physically present on the field.

Soil moisture sensors integrated into WSNs provide continuous updates on moisture levels, preventing both under- and over-irrigation. WSNs can be combined with weather forecasting data to predict rainfall and adjust irrigation schedules accordingly. WSNs can monitor factors such as temperature, humidity, and light intensity, helping farmers detect and address potential crop diseases or stress. WSNs can assess water quality by measuring factors like pH, EC and nutrient levels, ensuring that irrigation water is optimal for crop growth.

Despite their numerous benefits, WSNs for irrigation water management face challenges such as sensor cost, power usage, complicity, calibration, data security, and network reliability. Researchers are continuously working to address these issues and further enhance the technology's efficiency and usability.

Types of wireless sensor networks

The different types of wireless sensor networks commonly used in irrigation water management are as under

- Soil Moisture Sensors Network: These networks consist of soil moisture sensors strategically placed in the field. They measure the moisture content in the soil and transmit data to a central node. Farmers can use this information to determine the right amount of water to apply to the crops, preventing both underwatering and overwatering. Patel and Rank (2016) developed an empirical equation for estimating soil water content in clay loam soil by installing granular matrix sensors at different depths which measured accurately soil water content greater depths

- Weather and Environmental Sensors Network: These networks incorporate various sensors to monitor weather conditions and environmental factors such as temperature, humidity, wind speed, and solar radiation. This data helps farmers anticipate changes in weather patterns and adjust irrigation schedules accordingly.
- Crop Health Monitoring Network: This type of network focuses on monitoring the health of crops using sensors that measure parameters like leaf temperature, chlorophyll levels, and overall plant vitality. Detecting early signs of stress or disease allows farmers to take timely action.
- Automated Irrigation Control Network: Automated irrigation control networks combine various sensors to create a closed-loop system. These networks monitor soil moisture, weather forecasts, and other relevant data to automatically control irrigation systems, adjusting water delivery based on real-time conditions.
- Water Quality Monitoring Network: These networks are designed to monitor the quality of irrigation water, including parameters like pH, nutrient levels, and salinity. Maintaining proper water quality is crucial for crop health and growth.
- Remote Sensing and Satellite Network: Remote sensing technologies, including satellite imagery, can also be integrated with wireless sensor networks. These networks provide a broader perspective on large agricultural areas, helping farmers make decisions based on comprehensive data.
- Mesh Networks: Mesh networks are designed for robust communication in challenging environments. In these networks, sensors can communicate with each other in a multi-hop manner, creating redundant paths for data transmission. This ensures that even if one node fails, the data can still reach the central node.
- Mobile Sensor Networks: In some cases, mobile sensors on drones or autonomous vehicles can be employed to collect data from various parts of the field. These networks offer flexibility in data collection and monitoring, especially in larger agricultural areas.
- Energy-Harvesting Sensor Networks: Energy-efficient sensors that can harvest energy from their environment (solar, wind, vibrations, etc.) are being developed. These sensors eliminate or reduce the need for frequent battery replacement, enhancing the sustainability of the network.
- Decentralized Sensor Networks: In decentralized networks, sensors communicate directly with nearby sensors without relying on a central node. This can be useful in scenarios where real-time decisions need to be made at the local level, reducing latency and improving responsiveness.

Each type of wireless sensor network has its own advantages and applications, and the choice of network type depends on factors like the size of the agricultural area, the type of crops being grown, the specific monitoring needs, and available resources.

Wireless Communication Technologies for Irrigation Water Management

There are several wireless communication technologies that play a crucial role in enabling efficient irrigation water management through wireless sensor networks. different wireless protocols and standards that can be used in irrigation water management

- Wi-Fi (Wireless Fidelity): Wi-Fi technology allows sensors and control devices to connect to a local network and the internet. It is suitable for relatively short-range communication within a farm or field. Wi-Fi provides high data rates and can handle a large number of devices simultaneously, making it useful for transmitting real-time sensor data and receiving remote commands.Wi-Fi (2.4 GHz or 5 GHz) typically has a range of around 30 to 100 meters indoors and up to several hundred meters outdoors, depending on the number of obstacles and signal interference. Wi-Fi infrastructure costs include the price of Wi-Fi access points, routers, and network setup. The cost can range from INR 1,000 to 5,000+, depending on the coverage area and the number of devices to be connected.
- Zigbee: Zigbee is a low-power, short-range wireless communication protocol designed for applications that require low data rates and long battery life. It is ideal for connecting sensors and control devices within a limited area, such as a field. Zigbee's mesh networking capability allows devices to relay data over multiple hops, ensuring reliable communication over longer distances. The range of Zigbee (2.4 GHz or 900 MHz) varies depending on the power output and the presence of obstacles. It can range from 10 to 100 meters for indoor applications and up to 500 meters or more in outdoor line-of-sight scenarios. These devices are relatively affordable, and the cost depends on the number of sensors and control devices needed. Zigbee's low-power nature can lead to cost savings in terms of battery life and maintenance. The cost of Zigbee sensors and devices ranges from INR 500 to 2,000 per unit and that of Zigbee gateways ranging from INR 3,000 to 10,000+.
- LoRa (Long Range): LoRa is a long-range, low-power wireless communication technology that excels in covering large areas with minimal power consumption. It is well-suited for remote and rural locations where sensor nodes need to communicate over kilometers. LoRa WAN, a protocol built on LoRa technology, enables secure and efficient communication for Internet of Things (IoT) applications. LoRa technology can provide communication ranges of several kilometers in rural and suburban areas, and even more in open rural environments. The exact range depends on factors such as frequency, power output, and antenna design. LoRa devices can be cost-effective, especially for large areas requiring wide coverage. Costs include LoRa gateways (INR 10,000 to 20,000+) and end devices (INR 1,000 to 5,000 per unit), and the overall cost can vary depending on the network's size.
- RFID (Radio Frequency Identification): RFID technology utilizes radio frequency signals to identify and track objects equipped with RFID tags. In irrigation management, RFID can be used to monitor the movement of equipment, such as pumps and valves, as well as track the flow of water through pipelines. It can also help ensure that irrigation equipment is properly maintained and utilized. RFID's communication range can vary from a few centimeters to several meters, depending on the frequency, power, and type of RFID technology used. RFID costs depend on the type of RFID technology used (active or passive), the number of tags, and the read range required. Passive RFID tags tend to be more affordable than active ones. Passive RFID costs INR 10 to 50 per tag, while active RFID costs INR 500 to 2,000+ per tag.
- Sub-GHz Radio Communication: Sub-GHz (sub-gigahertz) radio communication technologies operate in frequency bands below 1 GHz. These technologies provide longer communication ranges and better penetration through obstacles compared to higher-frequency options like Wi-Fi or Bluetooth. Sub-GHz communication can be useful for

connecting sensors in challenging environments or over longer distances.Sub-GHz technologies can achieve ranges of several hundred meters to several kilometers, depending on the power output and environmental conditions. Sub-GHz communication costs include devices (1,000 to 5,000+ per unit) and infrastructure components, and the overall cost depends on the network's complexity.

