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Special Issue on Food Science and Technology

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SHASHIKUMAR J. N.

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From the Editor-in-chief's Desk

I am happy and proud to announce the release of the Special issue on Food Science and Technology for the month of August 2023. This issue, was specially curated to include the topic related to Food Science and Technology, Food Processing, Food Engineering, Food Quality Etc.

Food science and technology play a crucial role in our modern society for several reasons. Firstly, they ensure food safety by studying and developing processes to prevent contamination and spoilage, protecting consumers from harmful pathogens and toxins. Secondly, these disciplines contribute to food preservation and distribution methods, which are essential for feeding growing populations and reducing food waste. Additionally, food science and technology help improve the nutritional quality of foods, addressing health and dietary concerns. Lastly, they foster innovation in the food industry, leading to the development of new products and sustainable practices that benefit both consumers and the environment. In summary, food science and technology are indispensable in providing safe, nutritious and sustainable food for the global population.

It gives me great pleasure to inform you that we have curated and finalized 27 articles for publication in this issue.

I extend my heartfelt gratitude to the Guest Editor Dr. Shashikumar J.N. for his contribution as Guest Editor for this Issue and also for the dedicated editorial team and the talented authors for their invaluable contributions in bringing this issue to fruition. Your efforts have played a pivotal role in making AgriTech Today Magazine a source of enlightenment and knowledge in the agricultural domain.

Editor-in-chief

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Trends in Edible Packaging for Dairy and Food Industry

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Packaging is an enclosing of an entity with one or more specific materials. Packaging materials play an important role in containing foods and preserving the quality and safety of afood product throughout the supply chain until consumption and also to increase shelf life of food. The packaging material functions as a barrier to the migration of pollutants from the environment to the product. It is however attractive and also meet mechanical requirements for food applications (Manrich et al. 2017). The dairy & food industry has come to use a wide range of synthetic petroleum-based polymers that have provided convenience and ease of use in different situations. Thermoplastics are widely used for food packaging like (LDPE- low density poly ethylene, PP-poly propylene, PET - poly ethylene terephthalate, PVC - poly vinylchloride, HDPE - high density polyethylene). They are non-renewable and non-biodegradable and therefore they have become a serious environmental issue & solid waste problem. That worries all the investors of the food production chain. Therefore, innovative films derived from agro - food industry wastes and renewable low-cost natural resources have received greater attention as effective and economical replacement for conventional plastics. Some of these materials are edible, so they can be consumed together with the product or be in close contactwith the food, while being eco-friendly and ensuring that the package meets the primary objective of protecting the food (Girkar *et al.*, 2019).

Edible packaging

Edible packaging is "defined as thin layer of edible material formed on a food as a coating or placed on or between food components. A variety of polysaccharides, proteins, and lipids have been used, either individually or in mixtures, to produce edible film". Edible packaging is new innovative technology for food packaging. These are biodegradable and compostable, edible films are desirable because they also offer a lucrative outlet for surplus agricultural materials. On the other hand, these films have similar functions as those of conventional packaging, including barriers against water vapor, gases, and flavor compounds and improving structural integrity and mechanical-handling properties of foods. Smartly designed, they can also improve the quality, safety, shelf life, and functionality of food products, as well as increase food sensory attributes and convenience, while minimizing both spoilage and pathogenic microorganisms during storage, transportation, and handling. Moreover, the ediblefilms can be used to produce a soluble package for premixed food ingredients or additives andact as a separate layer of individual food portion. Edible films and coatings are – Generally Recognized as Safe (GRAS) (Girkar *et al.*, 2019).

Classification and sources of edible packaging materials

The materials used to produce edible packaging, both coatings and films, must meet two requirements; one is to be considered edible, and the other is the ability to form a continuous layer or film. In this group of materials are generally polysaccharides, proteins, and waxes thatcan create a constant coating or film. They can be divided into different categories according to their production method and origin. Edible films and coatings are classified into three main categories based on the materials used for their preparation: Polysaccharides, proteins, lipids. Films are usually prepared by dissolving the edible ingredient in water, alcohol, or a mixture of solvents. Very often, a plasticizer is added to the solution to enhance flexibility and elasticity. Other additives, like antimicrobial agents, colors, and flavors, can be combined with the solution to obtain specific film properties and functionality based on the final application (Janjarasskul and Krochta, 2010; Joya *et al.*,2017)

The polysaccharides used for making edible films include cellulose derivatives, chitosan, starch, starch hydrolysates (dextrin's), gums, alginate, carrageenan, pectin and others that should be chemically treated to increase water solubility like cellulose and chitin. Polysaccharides are widely available and usually cost effective. Due to the presence of a large number of hydroxyl and other polar groups in their structure, hydrogen bonds have a crucial function in film formation and final characteristics. The major mechanism of film formation in polysaccharide films is the breaking apart of polymer segments and reforming of the polymer chain into a film matrix or gel. This is usually achieved by evaporation of a solvent creating hydrophilic and hydrogen bonding and/or electrolytic and ionic cross-linking. Protein films originate from several sources including plant, meat, egg, and milk, for example, collagen, albumin, gelatin, casein, milk whey proteins, corn zein, ovalbumin, soy protein, peanut protein,pea protein, rice bran protein, cottonseed protein, keratin and wheat gluten. However, some considerations with respect to food intolerances, such as wheat gluten intolerance (celiac disease), or milk protein intolerance, allergies, or religious beliefs/banning, should be taken into account when protein-based films and coatings are used. The main mechanism of formation of protein films includes denaturation of the protein initiated by heat, solvents, or a change in pH, followed by association of peptide chains through new intermolecular interactions, being the protein-protein interactions, with disulphide, hydrogen, and hydrophobic bonds, the main associative forces in the film network. Proteins have good film- forming properties and good adherence to hydrophilic surfaces. commercial level, edible films are usually produced by continuous film casting, mold casting, or drawdown bar method. During casting, the wet film is coated onto a belt conveyor and then passed through a drying chamber, while mold casting and drawdown bar are cheaper and more accessible methods used for lab-scale film production.

Based on sources, edible packaging materials can be grouped like (1) Materials from direct biomass or natural sources (e.g., marine, agricultural, and animal sources), typified by proteins, polysaccharides, waxes, and lipids;(2) Materials produced by wild or genetically modified microorganisms, such as polysaccharides and some active compounds; (3) Materials produced by classical chemical synthesis, including surfactants, plasticizers, and other active compounds that are generally used in edible packaging (Pooja *etal.*, 2019).

Polysaccharide based edible films and coatings

Polysaccharides are long-chain polymers formed from mono- or disaccharide repeating units joined together by glycosidic bonds. As a result of a large number of hydroxyl groups and other hydrophilic moieties present in their structure, H-bonds play significant roles in film formation and characteristics. Generally, polysaccharide films are formed by disrupting interactions among long-chain polymer segments during the coacervation process and formingnew intermolecular hydrophilic and H-bonding upon evaporation of the solvent to create a film matrix (Janjarasskul and Krochta, 2010). Polysaccharide coating exhibit excellent aroma, oxygen, and oil barrier properties and they provide strength and structural integrity. However,they also provide very little resistance to water migration. Hydrogen-bonded network structure and low solubility provide excellent oxygen barrier properties. The films using polysaccharides may delay in ripening and help in prolonging the shelf life of coated produce (Pooja *et al*., 2019)

Method for application of polysaccharide edible packaging materials Dipping method

Dipping is the most common method of coating on the food product. It is the immersionof a food sample in the coating-forming dispersion (Senturk et al., 2018).

The dipping methodfor applying edible coating on food products consists of three steps:

i) Immersion & dwelling,

ii) Deposition and

iii) Evaporation of solvents.

In the first step, the substrate is immersed in thecoating emulsion/solution at a constant speed, the dwelling ensures enough quantity of solution for wetting substrate and complete interaction between both substrate and coating matrix. The deposition process is used to develop thin layers of the precursor emulsion on the surface of food products. The excess surface liquid drains and removes by deposition. During evaporation step, the solvent and excess liquid are evaporated from the surface of food products by using heating and drying procedure. The product will be dried either at room temperature or with the help of a dryer when the surplus coating is drained away. Thickness ofliquid coated films has been shown to rely on the characteristics of a coating solution such as density, viscosity, surface tension as well as surface withdrawal rate. In order to apply a thick coating layer, it is possible to dip the product item into a solution batter or molten lipid (e.g., chocolate coating).

Battering and/or breading of fresh and/or frozen products can enhance palatability and add taste to a product that is otherwise tasteless and decrease moisture loss andabsorption of oil in frying. It has also been seen that edible coating is difficult to apply on the cut surface of fruit or vegetable as the hydrophilic surface does not gel properly with the hydrophobic nature of coating material. A multi-layered methodology could be a solution to this issue: layer-by-layer electro deposition with physically or chemically connected two or more layers of material with dimensions of nanometer scale. (Suhag *et al* 2020).

The dipping process is widely used to apply edible coatings to fresh produce. In general, the fruits and vegetables are submerged for 5–30 sec in the formulation of edible coating, mostfruits are easy to use. The most effective way to increase the microbial stability of freshly cut fruit is by dipping them in aqueous solutions that contain antimicrobials. The most common method to regulate the browning of fresh fruit through the application of antioxidant treatmentsas dips following peeling and/or cutting. Dipping has proven less effective in direct applications on food surfaces of antimicrobial agents, as the loss of activity is caused by leaching on the food, enzymatic activity and the reaction with additional food constituents. applications of edible coating on the surface of fruits and vegetables using the dipping method.Due to its simplicity and low cost, the dipping method is the main laboratory coatingapplication method (Atieno et al., 2019).