- NB-IoT (Narrowband IoT): NB-IoT is a cellular-based technology that provides low-power, wide-area coverage for IoT applications. It is suitable for transmitting data from sensors distributed across a field to a central monitoring station. NB-IoT offers good coverage in rural areas and leverages existing cellular infrastructure. NB-IoT's range can reach up to several kilometers in good signal conditions. It's designed for wide-area coverage and can penetrate buildings and obstacles effectively.
- Cellular Narrowband IoT (cNB-IoT): cNB-IoT is an evolution of the NB-IoT standard that utilizes the existing cellular infrastructure to provide efficient IoT connectivity. It allows for better coverage in rural areas and supports applications requiring reliable, low-power communication over long distances. cNB-IoT's range is similar to standard NB-IoT, offering coverage of several kilometers in favorable conditions. cNB-IoTs like NB-IoT and LTE-M can involve higher costs due to subscription fees for cellular connectivity. The costs include SIM cards, data plans, and potentially higher-priced devices. It includes cost of cellular modules (INR 1,000 to 5,000+) and cellular data plan subscription fees which is varying based on usage.
- Ultra-Wideband (UWB): UWB technology uses low-energy, short-duration pulses to transmit data over a wide spectrum of frequencies. It is known for its high-precision location and positioning capabilities. In irrigation management, It can assist in accurately tracking the location of assets or equipment within a field. UWB can achieve very accurate positioning within a range of a few centimeters to a few meters, depending on the specific UWB technology used. This technology tends to be more specialized and can have higher costs (INR 20,000 to 50,000+ per unit) due to the accuracy and positioning capabilities it offers.
- LTE-M (Long-Term Evolution for Machines):LTE-M is cellular-based technology optimized for IoT applications. It offers higher data rates compared to NB-IoT and can handle more bandwidth-intensive applications. LTE-M is suitable for scenarios where real-time data and control are important, such as remote irrigation control. It offers similar range characteristics to NB-IoT, with coverage extending several kilometers and good building penetration.
- Bluetooth Low Energy (BLE):BLE is a short-range wireless technology designed for low-power, small-data applications. It's commonly used for connecting sensors and devices to smartphones or tablets. BLE can be employed for localized data collection and configuration of sensors in irrigation systems. BLE communication typically has a range of 10 to 100 meters, depending on signal strength and interference. These devices are relatively inexpensive (INR 500 to 2,000 per unit), making them a cost-effective option for short-range communication. The costs mainly depend on the number of devices and the application's complexity.
- GSM (Global System for Mobile Communications): GSM is a widely used cellular technology that provides voice and data services. It can be used for basic monitoring and

control applications in irrigation systems, especially in areas with good cellular coverage. While it might not be as efficient for IoT applications as more specialized technologies like NB-IoT and LTE-M, GSM can still serve as a cost-effective option.GSM's range can cover several kilometers, with urban areas generally having better coverage than rural or remote regions. GSM costs include cellular devices and subscription fees for data plans. While devices might be relatively affordable, ongoing data charges can add up over time.

- 5G:The next-generation cellular technology, 5G, promises significantly higher data rates, low latency, and improved connectivity. While its implementation in agriculture is still evolving, 5G has the potential to enhance real-time data collection, remote control, and advanced analytics in irrigation management.
- Satellite Communication: Satellite communication involves using satellites in orbit to relay data between remote sensors and a central monitoring station. This technology is particularly useful for large agricultural areas where traditional wireless networks might not have coverage. Satellite communication provides wide-area coverage, making it suitable for monitoring fields in remote or inaccessible locations. Satellite communication offers global coverage, making it suitable for remote areas. However, the exact range isn't measured in meters as with terrestrial technologies; it depends on the satellite network's coverage. Satellite communication can have higher upfront costs (INR 5,000 to 20,000+) due to the satellite modem and associated equipment. Additionally, subscription fees for satellite services contribute to on-going costs.
- Wireless HART (Wireless Highway Addressable Remote Transducer): Wireless HART is a wireless communication standard specifically designed for industrial automation and control applications. It is based on the HART protocol and enables communication between sensors and control devices. Wireless HART can be utilized in irrigation systems to gather data from sensors and remotely control valves and pumps.Wireless HART communication ranges are similar to Zigbee, with effective ranges of tens to hundreds of meters. These devices are designed for industrial applications and can have moderate to high costs. The cost includes devices, gateways (INR 2,000 to 10,000+ per unit), and setup.
- Infrared (IR) Communication: Infrared communication uses light signals in the infrared spectrum to transmit data between devices. While not as common as other wireless technologies, IR communication can be employed for short-range communication in localized irrigation setups, such as greenhouses. IR communication is limited to line-of-sight and has a range of a few meters to tens of meters, depending on the strength of the IR signals. IR communication devices (INR 100 to 500+ per unit) are generally affordable, but the limited range and line-of-sight requirement can influence the system's overall cost.

**Please note that these costs are approximate and intended for reference purposes. Prices can vary based on multiple factors, and it's recommended to research local suppliers and obtain updated quotes to get a more accurate understanding of the costs associated with implementing a wireless communication system for irrigation water management.*

SUMMARY

Each of these technologies offers unique advantages and is suited for specific use cases in irrigation water management. The choice of technology should align with the specific requirements of the irrigation system, such as communication range, data rate, power efficiency and environmental conditions. It is important to note that the cost considerations also extend beyond the technology itself to factors like installation, maintenance, data management, and potential integration with existing systems. When assessing the cost of implementing a wireless communication technology for irrigation water management, it is recommended to conduct a thorough analysis that takes into account the specific needs and application. In irrigation water management, the selected technology should enable reliable and timely transmission of sensor data, allowing farmers to make informed decisions to optimize water usage and enhance crop yield.

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REVOLUTIONIZING AGRICULTURE: THE CURRENT LANDSCAPE AND FUTURE PROSPECTS OF ROBOTICS IN FARMING

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Abstract

The surge in robotics for agricultural applications is reshaping farming practices by addressing complexities and labor shortages. This article delves into the evolution of robotics in agriculture, emphasizing the need for adaptable and durable robots to navigate the unstructured nature of farming environments. Autonomous operations like cultivation, inspection, and harvesting have become commonplace, alleviating labor-intensive tasks while ensuring precision and efficiency. Precision agriculture, reliant on electronic information, is increasingly intertwined with robotics, enhancing measurement, administration, and operations. From dexterous robotic hands for crop handling to sensor-equipped drones for precision farming, robotics is transforming agriculture, promising increased productivity and sustainable practices.

Introduction

In recent years, the use of robotics for agricultural purposes has increased dramatically, after addressing some of the difficulties and complexity this industry. Agriculture may be the sector that is amenable to the application of automation. Agriculture presents a variety of difficulties for robots. On one hand, agricultural situations are less structured and regulated than industrial ones. The complicated duties of agriculture, on the other hand, are occasionally unable to be broken down into simple actions, whereas industrial trial procedures can be developed by components to apply certain robots to specific activities. The aforementioned factors necessitate more adaptable and durable robots for agricultural applications (Roldan *et al.,* 2018). To solve the workforce shortage in agriculture, automation in agriculture has recently become popular. Autonomous agricultural operations like cultivation, inspection, spraying, trimming, and harvesting are now commonplace. Any component of a machine or piece of equipment intended to eliminate manual labour in agriculture is referred to as automated agriculture. The work of agricultural automation is primarily concentrated on autonomous vehicle applications, such as robot or tractor, where it is used to reduce the difficult, dangerous, risky, and prolonged labour conditions experienced by farmers while simultaneously offering a precise and effective operation and control system (Mahmud *et al.,* 2020). Agricultural robots play a unique role in the development of digital agriculture and offer a variety of benefits to farming productivity. Since the first industrial robots were developed in the 1950s, both science and business have started to pay attention to robotics (Cheng *et al.,* 2023). A robotic arm with its components, a navigation system, a vision system, a control system, communication components, as well as of course, a computer, a safety system, a remote assistance/tele-robotics method, an edge/cloud-AI adaptive learning system, as well as a farmer-friendly outstanding simple interface system—are all general components of an agricultural robot (Fountas *et al.,* 2020).

Role of Robotics in Precision Agriculture

A form of leadership that uses electronic information along with additional technologies to collect, process, and analyse spatial and temporal info in order to direct targeted actions that improve the effectiveness, efficacy, and long-term viability of agricultural operations is known as precision agriculture, or PA for short. According to this concept, the use of robots in farming positions can further PA by utilizing high-tech tools for accurate measurement, administration, and operations (Lytridis *et al.,* 2021).

Precision farming is increasingly dependent on robots. These automated assistants are made to quickly and accurately undertake monotonous duties, freeing farmers and farmworkers to concentrate on more difficult tasks. Precision agricultural robots with dexterous robotic hands and cutting-edge sensors can plant, weed, trim, and harvest crops. This improves productivity, decreases waste, and lessens the need for potentially dangerous pesticides and herbicides (Zerun *et al.,* 2022). Robotics must work hard in the field of forestry. All instruments must operate in a hostile environment. The obstacle to the development of more advanced autonomous and teleoperated functions and operations in forestry machinery is the accurate sensing and measurement of crucial objects and condition parameters in real time (Billingsley *et al.,* 2008).

As the agricultural automation process begins with soil preparation, sowing, plant growth, harvest, and then post-harvest management, it is important to complete these tasks successfully to produce satisfactory yields. These factors also control the environment in order to maximize benefits. The circumstances for using pesticides have improved with the development of new technologies. Since pesticides are expensive and dangerous for the environment and human health, care must be taken to ensure that they are used properly (Kulkarni *et al.,* 2020).

The autonomous robot has the potential to work in precision agriculture with ongoing monitoring using various sensing technologies, which provides various crop status parameters for better crop remedies, such as micronutrient accessibility, biomass index, condition of pest as well as disease, water stress, and thermal stress. Growing global population and dwindling numbers of agricultural laborers put pressure on the farming system. The use of agricultural robots could reduce the labour shortage and boost productivity. A platform known as an agricultural robot can be created by combining several technologies such as computer vision, picture processing, and mechatronics. This platform can provide the best option for automated agricultural operations (Kushwaha *et al.,* 2016).

Robotics in Agriculture in Future

Autonomous agriculture raises legal, ethical, and social issues, and the history of agricultural innovation is rife with slow adoption and failure. Depending on how technologies are developed and put into use, autonomous agriculture may present a number of opportunities, risks, and repercussions (Rose *et al.,* 2021). The usage of fleets for robots, in which numerous specialized robots work together to complete one or more agricultural tasks, is a development in the use of automation equipment in agriculture (Emmi *et al.,* 2014).

Robotics will be used in a variety of field tasks using drones to address crop management in terms of mobility, localisation, capture, targeting, and moving to the next target. The same procedure can be utilized for fruit harvesting, weeding, and spraying. However, robotic technology appears to be in its infancy, and it is necessary to use these technologies since labour is scarce, their wages are costly, and to assure longevity in field operations (Khadatkar *et al.,* 2022).

Numerous legal issues will surface as robots gain an ever-increasing capacity for autonomous operation. One unsettling potential is that as time goes on, robots may surpass humans at critical activities, and as a result, governments will face ethical and political pressure to forbid humans from carrying out those tasks. Legislators and policymakers would be wise to address these issues as soon as possible since they have the ability to prevent the adoption of highly autonomous robots until they are remedied (Sparrow *and Howard*, 2021).