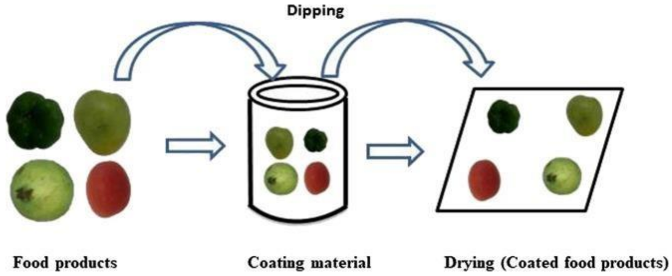

Fig. 2 dipping method of edible coating

The dipping method is beneficial for the food product to completely coat its surface. It ensures good uniformity across a rough and complex shape on the surface of food products. In some cases, this method usually provides a thick coating that might present difficulties with the food product respiration as well as storage. Several issues arise by dipping method, including dilution of coating, waste or dirt accumulation and the development of microbes in the dipping vat. Furthermore, drawback of the dippingmechanism is dilution of the external layer and degraded its functionality; i.e., after dipping, the natural wax coating of fruit and vegetables might be detached (Suhag *et al* 2020).

Application of Polysaccharide Based Edible Coating on Sapota

In this study they taken alginate as coating material. Alginate is extracted from brown algae & *azotobacter* & *pseudomonas*. They used sodium alginate (2%), pectin (2%), glycerol (2.5%) – were dissolved in the distilled water using the magnetic stirrer. After all the components were completely dissolved, the solution was cooled to (35°C). The coating of thefruits was done by dipping method. Treatments are divided by dipping time; they are 2& 4 mins in edible coating solution. After dipping they removed excess coating & dipped in 2% Cacl2 2&4 minutes accordingly and dried at 35°C, and stored for 30 days at 4°C. In this study they conducted physicochemical parameters like weight loss, total soluble sugars, ascorbic acidfor sapota fruit during storage. They observed high weight loss in control compare with coatedsapota. Weight loss is observed in coated also it is mainly due to blockage of lenticels.

During storage simple sugar molecules results increase in TSS. Increase level of TSS during ripening results reduction of ascorbic acid. They done sensory analysis using 9-point hedonic scale for sensory analysis. The sensory analysis of control and coated sapota fruits showed that, the polysaccharide coating with 2 min dipping time was effective in maintaining the organolepticproperties of the fruits up to 30 days of refrigerated storage when compared to that of control sapota fruits. From all samples Sodium alginate 2 mins dipping time showed significant reduction changes in physiochemical parameters. Finally, they concluded by applying polysaccharide edible coating to sapota fruits increased ripening period as well as organoleptic acceptability up to 30 days from 8 days. (Menezes., et al, 2016).

Protein Based Edible Films/Coatings

Protein-based edible films can be used for different food products to reduce the loss of moisture, to restrict absorption of oxygen, to reduce migration of lipids, to improve mechanicalhandling properties, to provide physical protection, or to offer an alternative to synthetic packaging materials. The protein-based edible coating also offers excellent mechanical and barrier properties against oil, oxygen and aroma. But they are limited resistance to water vapors (Raajeswari and Pragatheeswari 2019).

Together with non-edible films, protein-based edible films have another possible application for their use in multilayer food packaging materials. Collagen (fibrous proteins) has received the most attention in the production of edible films. Globular proteins of wheat gluten, corn zein, soy protein, whey protein and mung bean protein, have been investigated for their film properties (Wittaya, 2012). Protein-based edible films have the potential to be used for the special packaging of beans, nuts and cashew nuts. This protein based edible packaging materials also used in multi-layer packaging and also good film forming properties and good adherence to hydrophilic surfaces (Pooja *et al*., 2019).

Solvent Casting - Method of edible film preparation

The casting method (also called solvent casting) is the most commonly used method for a film formation at laboratory and pilot scales. This method involves three steps to prepare a filmfrom biopolymers:

i) Solubilization of biopolymer in a suitable solvent,

ii) Casting of the solution in the mold,

iii) Drying of casted solution.

Edible film formulation begins by the selection of the polymer or polymer mixture which forms the basic film. The selected polymer is dissolved or dispersed in a suitable solvent; for example, ethanol is used to dissolve soy protein isolate polymer; this step is called solubilization. Film formation in solvent casting depends on the solubility of the polymer rather than melting. In casting process, the obtained solution is poured into a predefined mold or Teflon-coated glass plates. Drying process provide sufficient time for evaporation of the solvent that makes a polymer film that adheres to the mold. The air drier such as hot air oven, tray dryer, microwave, and vacuum driers are used for the casting of films for easy removal of solvents and peel of film. The air-drying procedure forcasting of edible film is very important step for improving the intra-molecular relationship between the polymer chains and obtaining a suitable microstructure of the film. Casting of the film by using quick-drying methods has shown negative effects on physical and structural properties. Various studies have been done on the comparison between drying temperature andair- drying methods for the production of edible films. The developed edible film should be consistent and free from imperfections (non-consistency, inclusion and mechanical harm). The thickness, transparency, opacity, swelling degree, thermal stability, mechanical strength, oxygen transmission rate (OTR), water vapor permeability (WVP), and biological characteristics are the most important parameters of edible films. Cohesive matrix and plasticizers are used for the formation of an easily peeled edible film with an excellent mechanical strength, barrier properties, thermal stability, and uniform microstructure. The increased concentration of plasticizers in an edible matrix has positive impacts on the barrier.

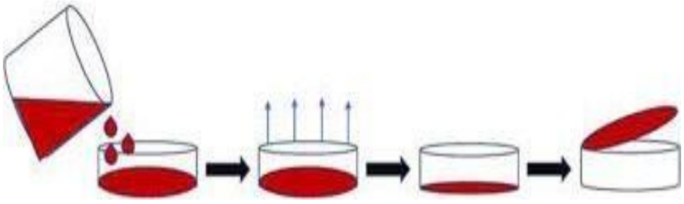

Fig. 3 Solvent Casting Method

Application of protein based edible film for cheddar cheese

Films were made from casein and 80 % whey protein concentrate (WPC). Glycerol and sorbitol were used independently as plasticizers. The biopolymer: plasticizer ratios were 1:0.25, 1:0.5 and 1:0.75 for glycerol and 1:1.0, 1:1.25 and 1:1.5 for sorbitol. The levels of glycerol and sorbitol were selected based on preliminary trials to obtain brittle-free films. Exactly 10 g of casein or WPC was weighed and dissolved in 200 mL of warm distilled water. The pH of the film-forming solution was adjusted to 5.6 by adding 2 N NaOH solution. The film-forming solution was heated and stirred at 85 °C for 15 min on a digital hot plate. The plasticizer was added, and heating was continued for another five min. Potassium sorbate at 0.2 % (w/w) was then added, and the film-forming solutions were cooled to 40–45 °C. The solution was degassed by applying vacuum, and cast on Teflon coated glass plates. The films were dried at 30 °C for 96 h, and tested for various functional properties. Two-month ripened Cheddar cheese was used for packaging trials.

Samples weighing 250 g were sealed using selectcasein and WPC films, wrapped with 50 µm (l ow density polyethylene) LDPE bag and storedat 5±1 °C for 30 days. Samples packed simply in LDPE bags served as control. The samples were drawn at 10th day interval and analyzed for various physicochemical and microbiological qualities. The film thickness, tensile and barrier properties of casein and WPC films were highly influenced by the type of biopolymer and the type and concentration of plasticizer used in film preparation. Casein films showed superior tensile and barrier properties than WPC films regardless of the plasticizer. Similarly, glycerol-plasticized films possessed better WVP barrier than sorbitol-plasticized films but their oxygen permeabilities were inferior. It was observed that Cheddar cheese packaged in LDPE deteriorated at faster rate than those sealed with additional layer of protein films.

The physico-chemical and microbiological data revealed that it was possible to extend the shelf-life of milk products by packaging them with an additional layer of casein and WPC films. The overall packaging requirement could also be reduced since the protein films acted as barriers to oxygen transfer. The sensory qualities of Cheddar cheese were not affected by edible film packaging. Finally, they Concluded - protein films restricting the growth of spoilage microorganisms and extended the shelf-life of Cheddar cheese during storage at 5°C **(**Wagh *et al*., 2014**)**.

Lipid based edible films/coatings

Lipid compounds have been utilized as protective wrapping for many years, but since they are not polymers, they do not have a large number of repeating units connected by covalentbonds to form coherent, stand-alone films. Thus, they are fragile and do not generally build cohesive, self-supporting film structures. Lipid coating has excellent barrier properties for water vapor and oxygen. Usually, wax films are substantially more resistant to moisture migration than other lipid or non-lipid edible films. Edible resins such as terpene resin, shellac;and wood resin are used to impart gloss to food commodities. Shellac used as an edible wrapping for the confectionary and fresh produce (Raajeswari and Pragatheeswari 2019). Owing to their relatively low polarity, lipids have been incorporated into edible film-forming materials to provide a moisture barrier within composite films. Nevertheless, there are disadvantages of employing lipids in edible packaging materials, such as their waxy taste and texture, greasy surface, and potential rancidity. The lipid components used to reduce water transmission while the other components serve as selective gas barriers and provide structural integrity and mechanical strength (Furkan *et al*., 2017).