Conclusion

The integration of robotics in agriculture marks a paradigm shift, offering solutions to labor shortages and enhancing precision farming practices. Autonomous robots, equipped with advanced sensors and sophisticated technologies, address the challenges of soil preparation, sowing, plant growth, and harvest. Precision agriculture, empowered by robotics, not only improves efficiency but also reduces waste and minimizes reliance on hazardous pesticides. As robotics evolves, future applications include collaborative fleets of specialized robots and drone-assisted tasks. However, legal, ethical, and social implications require careful consideration to ensure responsible adoption. Despite challenges, the future of agriculture lies in embracing robotics for increased productivity, resource optimization, and sustainable farming practices.

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ROLE OF MACHINE LEARNING IN AUTOMATED DISEASE IDENTIFICATION IN CROPS

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Abstract

Population growth over the last few decades has resulted in a greater demand for agricultural products. In this regard, crop yields must be enhanced. It is difficult to increase crop productivity due to diseases caused by fungi, bacteria and viruses. This can be prevented by developing effective methods of automatic detection and diagnosis of diseases on cultivated crops. Machine Learning (ML) techniques are capable of performing such automation in the plant disease detection process. This article presents a brief introduction to Machine Learning techniques used in the agricultural domain for automated detection, diagnosis and forecasting of diseases.

Introduction

Agricultural success depends on a delicate balance between human effort and nature, and the silent threat of plant diseases often looms over a successful harvest. The implications of these unseen threats reverberate far beyond the fields, impacting global food security and the livelihoods of farmers. Early detection becomes not just a necessity but a linchpin in preserving crop yields, ensuring a sustainable food supply, and alleviating economic burdens that echo through agricultural communities (Rumpf *et al.*, 2010).

Traditionally, the guardians against these agricultural adversaries have been the vigilant eyes of farmers, relying on visual inspection and the laborious processes of laboratory tests. However, these methods, while time-honored, come with inherent limitations. The subjectivity of visual inspections, coupled with the resource-intensive nature of laboratory analyses, has propelled agriculture into a new era—one marked by innovation and technology (Sharma *et al.*, 2022).

At the forefront of this agricultural revolution stands machine learning, a powerful ally in the quest for more efficient, accurate, and timely disease identification (Ahmed and Yadav, 2023). A thorough understanding of evolving landscape of agriculture and exploring how machine learning not only complements but transforms traditional practices is of paramount importance. As we delve into the nuances of visual symptoms, data intricacies, and the training processes of machine learning models, the promise of a resilient and sustainable agricultural future unfolds.

The Imperative of Early Disease Detection

The stakes in agriculture are high, and the impact of plant diseases on crop yields can be devastating. Early disease detection is not merely a matter of convenience; it is a crucial factor in mitigating economic losses and maintaining the delicate balance in the global food supply chain. The ability to identify and address plant diseases at their inception can significantly impact the livelihoods of farmers and contribute to global food security.The modernization of agriculture has witnessed an unprecedented influx of technology, transforming traditional farming practices into sophisticated, data-driven processes. From automated machinery to precision farming, technology has played an increasingly integral role in enhancing productivity and sustainability. Amid this technological renaissance, machine learning has emerged as a powerful ally, offering solutions to challenges that were once considered insurmountable (Panchal *et al.*, 2019).

Table 1. Automated Disease Identification: Traditional vs. Machine Learning Approach

Criteria	Traditional Methods	Machine Learning Approach
Accuracy	Subjective; varies with expertise	High, with continuous improvement over time
Speed	Time-consuming	Swift identification, real-time alerts
Cost	Variable; can be expensive	Efficient use of resources, reduced need for extensive laboratory tests
Flexibility	Limited adaptability to diverse environments	Adaptable to various crops and environmental conditions
Sustainability	Reliance on pesticides, may not be environmentally friendly	Promotes sustainable farming practices, reduced pesticide use
Scalability	Limited scalability, dependent on human resources	Scalable to large agricultural areas with automated systems
Data Requirements	Limited data utilization	Requires large, diverse datasets for training
Interpretability	Generally interpretable	Ongoing efforts to improve interpretability
Ethical Considerations	N/A	Requires responsible data handling and model use

Visual Symptoms and Machine Learning

A cornerstone in the fight against plant diseases lies in understanding and deciphering visual symptoms. Recognizing the importance of these visual cues, machine learning algorithms have been harnessed to not only identify but interpret these symptoms with remarkable accuracy (Saleem *et al.*, 2019). The combination of visual symptomatology and machine learning marks a significant stride towards more precise and timely disease detection in crops.

Leaf Discoloration, Lesions, and Patterns: Leaf discoloration, often a telltale sign of stress or disease, might present as subtle changes in hue or stark alterations in color. Lesions, akin to scars on a plant's canvas, speak volumes about encounters with pathogens or environmental stressors. Intricate patterns, seemingly random to the human eye, unfold as a code that, when deciphered, reveals the intricate story of a plant's struggle for survival.

Machine learning algorithms learn not just to identify the presence of visual symptoms but to discern the nuances within them. They become adept at distinguishing between benign variations and indicators of impending diseases. Through extensive training on diverse datasets, these algorithms unravel the complexities of visual symptomatology, akin to mastering a language spoken in the subtlest of visual cues (Vasavi *et al.*, 2022).

Harnessed Accuracy through Machine Learning: The significance lies not just in the identification of symptoms but in the profound leap towards interpretation. Machine learning algorithms, equipped with the knowledge distilled from vast datasets, demonstrate an extraordinary capacity to interpret visual symptoms with remarkable accuracy. It's not merely a binary acknowledgment of disease presence; it's an understanding of the specific nature and severity of the crop disease.

Data Collection and Preprocessing

The efficacy of machine learning models hinges on the quality and diversity of the data used for training. High-quality, labeled datasets containing a spectrum of images capturing healthy and diseased crops are the building blocks. However, the path from raw data to a robust model involves navigating challenges in data preprocessing (Sharma *et al.,* 2022). Techniques such as normalization, augmentation, and cleaning are employed to ensure that the data fed into the models is optimized for accurate disease identification.