Composite – Edible Packaging

Composite edible films and coatings are developed by use of more than one ingredient of edible packaging materials. Composite films can also be termed as multicomponent systems. Composite materials are a combination of edible substance that is made to overcome their flawsMost of the composite films consist of a protein, lipid layer and hydrocolloid components supported by a polysaccharide, or lipid material dispersed in a protein matrix or polysaccharide. Films are characterized by complexation of a hydrophilic layer with a hydrophobic layer (including lipids) which provides excellent barrier properties for food.

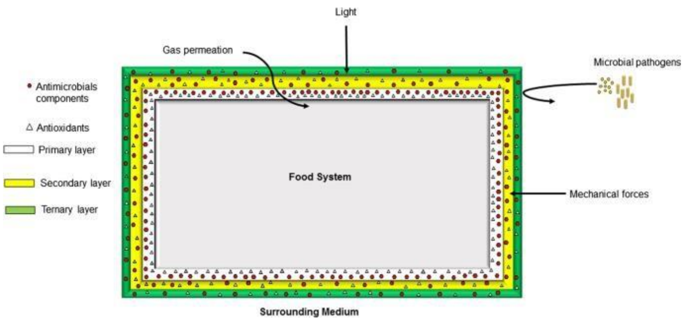

Fig. 3 Composite – Edible Packaging Method

Emulsion based films are formulated where lipid layer is uniformly distributed within biopolymer matrix. Composite films and coatings prepared by combination of two hydrocolloids. Based on the number of biopolymers, composite edible films have beenclassified as binary or ternary (Chanda and Preetam, 2018).

Advantages and dis advantages of edible packaging

Advantages

- Improves handling properties
- Enrich the film with nutrients
- Reduce packaging waste by applying edible packaging material as package
- Decreases use of synthetic packaging

Disadvantages

- High production cost because it's not industrialized properly
- Chemical composition has to match packaging material as well as food
- Not a good barrier against insects.

Table.2 Applications of Edible Packaging in Food Industry

Application	Components	Primary findings	References
Citrus fruits	Chitosan, Alovera extract (C)	Shelf life extended 5 days (5°C)	Vieira *et al.*, 2016
Tomato	Chitosan, acetic acid (F)	Prevent wt. loss & maintain freshness	Limchoowoong *et al.*, 2016
Fresh cut apples	Casava starch, glycerol, carnauba wax & stearic acid (F)	Increase WVR & reduction in weight loss	Chiumarelli and Hubingar, 2012
Chicken breastfillets	WPI, glycerol, oreganooil, clove oil (F)	Increase shelf life 6 to 13 days (4°C)	Fernandezpan *et al.*, 2014
Golden Pomfret(Fish)	Gelatin, chitosan(C)	Inhibition of wt loss	Feng *et al.*, 2016

Table. 3 Commercial Brands of Edible Packaging materials

Company	Product	Uses
Improveat	Bio cheese coat	Prolongs shelf life of cheese
Wiki foods	Wiki pearl	Wraps the food into a pearl
AgriCoat NaturalSeal	Semper fresh, nature seal	Pre and postharvest protection
BASF	Fresh seal	Postharvest –extends shelf life while shipping
Fruit Symbiose	Purbloom	Micro-coating for fresh cut vegetables and fruits

Future prospects of edible packaging

To make user-friendly and convenient for user cut to size and packaged for specific applications used in industries. Development of Composite edible packaging can add value to product. Research required for Nano- edible packaging systems, Edible packaging for milk and milk products in India.

Conclusion

- Consumer demands – Natural, safer food packages this is a big challenge to researchers.
- In order to fulfil desired film properties - integrated and synergistic composite ingredients were used.
- Edible constituents have no health risk to humans.
- Research was increased and several performances have been advanced in edible packaging.
- Lab research - need scaling up – industrially for edible packaging in India.
- Hopefully, in a few coming years - EP materials could be in potential use.

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Millets: Smart Nutritive Food

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Malnutrition is a major public health problem worldwide associated with micronutrient deficiencies (especially iron, zinc and vitamin-A) which leads to poor health and reduced productivity. Millets have been touted as a potential solution to malnutrition due to its nutritional profile, drought tolerance, climate resilience, affordability and sustainability. They are a group of small-seeded cereal crops that are grown primarily for food in developing countries like India. These are among the earliest food known to humans and may have been the first cereal grain to be used for domestic purposes. Due to their ability to grow in subpar soils and dry environments, these crops are crucial sources of food in regions that are prone to drought and food insecurity. Some common types of millets in the country include pearl millet, sorghum, foxtail millet, proso millet, finger millet, little millet, barnyard millet and kodo millet (Fig 1). Both major and minor millets are good sources of nutrients, including protein, fiber, vitamins and minerals (Table 1).Additionally, millets are non-glutinous, contain a higher level of fiber and have low glycemic index compared to other staple cereals, making them a good option for people with gluten intolerance or who are looking for a healthier food option.Taking into account the crop's importance both nationally and globally, the United Nations has designated 2023 as 'The International Year of Millets' to highlight the significance of millets as a food source, their potential to enhance food security and nutrition and to promote sustainable agriculture.

Despite all nutrients, millets contain various anti-nutritional factors that bind to the nutrients in the food and reduce their bioavailability for utilization by the human body. The main anti-nutrients found in millets include phytic acid, tannins, polyphenols and enzyme inhibitors. Phytic acid can bind to minerals such as calcium, iron and zinc, making them less available for absorption. Tannins can hinder the digestion of proteins, carbohydrates; and enzyme inhibitors interfere with the digestion of certain enzymes. Polyphenols are considered vital for life nonetheless; they show an inhibitory effect on iron absorption and restrict the growth of beneficial microbes in the body. However, mitigating strategies such as soaking (12 to18 hrs in water for reducing the levels of soluble phytic acid and enzyme inhibitors), sprouting, decortication (dehulling), germination, heating and fermentation (improves antioxidant properties, protein digestion and helps in detoxification) of millets can reduce the levels of anti-nutrients and enhance their nutritional value.

Fig 1: Most common millets grown in India

Anti-nutrients and strategies to mitigate

Despite all nutrients, millets contain various anti-nutritional factors that bind to the nutrients in

the food and reduce their bioavailability for utilization by the human body. The main anti-nutrients found in millets include phytic acid, tannins, polyphenols and enzyme inhibitors. Phytic acid can bind to minerals such as calcium, iron and zinc, making them less available for absorption. Tannins can hinder the digestion of proteins, carbohydrates; and enzyme inhibitors interfere with the digestion of certain enzymes. Polyphenols are considered vital for life nonetheless, they show an inhibitory effect on iron absorption and restrict the growth of beneficial microbes in the body. However, mitigating strategies such as soaking (12 to 18 hrs in water for reducing the levels of soluble phytic acid and enzyme inhibitors), sprouting, decortication (dehulling), germination, heating and fermentation (improves antioxidant properties, protein digestion and helps in detoxification) of millets can reduce the levels of anti-nutrients and enhance their nutritional value. Role in climate resilience

Role in climate resilience

Millets are known for their adaptability to a range of environmental conditions, such as drought, high temperatures and poor soils. This adaptability makes millets an ideal crop for areas that are vulnerable to climate change impacts. Millets are adapted to water deficit conditions and also have high water use efficiency thus, help in soil moisture conservation. Additionally, the carbon footprints of millets are comparatively lower than cereals indicating less greenhouse gas emission. Millets are an essential component of traditional agricultural system and are often grown in mixed cropping systems with other crops. This diversity helps to maintain soil health, reduce the risk of crop failure and support the resilience of the ecosystem thereby help to improve food security in areas that experience more frequent and intense weather extremes.

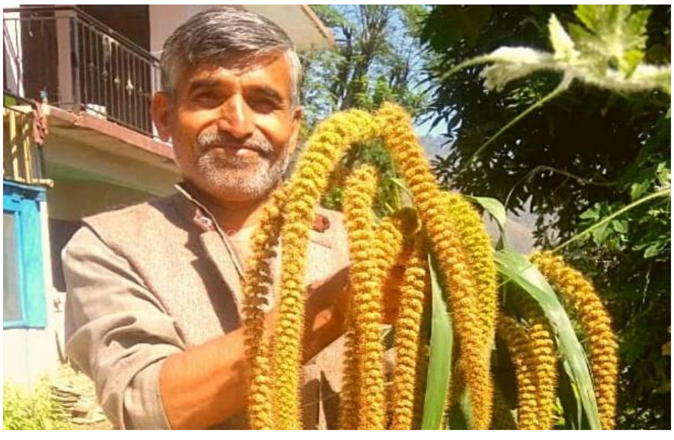
Processed products of millets

Processing has the potential to enhance farmer's income by adding significant value to the agricultural produce. Several value-added products of millets such as muffins, cookies, chapati, upma, noodles etc. (Fig 2) are available in the market and gaining the attention of economically rich and health-concerned masses of society.

Fig 2: Processed products of millets

Success story

Nekram Sharma is an organic farmer from district Mandi, Himachal Pradesh who is reviving the traditional crop system of *nau anaj*which is a natural intercropping method of growing nine foodgrains on same piece of land without any



chemical usage and cutting down water usage by 50% along with raising land fertility. He is producing local indigenous seeds and distributing it to 10,000 farmers in six states at no cost. The 59years old farmer has got the prestigious Padma Shri award in 2023for his distinguished service in the field of agriculture. These crops are a combination ofmaize, moong, beans, rajmash, urd bean, amaranths, foxtail millet, finger millet and buckwheat.

Conclusion

While there is a great potential for millets to play an important role in addressing malnutrition, their impact depends on a range of factors, including local agro-ecological conditions, the availability of high-quality seed and other inputs and the extent to which they are incorporated into the diets of communities. Besides, it will be important to ensure that the promotion of millets does not come at the expense of other nutritious and culturally-important foods.

Table 1: Quality traits and varieties released of major and minor millets

Millets	Scientific name	Chromosome no.	Varieties released (2014-21)	Quality trait
Major millets				
Sorghum	*Sorghum bicolor*	2n=2x=20	43	Known as ‘camel crop’ High in carbohydrates
Pearl millet	*Pennisetum glaucum*	2n=2x=14	52	High iron content
Minor millets				
Foxtail	*Setaria italica*	2n=2x=18	8	High in proteins, carbohydrates and minerals such as copper and iron
Finger millet	*Eleusine coracana*	2n=4x=36	28	Very high amount of calcium, high in fibre, powerhouse of proteins and amino acids
Proso millet	*Panicum miliaceum*	2n=4x=36	4	High protein content, well adapted to dry sandy soils
Barnyard millet	*Echinochloa esculenta*	2n=6x=36	4	High in fibre, carbohydrates,phosphorus and iron
Little millet	*Panicum sumatrense*	2n=4x=36	11	High iron and fibre content, reduce fat deposition in body
Kodo millet	*Paspalum scrobiculatum*	2n=4x=40	4	Digestion-friendlymillet, rich in phytochemicals, phytate and minerals

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Liposome Technology: Enhancing Functional Foods and Nutraceuticals for Health and Vitality

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In 1965, British researcher Bangham made the groundbreaking discovery of liposomes by dispersing phospholipids in water and examining them under an electron microscope. Later, in 1968, Sessa officially coined the term "liposomes" to refer to these structures. Since 1971, liposomes have been recognized as a prominent microencapsulation technique for delivering drugs to treat various diseases. This method involves encapsulating materials in capsules, allowing for controlled release at specific locations and rates. Over time, liposomes have evolved significantly from being utilized primarily as pharmaceutical, therapeutic,and personal-care delivery systems to gaining prominence as promising candidates for functional food ingredients research. Liposomes are closed vesicles that self-assemble, featuring a phospholipid bilayer structure that sets them apart from the surrounding water environment. These particles vary in size, ranging from 10 nm to several micrometers, encompassing a wide range of dimensions.

When phospholipids are dispersed in an aqueous medium, they exhibit "the hydrophobic effect," causing the hydrophobic tail to interact with the polar environment and shield the surrounding aqueous medium. Additionally, van der Waals interactions and hydrogen bonding between phospholipids and water molecules play a role in organizing the phospholipids into closed bilayered vesicles. This way liposomes provide a distinctive capability to transport both hydrophobic and hydrophilic molecules simultaneously (Liu *et al.*, 2020)

Liposomes have been employed to encapsulate different bioactive compounds (BACs) in the form of nanoliposomes or micro liposomes enabling their application as functional food ingredients. By employing liposome technology, it becomes possible to improve the solubility and bioavailability of a wide range of nutrients. Additionally, this technology enables controlled release at specific locations, making it a valuable method for encapsulating various bioactive compounds (BACs) in functional foods and nutraceuticals

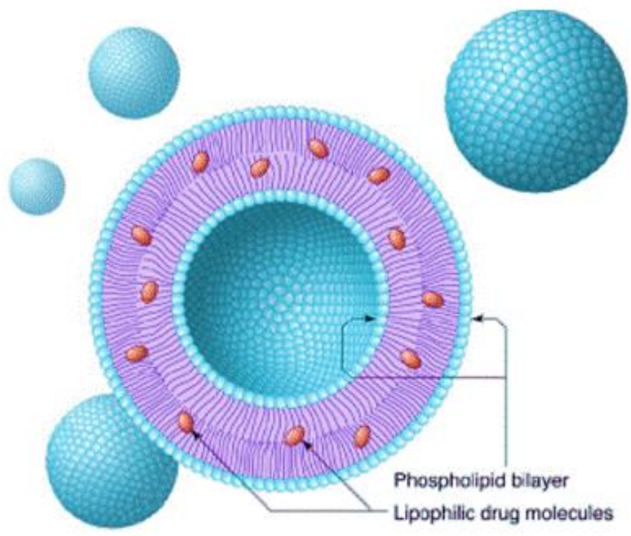


Figure 1: Structure of liposomes

Classification

Liposomes can be categorized into three groups based on their surface charge: neutral liposomes, negative liposomes, and positive liposomes. Additionally, considering the number and structure of lipid bilayers, liposomes fall into three types: unilamellar vesicles (ULV), multilamellar vesicles (MLV), and multivesicular vesicles (MVV).

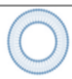
TYPE OF LIPOSOMES	ABBREVIATION	DIAMETER	SCHEMATIC REPRESENTATION
Small unilamellar vesicles	SUV	20-200nm	
Large unilamellar vesicles	LUV	Above 200 nm	
Giant unilamellar vesicles	GUV	Higher than 1 µm	
Multilamellar vesicles	MLV	0.5-5 µm	
Multivesicular vesicles	MVV	Higher than 1 µm	

Table 1: Classification of liposomes based on number and structure

Liposome Preparation

The preparation process of liposomes for functional food applications typically involves four essential stages: (Ajeeshkumar *et al.*, 2021)
(1) drying lipids dissolved in an organic solvent,
(2) exposing the lipid to an aqueous medium,
(3) purifying the resulting liposome,
(4) analyzing the final product.

1. **Drying of lipids dissolved in organic solvent**

The primary constituents forming the wall of liposomes are phosphatidylcholine (PC), phosphatidylethanolamine(PE), phosphatidylserine(PS), and phosphatidylglycerol (PG). Phospholipids are dissolved in a solvent or a mixture of solvents to achieve a uniform distribution of lipids in the solution. For lipophilic bioactive compounds (BACs), an appropriate solvent may be added to the mixture and then dried.On the other hand, for hydrophilic BACs, they can be added to the dried lipids during the hydration process with the aqueous phase.

2. **Exposure of the lipid to aqueous media**

Hydrophilic bioactive compounds (BACs) are introduced into the aqueous phase to be encapsulated by binding with the hydrophilic components of the phospholipids through a hydration process of the lipid phase (LP). On the other hand, hydrophobic BACs can be entrapped within the phospholipid bilayer.

3. **Refining the synthesized liposome**

Frequently used purification techniques include, centrifugation, ultrafiltration, column chromatography, dialysis and the ion-exchange chromatography method. The successful encapsulation of the desired compound is accomplished by eliminating unwanted substances such as unencapsulated BACs and solvent residues.

4. **Final product analysis**

The liposome characterization are mainly done through zeta potential, polydispersive index (PDI), size distribution, encapsulation efficiency (EE) and visual appearance (Panahi *et al.*, 2017).Encapsulation Efficiency (EE) refers to the percentage of BAC that is trapped inside the liposomes, relative to the total initial amount of BAC used in the process. The zeta potential results reveal the effective surface charge of the liposomes, which significantly influences their aggregation and stability. PDI (Polydispersity Index) quantifies the width or variability of size distributions. This parameter allows us to assess any changes in the size of liposomes after loading with BACs by measuring the uniformity of the size distribution.

Applications of Liposomes

Lipsomes offer advantages in various applications, including food, functional food, and BACs delivery systems.

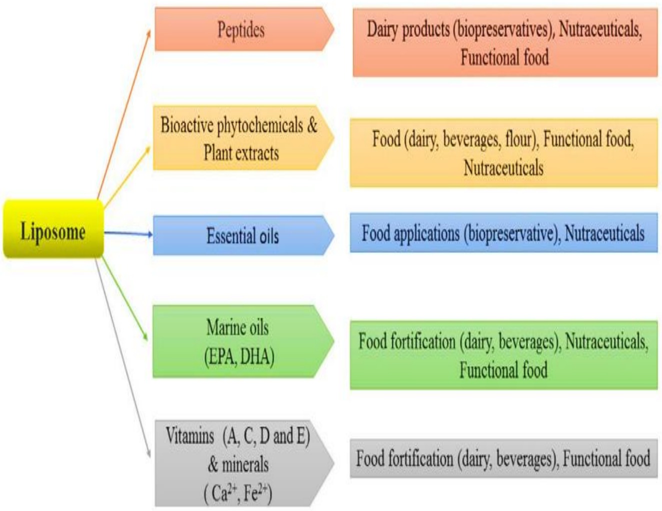


Figure 2: Application of liposomes in food industry

1. **Encapsulation of antimicrobial peptides**

Antimicrobial polypeptides, like nisin and lysozyme, exhibit inhibitory effects against gram-positive pathogens such as *Listeria monocytogenes*, *Staphylococcus aureus*, and Bacillus spp. These peptides are effective in controlling undesirable bacteria in food products like cheeses and contribute to prolonging their shelf life.Nevertheless, there are several limitations associated with the direct addition of nisin or other antimicrobials to food products. For instance, when nisin is added directly to milk, a notable reduction in its antimicrobial activity has been observed due to its adherence to milk fat globules.