Training Machine Learning Models

In the realm of machine learning dedicated to disease identification in crops, a methodical approach is employed to refine algorithms for optimal performance. This process, crucial to the effectiveness of the models, involves a careful selection of appropriate algorithms, feature extraction, model optimization, and validation through real-world case studies (Varshney *et al*., 2021).

1. Selection of Appropriate Algorithms: The initial step in this meticulous process is the selection of suitable algorithms tailored to the task of disease identification. This decision is contingent upon factors such as the nature of the visual symptoms, dataset size, and desired model interpretability. Algorithms range from classical decision trees to more complex neural networks, each chosen with a specific purpose in mind.

2. Feature Extraction: Following algorithm selection, the focus shifts to feature extraction, a critical phase where the algorithms learn to recognize and decipher distinctive patterns within visual symptoms. Features, representing the essential elements for predictions, could include color gradients, texture variations, or structural characteristics in the context of plant pathology. This step requires a deep understanding of the visual cues indicative of specific diseases.

3. Model Optimization: The process proceeds with model optimization, involving the fine-tuning of parameters to enhance performance. Achieving a delicate equilibrium between model accuracy and generalizability is a nuanced task, demanding iterative adjustments. This optimization phase transforms algorithms from theoretical constructs into refined instruments capable of accurate disease identification.

Real-World Case Studies

Cross-Crop Identification: One of the remarkable facets of these trained models is their ability to transcend crop-specific boundaries. The algorithms, having learned the universal language of visual symptoms, exhibit a virtuoso performance in cross-crop identification. A model trained on one crop, armed with the knowledge of disease patterns, can seamlessly adapt to identify diseases in a completely different crop—demonstrating a versatility that augments their real-world applicability (Orchi *et al*., 2021).

Continuous Learning and Adaptation: The training process is not a one-time event but a continuous cycle of learning and adaptation. As new data emerges and diseases evolve, the models must be updated to stay relevant (Wani *et al*., 2022). This perpetual motion ensures that the symphony of machine learning in disease identification remains attuned to the ever-changing dynamics of agricultural landscapes.

Real-world Impact: The integration of machine learning in agriculture has already yielded promising results. Automated disease identification systems provide farmers with timely alerts, allowing for swift intervention and targeted treatments. This not only preserves crop yields but also reduces the need for excessive pesticide use, promoting sustainable farming practices. The real-world impact is tangible, with increased efficiency in disease management translating to economic benefits for farmers.

Challenges and Future Prospects

While machine learning holds tremendous promise, challenges such as the need for large, diverse datasets and ethical considerations must be addressed. Ongoing research aims to enhance the interpretability of machine learning models and develop more robust systems that can adapt to diverse agricultural environments (Table 2). The future holds exciting prospects for the continued integration of machine learning in agriculture, promising a new era of precision farming (Wani *et al*., 2021).

Table 2. Challenges and Future Prospects in Machine Learning for Precision Agriculture

Challenges and Considerations	Elaboration and Solutions
Data Challenges	Large, diverse datasets are vital. Collaborative efforts for comprehensive data collection and sharing are essential.
Ethical Considerations	Prioritize data privacy and responsible model use. Ensure transparency in model development for stakeholder trust.
Model Interpretability	Ongoing research focuses on enhancing interpretability. Develop techniques for transparent and understandable model decisions.
Robustness in Diverse Environments	Ensure machine learning models are robust and adaptable to diverse agricultural conditions, soil types, and cropping practices.
Integration of Emerging Technologies	Seamless integration with sensor technologies, IoT devices, and other innovations amplifies the impact for comprehensive solutions.
Continuous Research and Collaboration	Collaborative efforts between academia, industry, and practitioners drive innovation and address emerging challenges.

Conclusion

As we stand on the cusp of a technological revolution in agriculture, the marriage of machine learning and plant pathology presents a beacon of hope. The ability to swiftly and accurately identify diseases in crops not only safeguards the livelihoods of farmers but also contributes to global food security. The journey towards automated disease identification is a testament to the relentless pursuit of innovation in the face of agricultural challenges, marking a transformative chapter in the history of farming. In retrospect, the rise of machine learning in agriculture symbolizes a shift from traditional, labor-intensive methods to a future where data-driven insights empower farmers with unprecedented capabilities. Visual symptoms, once deciphered by keen human eyes, are now interpreted with precision by algorithms, offering a level of accuracy and efficiency previously unimaginable.

Sustainable farming practices, facilitated by reduced pesticide usage and increased efficiency in disease management, emerge as beacons of environmental responsibility. However, this journey is not without challenges. The need for vast, diverse datasets and ethical considerations in data handling underscores the responsibility that accompanies innovation. As we navigate these challenges, ongoing research strives to make machine learning models more interpretable and adaptable to the nuances of diverse agricultural environments and in the face of these challenges, the future holds exciting prospects for agriculture.

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REVOLUTIONIZING NUTRITION: THE RISE OF NANO-FORTIFICATION IN SPECIALIZED DIETS

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Abstract

Nano-fortification is a revolutionary technique in the nutraceutical industry that involves the application of nanotechnology to increase the nutritional value of food products. With this novel approach, the bioavailability and effectiveness of meals are enhanced by adding nanoparticles, which can have a size range of 1 to 100 nano-meters. The main goal of nano-fortification is to meet dietary requirements and correct nutritional deficiencies, providing a targeted remedy for people with different health issues. Nano-fortification enables exact nutritional level change without compromising flavour or texture, making food items suitable for individuals with chronic conditions, athletes, or the elderly. Foods supplemented with nanoparticles have higher bioavailability of nutrients, which improves absorption in the digestive tract. Nano-fortification proves to be a promising technology, but to solve safety issues and create moral standards for the appropriate use of nano-fortification in the food business; more research and cooperation are needed.

Keywords: Nano-fortification, Bioavailability, Macronutrient, Malnutrition, Nano-technology

Introduction

From the past few decades, nanotechnology has gained popularity as a promising technology that has transformed the food industry. This nanotechnology creates and uses materials with unique qualities by working with atoms, molecules, or macromolecules that are between one to one hundred nano-meters in size. The produced nano-materials have an internal structure or one or more outward dimensions on a scale ranging from (1 – 100) nm, which made it possible to observe and work with the matter at the nanoscale. Due to their increased surface-to-volume ratio and additional unique physiochemical characteristics, such as those related to thermodynamic properties, toxicity, colour, diffusivity, strength, optical, solubility and magnetic properties etc. It is found that these substances possess distinctive equalities that distinguish them from their macro scale. Because of the new industrial revolution that nanotechnology has brought about, both developed and emerging nations want to increase their investments in this field. Thus, the invention and deployment of structures, materials, or systems with novel qualities in a variety of fields, including food, medicine, and agriculture, is made possible by the vast array of potential that nanotechnology presents.