Thus, the encapsulation of nisin and other antimicrobials within systems like liposomes presents a promising solution to address these limitations and create antimicrobial formulations more suitable for food applications, particularly in cheeses. The co-localization of liposomes and microorganisms during cheese ripening suggests that liposomes could potentially be utilized to deliver antimicrobial agents precisely to the areas where microorganisms are present in food products. This targeted approach may enhance the effectiveness of antimicrobial treatment in foodstuffs. The use of nanoliposomes containing nisin, formulated with distearoylphosphatidylcholine (DSPC) and distearoylphosphatidylglycerol (DSPG), demonstrated effective inhibition of the growth of *L. monocytogenes* strains in UHT-processed milk samples for 48 hours at 25°C. Remarkably, this antimicrobial effect was observed regardless of the milk's fat content. Liposomes were found to enhance the antilisterial activity of pediocin AcH in various food matrices, including beef tallow and muscle slurries(Emamie*t al.*,2016)

2. **Encapsulation of polyphenols**

The potential health benefits of polyphenols and their usage as additives in functional foods have been constrained by factors like limited stability, conditional solubility, and poor bioavailability. Additionally, they are known to impart unpleasant tastes, such as astringency, when incorporated into food products.

(Takahashi*et al.*,2009) findings indicated that encapsulated curcumin, a natural polyphenolic compound derived from turmeric, exhibited a swifter absorption rate and improved absorption compared to its free form or a blend of curcumin and lecithin. Furthermore, the plasma's antioxidant activity after consuming orally administered curcumin enclosed in liposomes was notably greater than the antioxidant activity observed in the other two treatment groups.

3. **Encapsulation of essential oils**

Essential oils are intricate and volatile compounds produced by aromatic plants as secondary metabolites, known for their potent fragrance. These oils exhibit a diverse range of biological traits, including antioxidant, antifungal and bactericidal effects.Nonetheless, it is widely recognized that the majority of essential oils are inherently unstable from a biological perspective, making them susceptible to factors such as oxygen, light, and temperature.The utilization of liposomes has been suggested as a strategy to enhance the solubility and bioavailability of essential oils, offering protection and the ability to regulate their release.

4. **Encapsulation of vitamins**

Numerous vitamins exhibit instability within food systems, making them prone to degradation. The pace and degree of degradation are influenced by factors such as the chemical makeup of the vitamins, attributes of the food matrix, processing circumstances, and conditions during distribution and storage.Using liposomal encapsulation seems to offer a viable approach to safeguard both water-soluble and lipid-soluble vitamins from degradation.

Liposomes containing encapsulated Vitamin E and C, formed using SPC (soy phosphatidylcholine), were introduced into orange juice with the aim of creating a fortified beverage that enhances its nutritional content. (Marsanasco*et al*., 2011).

5. **Encapsulation of marine oils**

The beneficial impacts of marine oils on health are directly associated with the existence of oils that encompass long-chain ω-3 polyunsaturated fatty acids (PUFAs), namely EPA and DHA.The primary drawbacks of marine oils stem from their heightened vulnerability to oxidation, a consequence of their elevated levels of polyunsaturated fatty acids (PUFAs) and monounsaturated fatty acids (MUFAs).In the latest developments, a nanoliposome powder containing shrimp oil has been created to facilitate and expand its utilization in the realm of food and beverages. The formulation of nanoliposomes with shrimp oil was devised and subsequently converted into powder form using freeze-drying and spray-drying techniques.(Gulzar &Benjakul, 2020)

Conclusion

The utilization of liposome technology has emerged as a practical and effective method for the creation and utilization of bioactive compounds (BACs) in the context of functional foods and nutraceutical applications. Liposomes provide a successful strategy for safeguarding and managing the release of delicate substances, prolonging the shelf life of food products, preserving the integrity of functional components post-consumption, and enhancing the absorption of bioactive molecules.

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Nanotechnology in Food: Applications and Safety Considerations

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Understanding and manipulating matter at dimensions between 1 and 100 nm, where special phenomena allow for fresh applications, is referred to as nanotechnology. It is also known as the study of atomic and molecular scale manipulation of matter. Its scale varies from 1 to 100 nm, extending its potential from mechanics to medicine and enabling the development of new tools and methods. A nanoparticle is a tiny item that functions as a single entity for various purposes based on its properties. They are categorised based on their traits, dimensions, and structures. It deals with objects that can manipulate individual atoms and nanoscale building blocks, as well as materials having nanoscale structures.

Nanotechnology harnesses the characteristics of nanoparticles in multiple domains across a wide range of sectors. In the fields of engineering, energy, and medicine, there have been significant advances in nanotechnology. Food and farming systems could be revamped by nanotechnology. The features of the food at the nanoscale level can impact new goods and ingredients' molecular production as well as its efficacy, bioavailability, nutritional value, and safety. One of humanity's greatest problems — the food crisis, is being addressed with the use of nanotechnology. An array of products has been discovered recently, including nanoparticulate delivery systems that serve a variety of processes, including transporting functional compounds to the site of action, and nano encapsulated food ingredients.

The United States Department of Agriculture (USDA) roadmap, which was issued in 2003, was the first to explore the use of nanotechnology in the agriculture and allied sectors.

Government-funded programmes and research centres have been developed in nations including Brazil, India, the Philippines, Chile, Mexico, and South Africa, with many developing nations emerging as leaders in the field of nanotechnology. Nanotechnology is one such field where nations work together as well as compete with each other to attain the zenith of the field.

The safety of nanomaterials in food and food-related items will determine how well-liked they are by the general public. As a result, a unified international regulatory framework is required for nanotechnology in food.

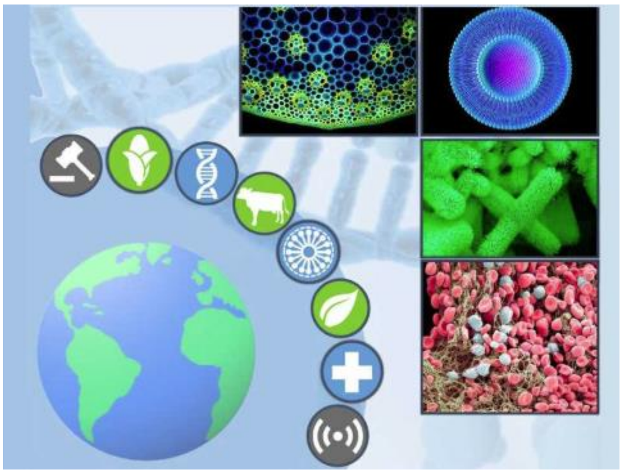

Fig 1: convergence of nanotechnology with food and agriculture

Image source: https://iupac.org/wp-content/uploads/2019/12/GRC-Nano_200621.png

Application of nanotechnology in food sector

Food packaging

Certain foods are highly perishable as they contain high amounts of moisture and make it unacceptable for its consumption by the consumers during prolonged storage. Packaging plays a crucial function in protecting these foods from the environment, keeping them contained, extending the shelf life of food, increasing food safety and maintaining its nutritional value. The use of nanotechnology in food packaging is expanding substantially globally. Initially the nanocomposite was created by combining an organic and an inorganic element in order to generate a material with greater durability. Nanotechnology can enhance the quality and safety of foods through packaging in a number of ways, including the enhancement of vapour and gas barrier attributes by the integration of nanofillers, antibacterial properties of nanocomposite films, and smart packaging based on nanosensors. An instance for this is a packing material composed of calcium carbonate and potato starch. The use of starch nanoparticles, also referred to as starch nanocrystals, as nanofillers in composite materials has been found to improve the strength, flexibility, biodegradability, water impermeability, heat, and barrier properties of the materials.

Dietary supplements

For increased absorption and bioavailability of nutrients and health supplements nanomaterials are used as components. The essential vitamins, flavors, minerals, antioxidants are encapsulated using nanotechnology that helps curb various deficiency symptoms and disorders. There is no denying the significance of a balanced diet that contains the essential nutrients in adequate amounts for the well-being of humans as well as animals. For these uses, biodegradable natural or semisynthetic nanocarriers such as "polymeric matrices, micelles, liposomes, nanoemulsions, solid lipid NPs, nanostructured lipid carriers", or appropriate inorganic matrices are particularly advantageous, ensuring not only improved stability but also frequently controlled release of nutrients.

Food processing

Farm to Fork. This is the common phrase that is used to describe food processing in recent times. It refers to various techniques and methodologies that are incorporated to transform a raw agricultural produce into a palatable food product. The method is used to enhance the taste, shelf life, texture of foods without leaching of its nutrients.

The basic idea behind adopting nanotechnology in food processing is emphasizing interactive foods and food preservation. In order to prepare and preserve beverages, meat, cheese, and other foods, nano-encapsulated active substances, including vitamins and fatty acids, are now commercially available. Many foods now employ nanoparticles to enhance their flow characteristics and stability upon processing. For instance, aluminosilicate compounds are frequently utilised as anticaking agents in granular or powdered processed foods. Milk protein self-assembled stiff hollow nanotubes that are a few micrometres long have the potential to be exploited as innovative ingredients for controlled release, viscosification, gelation, and nanoencapsulation processes.

Food storage

Nanomaterials' antibacterial qualities make it possible for them to keep food fresh during storage and transportation. Nano sensors are now employed to detect the quality deterioration during the storage of food products. Pathogenic bacteria, toxins that contaminate food, adulterants, fertilisers, pesticides, taste, and odour in stored products can be detected using the nanosensors.

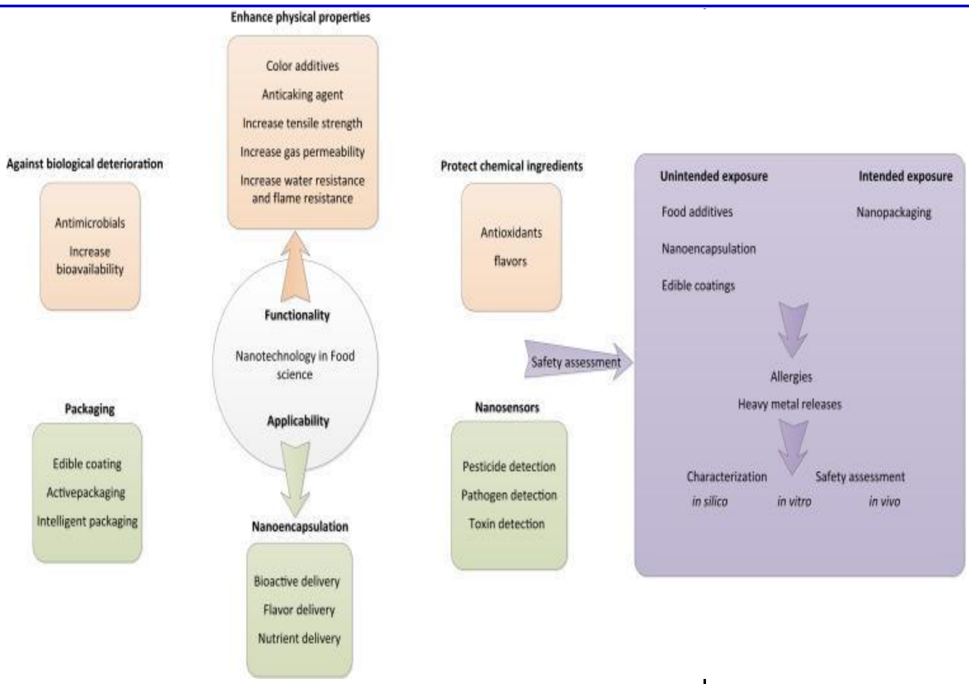

Fig 2: Diagram showing the functionality, applicability, and safety assessments of nanotechnology in food

Safety and efficacy of nanotechnology

It becomes inevitable that, whether intentionally or otherwise, human exposure to nanomaterials will rise in various ways. However, a few studies have investigated food samples used as food additives/ingredients and food packaging to examine the possible toxicity of the presence of nanomaterials in foods. The bioavailability, biodistribution, pathways, and ultimate toxicity of nanomaterials are all unidentified. They may bioaccumulate in numerous human organs after being absorbed in the digestive system, which could have negative effects. Additionally, nanoencapsulation permits oral ingestion of nanomaterials for direct contact with people.

The two major concerns of nanotechnology are allergy and heavy metal release, which cause adverse effects of nanomaterial exposure. Thorough characterization and assessment in silico, in vitro, and in vivo are required for the safe use of nanotechnology to the food companies. A study on TiO_2 in sugar-coated chewing gum indicated that over 93% of the TiO_2 in gum is of nanosize, drawing attention to the growing usage of nanomaterial substances in meals as flavour or colour enhancers

A report on the safety of food and animal feed using nanoscience and nanotechnology was issued in March 2009 by the scientific committee of the European Food Safety Agency. In May 2011, a document offering practical advice to regulators on how to assess applications from industry to use engineered nanomaterials in food additives, enzymes, flavorings, food contact materials, novel foods, food supplements, feed additives, and pesticides was released. This guidance document described how to assess potential risks associated with certain food-related uses of nanotechnology. Until the safety of nanotechnology products has been shown, certain social and non-governmental organisations, such as Action Group on Erosion, Technology, and Concentration (ETC Group), have advocated for a moratorium on their release.

Conclusion

The advancements in food processing nanotechnology are more concerned with the texture of food components, encapsulating food additives, creating novel tastes and sensations, managing the release of flavours, and enhancing the bioavailability of nutritional components. Due to the dependence of many foods' distinctive features on components with a size of a few nanometers, nanotechnology is a natural component of food processing and conventional foods. The safety of nanomaterials in food and food-related commodities will determine the level of acceptance by the general public. It is essential to have a unified international regulatory framework for food-related nanotechnology. Due to the special characteristics of nanomaterials, the food industry as well as related industries including agriculture, packaging, and food processing have seen significant changes.

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The Application of Micronutrients in Vegetable Crops: Enhancing Growth, Yield and Nutritional Quality

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Vegetable crops play a crucial role in human nutrition, providing essential vitamins, minerals, and dietary fibre. To ensure their optimal growth, development, and nutritional value, it is imperative to understand the importance of micronutrients. While macronutrients such as nitrogen, phosphorus, and potassium are vital for plant growth, micronutrients, including iron, zinc, manganese, copper, boron, molybdenum, and chlorine, are equally essential for their overall health and productivity. This essay aims to explore the application of micronutrients in vegetable crops, highlighting their significance in enhancing growth, yield, and nutritional quality.

In India, adoption of intensive and modern cropping practices with high-yielding crop cultivars and unbalanced fertilizer application resulted in emergence of widespread micronu- trient deficiency in soils and crops of India leading to re- duced crop yield and low micronutrient concentration in agricultural produce. According to results from the analy sis of more than 2.0 lakh soil samples collected from 508 districts of the country, on average 36.5, 12.8, 7.1, 4.2 and 23.2% soils are deficient in Zn, Fe, Mn, Cu and B respec- tively. More than 50% samples are found deficient in Zn and B in 110 and 63 districts of the country, respectively. Over the years, Zn deficiency has declined in soils of the country because of regular and more use of Zn fertilizer whereas deficiency of Fe and Mn increased slightly. In ad- dition, multi-micro and secondary nutrient deficiencies like S+Zn, Zn+B, S+B, Zn+Fe, S+Fe, Zn+Mn, Zn+Cu and Fe+B, S+Zn+B, S+Zn+Fe and Zn+Fe+B have emerged in different parts of the country. Responses of different crops to micronutrient application have been recorded in different micronutrient deficient soils. Inclusion of micronutrients in balanced fertilization schedule increased internal use effi- ciency of NPK. Therefore, micronutrient management de- pending upon crops, soil types, severity of deficiency, source, method, time, rates and frequency of application needs to be undertaken for sustainable agricultural production and maintenance of human health.

Importance of Micronutrients:

Micronutrients are required in smaller quantities but are equally vital for plant health. They play essential roles in various physiological and biochemical processes, including photosynthesis, enzyme activation, hormone synthesis, and cell division. Deficiencies of micronutrients can result in visible symptoms such as leaf chlorosis, stunted growth, poor fruit set, and reduced yield. Hence, the application of micronutrients is crucial for maintaining balanced plant nutrition and maximizing crop productivity.

Role of different micronutrients

- Iron (Fe) is an essential micronutrient required for normal growth and plant function. Iron act as catalyst in synthesis of chlorophyll molecule and helps in the absorption of other elements. It is a structural component of porphyrin molecules like cytochrome, hemes, hematin, ferrichrome and leg hemoglobin. These substances are involved in oxidation- reduction reactions in respiration and photosynthesis. It also involves in DNA synthesis, protein synthesis, reduction of nitrates and sulphates. Further many metabolic pathways are activated by iron and it is a prosthetic group constituent of many enzymes. Vegetable crops like tomato, onion, carrot and spinach contain high percentage of Iron.

- Zinc (Zn) is another important micronutrient that plays a critical role in plant growth and development. It is necessary for the synthesis of proteins and enzymes, and also plays a key role in the development of plant tissues. Zinc deficiencies can result in poor growth, small leaves, and poor crop yields. To address zinc deficiencies, farmers can apply zinc sulphate or zinc chelates to the soil or spray zinc foliar applications directly onto the leaves. In states like Gujarat, Bihar and Madhya Pradesh zinc deficiency is found almost stagnant during four decades despite much efforts have gone to popularize zinc application in various crops. Zinc deficiency is increasing in soils, so zinc content in seed and in blood plasma of animal and humans is decreasing. In Haryana and Punjab, zinc concentration in grains of wheat is improving from 23 to 72 mg kg-1.
- Manganese (Mn) serves as an activator for enzymes in growth processes. It assists iron in chlorophyll formation. It is part of the system where water is split and oxygen gas is liberated. The other protein in which manganese is an integral constituent is the manganese containing superoxide dismutase. This enzyme is widespread in aerobic organisms. The function of this enzyme is to provide protection from free oxygen radicals formed when O2 receives a single electron. Superoxide dismutase convert this highly toxic free radical into hydrogen peroxide (H2O2) which is subsequently broken down to water.
- Copper (Cu) is a secondary micronutrient that is important for carbohydrate and nitrogen. It is required for lignin synthesis which is needed for cell wall strength and prevention of wilting. It is present in plants in complexed form. Like other potentially toxic heavy metals, copper in excess is bound to phytochelatins (Greek meaning "plant claws") and sulfur containing peptides. Copper in solution is present as cuprous (Cu+) and cupric (Cu++). Cuprous copper is readily oxidized to cupric and so cuprous copper is only found in complexed forms. Cuprous complexes are usually colorless, whereas the cupric complexes are often blue or brown. Copper is an activator of several enzyme systems in plants and functions in electron transport and energy capture by oxidative proteins and enzymes. It may play a role in vitamin A production
- Boron (B) is another important secondary micronutrient that is necessary for the growth and development of vegetable crops. It plays a role in the development of cell walls, and is also involved in the transport of sugars and the metabolism of carbohydrates. It is necessary for sugar translocation and helps in pollen grain germination. It is present in soil solutions with a pH less than 8 mainly as an un-disassociated boric acid (B(OH)3), the principle form taken up by roots, and disassociates to B(OH)4 - only at higher pH values.
- Molybdenum (Mo) is a secondary micronutrient that is necessary for the metabolism of nitrogen in plants. It plays a key role in the conversion of nitrate to ammonia, which is necessary for the synthesis of amino acids and proteins. It is related to the valency changes it undergoes as a metal component of enzymes. Only a few

enzymes have been found to contain molybdenum in plants. In higher plants two molybdenum containing enzymes, nitrogenase and nitrate reductase, are of vital importance in crop production. All biological systems fixing N2 require nitrogenase. Each nitrogenase molecule contains two molybdenum atoms, which are associated with iron. Therefore, the root nodule requirement is relatively high.