The use of nano-technological techniques in fortification has several advantages, such as increased stability, prolonged release, improved organoleptic qualities, enhanced stability, and enhanced bioavailability because of improved release profile dynamics. For fortification, a variety of nano-materials are used, including carbon, inorganic, organic, and composites. Of these, organic nano-materials are used most frequently because they are lipid-based (liposomes, solid lipid nanoparticles, nanostructured lipid complex, nano-emulsion, and cubosomes), biopolymeric, polysaccharide, and protein nano-materials.

What role does nano-fortification play?

The World Health Organization (WHO) and Food and the Agriculture Organization (FAO) jointly lead Codex Alimentarius, which defines "fortification" as the deliberate addition of vital micronutrients, such as vitamins, minerals, and amino acids, to enhance the nutritional value of food for a population. It may be strictly commercial or it may be a public health strategy. Reaching a sizable population may be advantageous for this approach. The need for nano-fortification increased due to the conventional method sinability to produce flavor profiles, good stability, and high bioavailability, which led to a shift in fortification methods to nano-fortification. The process of "nano-fortification" encapsulates nutrients using nano-materials because of their small size, which contributes to their high loading capacity, high polydispersity index, and strong encapsulation efficiency.

The appropriate agency should evaluate and approve a substance's physical, chemical, and safety characteristics before adding it to the nano-fortification program. The following are the general requirements for nano-fortification: lack of nutrients, frequent intake by the intended audience, food carrier, non-toxicity by increased consumption, tolerable alteration in organoleptic qualities, chemical stability, bioavailability, homogeneity, central control, and scalability.

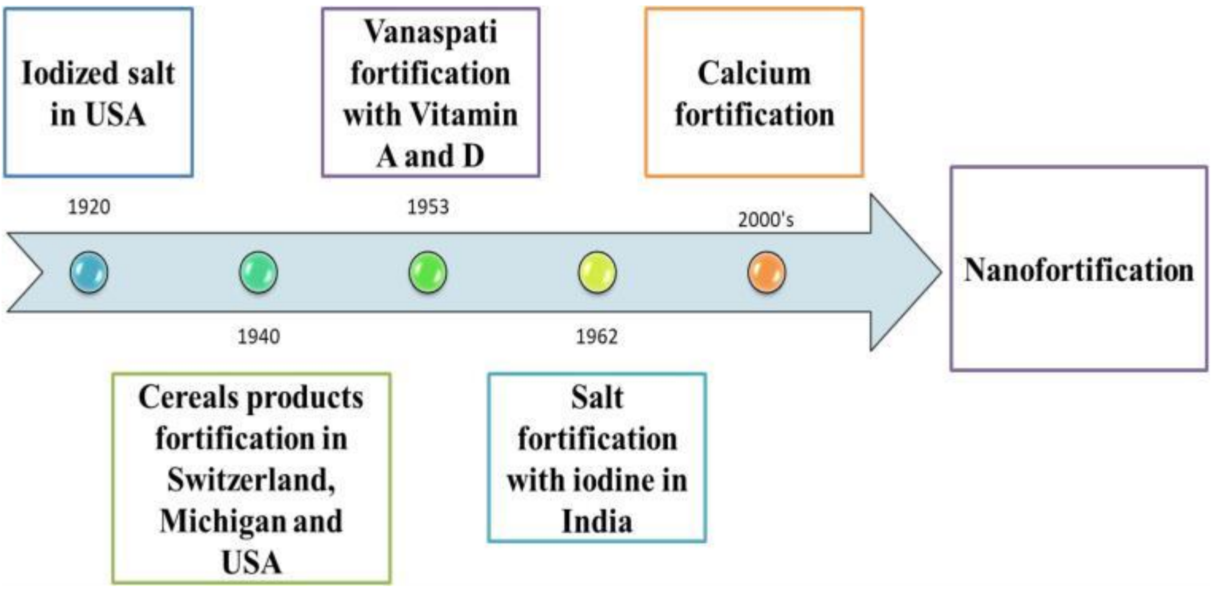

Fig. 1. Timeline of nano-fortification process (Source – Rathee *et al.,* 2022)

Focusing on Specific Conditions:

The potential of nano-fortification to produce personalized nanofood products that are suited to the nutritional needs of people dealing with certain health issues is one of its most intriguing features. Nano-fortified foods are precisely engineered to provide optimal nutrition, whether they are being used to support individuals with chronic illnesses, solve nutritional gaps in senior populations, or meet the dietary needs of sports

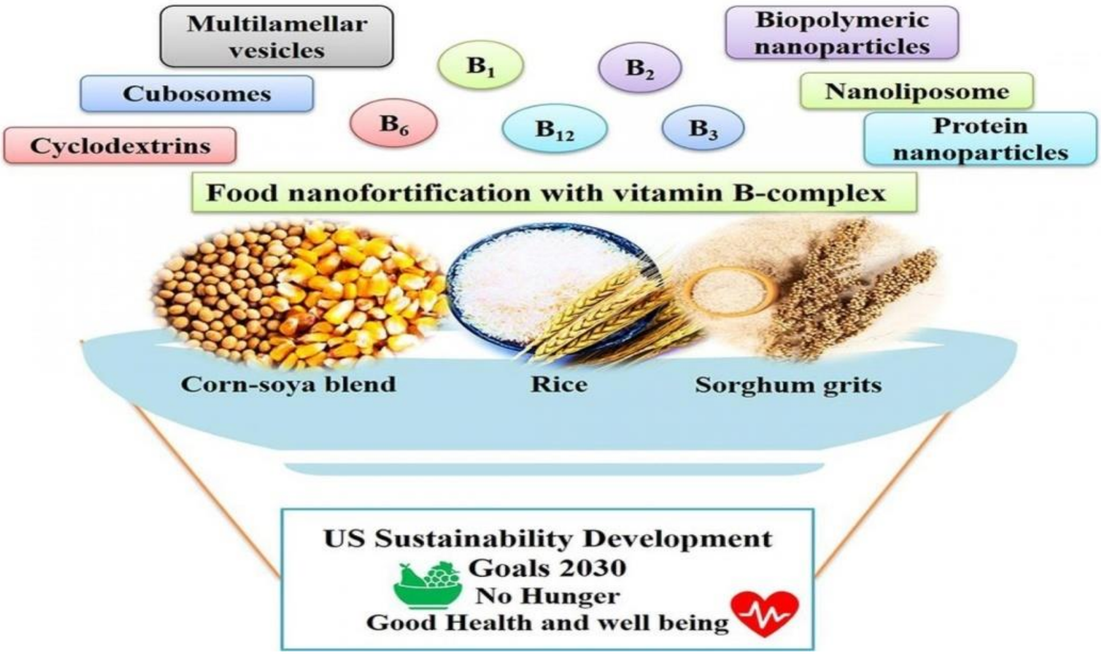

Fig.2. Graphical presentation of Food nano-fortification with vitamin B-complex
(Source- Ratheee*et al.,* 2022)

4. Advantages of Nano-fortification:

a) **Improved Bioavailability:** By improving nutritional absorption in the digestive tract, nanoparticles help the body get the most out of the fortified food.

b) **Customization for Particular Conditions:**By precisely adjusting nutritional levels, nano-fortification guarantees that people with special dietary needs get the right ratio of vitamins, minerals, and other necessary components.

c) **Enhanced Texture and Taste:**Nano-fortification has a negligible effect on the sensory qualities of the products, which makes them more pleasant to customers than traditional fortification techniques, which may change the taste and texture of food.

d) **Increased Stability:** Foods enriched with nanoparticles often have a longer shelf life. This guarantees that people have access to nutrient-dense foods for a longer amount of time while also reducing food waste**.**

e) **Food Production and Agriculture: -**Targeted pesticide distribution using nanofortified formulations can lessen environmental impact and increase agricultural pest management effectiveness.

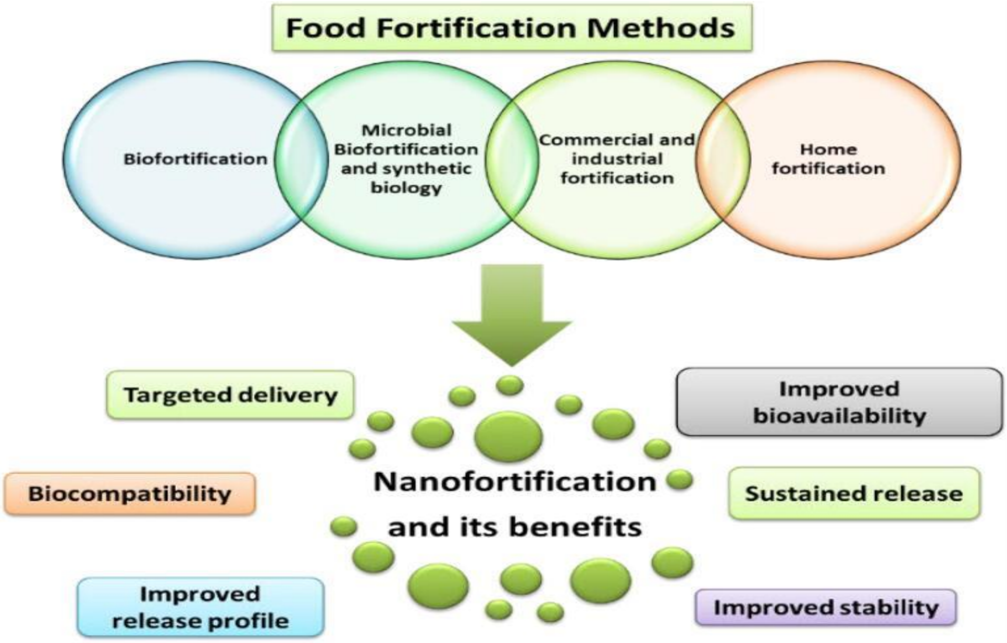

Fig. 3. An illustration of the trending fortification methods and nano-fortification
(Source- Rathee *et al.,* 2022)

5. Application of Nano-fortified Products:

a) **Nano-fortified Sports supplements:-**Energy bars and drinks with nanotechnology can help athletes recover more quickly and perform better by supplying the right amounts of nutrients.

b) **Nano-Infused Elderly Nutrition:**- Age-related nutritional deficits are addressed by specially created nano foods for the elderly, which promote bone health, cognitive function, and general vigour.

c) **Precision Nutrition for Chronic Illnesses: -** Nanofood items that provide specific nutrients to meet health needs can be helpful for people managing long-term diseases like diabetes or cardiovascular disease.

d) **Safer Techniques for Processing and Cooking: -** Increasing the effectiveness of cooking procedures, refining processed foods' texture, and maintaining the nutritional value when cooking.

e) **Enrichment of Major Foods:-**Adding nano-fortified components to common foods including wheat, rice and maize. Strengthening frequently consumed foods to address nutritional shortages and contribute to the greater fight against malnutrition.

6.Challenges and Future Prospects:-

Despite the enormous potential of nano-fortification, safety issues, ethical issues, and legal frameworks must be taken into account. To ensure that nanotechnology is developed and used responsibly in the food business, researchers and policymakers must collaborate. As nano-fortification develops further, it has the potential to significantly change how we think about nutrition. Through customization of food items to fit the specific requirements of various groups, nano-fortification holds the power to transform eating habits and build a stronger, more resilient community. Foods supplemented with nanoparticles have higher bioavailability of nutrients, which improves absorption in the digestive tract. The topic is full of promise, but to solve safety issues and create moral standards for the appropriate use of nano-fortification in the food business, more research and cooperation are needed.

Conclusion

To sum up, nano-fortification is leading the way in a nutritional revolution that is changing the way we treat dietary deficits and meet specific nutritional demands. Nano-fortification guarantees the accurate distribution of nutrients, providing improved bioavailability and stability in a variety of food products through a variety of cutting-edge techniques such as encapsulation, nanoparticle spraying, and nano-composite creation.