- Nickel (Ni) is important for activation of urease, an enzyme essential for nitrogen metabolism and also control senescence. It is required for iron uptake and it can substitute for zinc and iron as a cofactor for some enzymes. It is considered as an essential element for higher plants nutrition; on the other hand, Ni at relatively higher concentrations may be toxic to most of plant species.
- Chlorine (Cl) is most commonly used as sanitizer, due to its low cost for maintaining the fruit quality like appearance, soluble solids content, acidity, pH, texture and flavor, shelf life and also control microbial growth. It is essential for photosynthesis (chlorotic tissues), helps in stomatal regulation and raises cell osmotic potential, necessary for shoot apex and root growth.
- Cobalt (Co) has a role in nodulation and hence it is imperative that adequate cobalt supply is made to lignin vegetables like French bean, garden pea, pea and other vegetable beans, and take advantage of their capacity for symbiotic N2 fixation. Economy in N also assures better soil-health due to reduced NO3 pollution and better organic matter status even in marginal soils.

Table – 1 Crop-Specific Micronutrient Requirements (in ppm)

Vegetable	Fe	Mn	Zn	Cu	B
Beans	50-300	50-300	20-200	7-30	20-75
Beet root	50-200	50-250	20-200	5-15	-
Brinjal	50-300	40-250	20-250	8-60	25-75
Cabbage	30-200	25-200	20-200	5-15	25-75
Carrot	50-300	60-200	25-250	5-15	30-100
Cauliflower	30-200	25-250	20-250	4-15	30-100
Onion	60-300	50-250	25-100	15-35	22-60
Peas	50-300	30-400	25-100	7-25	-
Radish	50-200	50-250	19-150	5-25	25-125
Tomato	40-200	40-250	20-50	5-20	25-60
Turnip	40-300	40-250	20-250	6-25	40-100

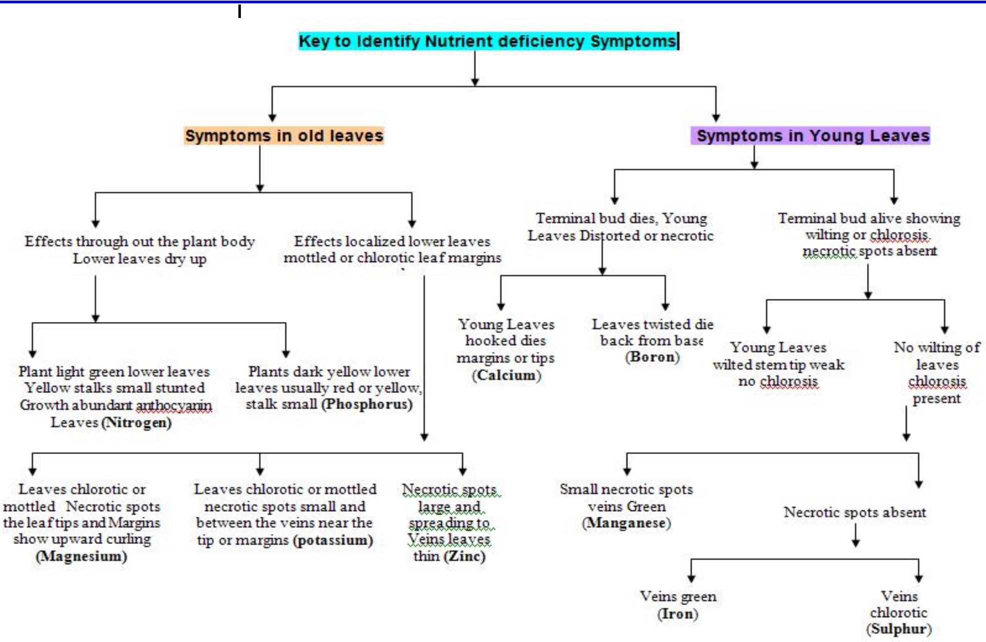
Source: Anjaneyulu, K. and Raja, M.E. (1999). Micronutrient disorders in vegetable crops and their correction. *Indian Horticulture (Jan.-March)*. pp 15-16.

General description of mineral toxicity symptoms on plants

- **B:** High B may induce some interveinal necrosis, and severe cases turn leaf margins straw color (dead) with distinct boundaries between dead and green tissue. Roots appear relatively normal.
- **Cl:** High Cl results in burning leaf tips or margins, reduced lead size, sometimes yellowing, resembles K deficiency, and root tips die.
- **Cu:** High Cu may induce Fe deficiency (chlorosis). Light colored leaves with red streaks along margins. Plants become stunted with reduced branching and roots are often short or

barbed (like wire). Laterals may be dense and compact.

- **Fe:** Excess Fe is a common problem for plants grown in flooded acidic soil. May induce P, K and Zn deficiencies. Bronze or blackish-straw-coloured leaves extending from margins to midrib. Roots may be dark red and slimy.
- **Mn:** Excess Mn may cause leaves to be dark green with extensive reddish-purple specks before turning bronze yellow, especially interveinal tissue. Uneven distribution of chlorophyll. Margins and leaf tips turn brown and die. Sometimes Fe deficiency appears, and main roots become stunted with increased number and density of laterals.
- **Mo:** Excess Mo induces symptoms similar to P deficiency (red bands along leaf margins), and roots often have no abnormal symptoms.
- **Zn:** Excess Zn may enhance Fe deficiency. Leaves become light colored with uniform necrotic lesions in interveinal tissue, sometimes damping off near tips. Roots may be dense or compact and may resemble bared wire.
- **Ni:** High Ni results in white interveinal banding alternating with green semichlorotic areas with irregular oblique streaking,dark green veins and brown patches. Yellowing of leaves may resemble Fe or Mn deficiency.
- **Co:** Pale green leaves with pale longitudinal stripes.



Source: https://agritech.tnau.ac.in/agriculture/mpt_key.jpg

General description of mineral toxicity symptoms on plants

- **Fe:** Leaves turn yellow, midriff remains green and middle part remains yellow, in severe conditions leaves become white, young leaves show stunted growth and in rare case edges of leaf and leaf tip are burnt.
- **Zn:** Deficiency of zinc causes the plant to appear weak, the leaves turn yellow, rust spots appear on the leaves and short internodes, the plant is stunted, the seeds are not filled, the leaves fall and the new leaves are small and bunched.
- **Cu:** Intervein turns yellow, leaves turn brownish green. Leaf loses its colour. The leaves are wilted. The top of the leaf dries up.
- **Mg:** New leaves become pale. The middle old leaves turn yellow and die. On top of it, white coloured spots are formed. Even the smallest veins remain green.
- **Mo:** The anterior surface of the leaf assumes a whip-like shape. The leaves are yellowish green and appear pale. Sometimes a gummy sap oozes

from under the affected branch. The leaves become twisted. The edge of the leaf breaks.

- **Bo:** The leaves around the growing bud turn blue, the leaf blade, bud and tip are especially affected and burn, growth is stunted and seeds do not set.

Type of application methods

Vegetable crops respond very well to the application of micronutrients. Generally, micronutrients are applied in following ways:

i. **Soil application:** Micronutrient containing materials can well be applied to soil mixed with other fertilizers at the time of land preparation or transplanting of vegetables. Care should be taken to avoid excess application of micronutrients to avoid toxicity. Doses of micronutrients depend on soil type, crop, etc. On the basis of soil and plant analysis report, the foliar recommendation has been given for different micronutrients is as follows: Rate of application varies with the type of soil. As a higher rate of manganese is required for both organic and sandy soils which are alkaline in reaction; high rate of zinc is applied when soil is neutral to alkaline in reaction.

ii. **Seedling root dip:** This method of application is not widely practiced in India. Generally, 0.2-0.3 per cent solution of zinc sulfate is used for root dipping of vegetable seedlings.

iii. **Seed treatment:** Seeds of vegetables can be treated with the chemical compounds containing Cu, Fe, Zn, B, Mn, etc. prior to sowing. Seed treatment of pumpkin and squashes with borax @ 0.5% increases number of female flowers and ultimately yield.

iv. **Foliar spray:** Foliar application of micronutrients is widely used. Most of the micronutrients, after foliar spray, enters the plant body though leaves within few hours to one day. They mostly enter the leaf via stomata. Since the stomata are mostly present on the undersurface of the leaf, the foliar spray should be applied to both under and upper surfaces of the leaf as evenly as possible for rapid and complete absorption of the nutrient solution. 2-4 foliar sprays at an interval of 7-10 days are sufficient to correct the deficiency symptoms.