Nano-fortification aims to combat malnutrition, assist particular medical conditions, and transform food habits. This technology allows customized solutions that prioritize both efficacy and palatability, from targeted nutrition for the elderly and those managing chronic conditions to sports supplements boosted by nanotechnology.

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REVOLUTIONIZING CULINARY ARTS: EXPLORING THE WONDERS OF 4D FOOD PRINTING

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Abstract

The article introduces the concept of 4D printing as an evolution of three-dimensional (3D) printing, addressing its limitations and showcasing its potential applications in the food processing industry. Originating from Hideo Kodama's 1981 invention of 3D printing, Skylar Tibbits introduced 4D printing in 2013, leveraging smart materials for self-repair, self-assembly, and significant time savings. The basic components of 4D food printing include printers, printing software, and printing inks, with applications ranging from shape-changing food packaging to smart food structures and edible sensors. The advantages of 4D food printing include the preparation of visually appealing and healthy food, reduced food waste, cost efficiency, and precise control over food structure. However, limitations include the inability to print curved surfaces, environmental instability, and higher costs. Despite being in its early stages, 4D printing holds promise for personalized and innovative food products, with further research needed for its full integration into the food industry.

Introduction

Three-dimensional (3D) printing is an additive process which was invented by Japanese researcher Hideo Kodama in 1981. 3D printing is based on working principle of stereo lithographic. It possesses three dimensional x, y and z axis. The negative influence of 3D printing on this technology is that it takes a long time to create the components and is a sluggish process. These drawbacks of 3D printing may be overcome by 4D printing. Skylar Tibbits has invented 4D printing in February 2013. In this technology, smart materials are incorporated because the 4th dimension is time and it has self-repair, self-assembly and it would save 70% to 90% of printing time. 4D printing refers to the additive manufacturing technique that allows objects to transform or self-assemble over time in response to external stimuli, such as heat, light, or moisture.

Components of 4D Printing

The basic components of 4D food printing are printers, printing software and printing inks, which enable the targeted and predictable evolution of the printed products over time.

Printers: Fused deposition modelling printer commonly used for 4D food printing due to high universality, low price and simple operation.

Printing software: printing software determines the quality of 4D food printing. At present, 4D intelligent software mainly includes forward design and reverse design. Forward design is to determine final changes according to material structures, material characteristics and simulation. Whereas Reverse design mainly focuses on the implementation of the required function or shape (Hu *et al*., 2020).

Printing inks: The materials used in 4D food printing are mainly soy protein isolate, starch gels or hydrogel systems. Food materials of printing are chocolate, dough, cheese, mixture of fruits and vegetables, meat, protein and starch (Kim *et al*., 2018).

Application of 4D Food Printing

4D printing is still an emerging field, there are potential applications for this technology in the food processing industry. There are some examples are discussed below:

Shape-changing food packaging: 4D printing can be used to create packaging materials that change shape or properties based on environmental conditions. For example, a package could change its shape to accommodate different food shapes or sizes, or it could release specific substances to extend the shelf life of the food.

Tao *et al*., (2019) developed four types of flour-based food, including self-wrapping tacos, self-folding flavoured cookies, self-assembling noodles for accessibility, and four personalized semolina pasta shapes from flat-pack material that can save up to 76% in packing space.

Smart food structures: 4D printing can enable the development of smart food structures that respond to external stimuli. This could include the release of flavours, nutrients, or even medication based on specific triggers. For example, a printed food product could release a particular flavour when heated or dissolve slowly when exposed to saliva Song *et al*., 2019. There are different pH solutions are utilized to alter the flavour of printed food that comprised of soy protein isolates, beetroot powder, and pumpkin powder. Results showed that the desired volatile components (aromatic compounds and terpene esters) changed at pH values of 8 and 10 Phuhongsung *et al*., (2020).

Edible sensors and indicators: 4D printing could be utilized to create edible sensors and indicators that provide information about food quality, freshness, or nutritional content (Ghosh *et al*., 2022). These sensors could change colour, shape, or texture in response to certain conditions, indicating if the food is spoiled or if specific nutrients are present. Ghazal, Zhang, and Liu (2019) produced a 4D healthy food by combining two 3D printed gels: an anthocyanin-potato starch gel and a lemon juice gel.

Food dehydration: 4D printing techniques can be applied to dehydrate the food products more efficiently. Z. Liu *et al*., (2021) studied the effect of three different dehydration mechanisms such as Microwave dehydration, Infrared dehydration and Air dehydration on the shape-changing property of the 3D printed starch-based gel. They observed that the rapid dehydration rate, low shrinkage ratio, and internal heating model of microwave dehydration were not conducive to bend the sample.

Advantages of 4D Food Printing

1. 4D food printing can be applied to prepare 3D healthy food products with different colours and more visual appealing using only one formulation and then sprayed with different pH solutions, which in turn saves raw materials, time, and efforts.
2. It offers new ideas to innovate novel food products that boost the interaction between food and diners.
3. It reduces food waste through underutilized food materials and the expansion of utilizing existing ingredients.

4. 4D food printing helps in cost reduction in preparing and transporting food as a result of low-volume manufacturing as well as the simple supply chain.
5. Printing technology is evolving to the point where it can control food structure from the macroscopic to the microscopic scale.

Limitations of 4D Food Printing

1. 4D printing can only print objects with flat layers and is unable to create integrated parts with curved surfaces that increase objects' strength.
2. It is less stable regarding environmental temperature.
3. The higher costs of programming and printing process are limiting the development of this technology.

Conclusion

It's important to note that 4D printing in the food processing industry is still in its early stages of development. 4D printing is extension of 3D printing technology, it gives consumers the freedom to customise their meals by adding desired qualities. As of right now, printed food products are mostly confined to soy protein isolate, starch gels, and hydrogel systems, with external stimulation parameters like pH, water absorption, microwave, and temperature. The variations in the printed product's characteristics (colour, shape, nutrition and flavour) are caused by variations in the material's qualities, internal structural layout, and spatial arrangement of food ingredients. Further research, experimentation, and advancements in materials and techniques are necessary to fully realize the potential of this technology in the food industry.

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