Table 4: Recommended concentration of micronutrients for foliar application

Micronutrient	Concentration
B	0.5-0.6% borax
Cu	0.1-0.2% copper sulphate + 0.5% lime*
Fe	0.4% ferrous sulphate + 0.2% lime*
Mn	0.4-0.6% manganese sulphate + 0.2-0.3% lime*
Mo	0.05% sodium or ammonium molybdate
Zn	0.4-0.6% zinc sulphate + 0.1-0.3% lime*

*Lime is added to neutralize the solution, otherwise leaves may get scorched. Minimum 450 litres of water must be used per hectare.

Source: Choudhary, B.A., Sharma, B.D. and Sharma, S.K. (2013). Micronutrients in vegetable crops. CIAH/Tech./Pub. No. 44, pp. 25. Central Institute for Arid Horticulture, Bikaner, Rajasthan, India.

Application methods for vegetables

- Brinjal: Supplementation of copper (40 kg/ha) in unploughed soil increased the yield of brinjal as well as increased ascorbic acid content, in addition to significant increase in total soluble solids, crude protein and acidity quality. Ascorbic acid, acidity and protein content of the fruits can be improved along with brinjal production by spraying boron, and the time of first fruiting can be advanced by a week or so. Supplementation of zinc (25 kg/ha zinc sulphate) and copper (12.5 kg/ha copper sulphate) increases yield and ascorbic acid content. Combined supplementation of these elements maximizes yield and quality. Zinc and copper are necessary for high yield and quality of brinjal.

- Cauliflower: Along with the major nutrients, the production can be increased by the use of micronutrients such as zinc, boron and molybdenum. Soil application of zinc (4.2 kg/ha) significantly increased leaf area, boll size, leaf to boll ratio and cold weight. Such results are recorded in many parts of the country. Some micronutrients interact beneficially with the major nutrients. Also, some negatives are also seen. According to a study, these elements can be better utilized by cauliflower if boron is supplemented along with phosphorus. Boron deficiency does not cause cavities in bolls. Generally giving 15 kg borax per hectare can increase leaf number, boll size, boll weight and yield. Another important micronutrient for cauliflower is molybdenum, which was found to increase leaf width, boll diameter, boll weight and leaf molybdenum content at 0.24. Research has shown that adding sat, boron and molybdenum to the soil or by spraying can increase the production of cauliflower.
- Chilli: Plant height and leaf area can be increased by spraying boron. From the quality point of view, boron supplementation increases the content of ascorbic acid, casein and chlorophyll a, chlorophyll b and total chlorophyll. If potassium and zinc are supplemented simultaneously, the production is increased.
- Coriander: Many coriander seeds are added to vegetables and dishes as for flavour and aroma. Spraying of ferrous sulphate solution (0.5%) in deficient soils at 45 days after sowing has been found to be very beneficial for this crop.
- Garlic: Zinc is important in this crop with special medicinal properties. Its supplementation increases bud number and weight. The results also suggest that supplementation with selenium appears to increase the selenium content of garlic plants. Therefore, this sowing garlic on soil contaminated with selenium leads to its special uptake, hence it is worth considering from the health point of view.
- Onion: It provides protection against intense summer heat (loo). Onion is used throughout the year in salads, spices and cooking with other vegetables. Gujarat ranks first in the productivity of this crop. Spraying copper solution in onion maximizes productivity. Combined supplementation of copper, zinc, boron and iron has been found to be particularly useful for this crop. It also maximizes total soluble solids, total sugars and onion production and ascorbic acid.
- Okra: Spraying of copper (0.25%) in okra has been found useful. Besides, the yield can be increased by spraying the composite mixture.
- Potato: Potato is an important vegetable crop. Micronutrients like iron, zinc and boron and sulphur are especially useful for this. The maximum amount of iron is required in potato leaves at 40-70 days. So it is advisable to sprinkle iron after 40-50 days. Adding these nutrients to potato crops with manure can be of particular benefit.
- Sweet potatoes: Research suggests that boron supplementation has can be useful in increasing yield for sweet potato crops.
- Tomato: Calcium, zinc and boron are important micronutrients for tomato. Its supplementation can lead to increase in production along with better quality. High levels of ascorbic acid and

acidity can be achieved with zinc and boron supplementation.

Conclusion

In conclusion, the application of micronutrients in vegetable crops is essential for maximizing their productivity and nutritional value. Micronutrients such as iron, zinc, manganese, copper, boron, and molybdenum play critical roles in various plant processes, including photosynthesis, enzyme synthesis, and nutrient uptake. Deficiencies in these micronutrients can lead to stunted growth, poor crop yields, and nutrient deficiencies in the harvested vegetables. However, by applying micronutrient fertilizers to the soil or using foliar sprays, farmers can effectively address these deficiencies and promote healthy growth and development in vegetable crops. By recognizing the importance of micronutrients and implementing proper application strategies, farmers can enhance the quality and quantity of vegetable production, contributing to improved food security and nutrition for the growing population.

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Table 2: Micronutrient absorption by vegetables (g/ha)

Type of Crop	Area cultivated	N	P	K	S	Fe	Mn	B	Zn	Cu	Mo
Vegetable	884	21.72	25.68	229.2	14.93	3926	238	501	151	102	21

Source: Fertilizer News (2001), 46(5) pg: 41-56

Table 3: Source and rate of micronutrients for soil application

Micronutrient	Source	Quantity required (kg/ha) (every 3 years)	Volume of solution + Lime solution Percentage (for spraying)
B	Borax- 11% Boron Boric acid- 17% Boron	15 10	0.2
Cu	Copper sulfate- 25% Cu	20	0.4+0.25
Fe	Ferrous sulfate- 20% Fe	50	0.5+0.25
Mn	Manganese sulfate- 24% Mn	40	0.5+0.25
Mo	Sodium molybdate- 38% Mo Ammonium molybdate- 54% Mo	1.5 1	0.05
Zn	Zinc sulfate- 21% Zn	25	0.5+0.25

Source: Shakbhaji Pako Magazine (March 2013) AAU

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Plant-Based Meat Alternatives: Navigating Consumer Preferences, Health Implications, and Environmental Impact

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Existing food systems pose threats to both human well-being and the environment. Research indicates that a shift towards reduced meat consumption and increased reliance on plant-based foods would align with goals related to climate change mitigation and public health enhancement (Bryant *et al.*, 2019). To facilitate this transition, it is crucial to gain a deeper understanding of the factors influencing individuals' choices of plant-based foods. A robust industry centered around plant-based foods has emerged to cater to consumer preferences and encourage the adoption of plant-based diets. Traditional plant-based diets are characterized by their low energy density, rich nutrient content, and minimal saturated fat, which are believed to offer various health advantages. However, the contemporary fast-paced way of life has fueled a rising demand for plant-based convenience foods that simulate the taste and texture of meat, often through intensive processing. While processing can enhance safety, taste, and nutritional enrichment, it is noteworthy that extensive processing, particularly ultra-processing, has been linked to adverse health effects.

Certain calculations indicate that the production of food is currently accountable for about one-third of human-caused greenhouse gas emissions. Additionally, meat and dairy products necessitate greater land and water usage compared to plant-based foods, potentially contributing to the advancement of deforestation and the decline of biodiversity. Despite being historically perceived as a vital dietary element, supplying essential nutrients like vitamin B12, iron, and calcium, excessive consumption of meat, especially processed varieties, has been linked to specific harmful health outcomes. Current levels of consumption of animal-based protein are at an unsustainable level. In the year 2021, global meat consumption was estimated to reach 328 million metric tonnes, with a projected increase of roughly 70% by the year 2050. The excessive intake of red and processed meat has been linked to an elevated risk of non-communicable ailments such as type 2 diabetes, colorectal cancer, and a decrease in life expectancy (Richi *et al.*, 2015). In fact, the World Health Organization (WHO) categorizes red meat as a Group 2A carcinogen (a probable cause of cancer) and processed meats as a Group 1 carcinogen (a confirmed cause of cancer) (Bouvard *et al.*, 2015).

Innovative plant-based meat substitutes, crafted to mimic the cooking techniques, sensory attributes, and nutritional characteristics of their animal-based counterparts, could present a promising route to assist in achieving the necessary dietary change (Choudhury *et al.*, 2020). This progressive move towards less meat consumption and greater involvement with plant-derived foods has reportedly led to a flourishing industry centered around plant-based foods. However, expediting this transformation necessitates an enhanced comprehension of the factors that shape decisions related to the selection of plant-based foods.

Consumer factors impacting the choice of plant-based foods

An individual's food-related actions can be influenced by a variety of intricately interrelated circumstances. General and plant-based food preferences have been observed to be mostly influenced by taste, price, and convenience. These are considered the primary factors. Demand for plant-based foods has increased, more closely matched with aspirational factors due to growing awareness of animal welfare, environmental sustainability, and personal wellness (Figure 1).

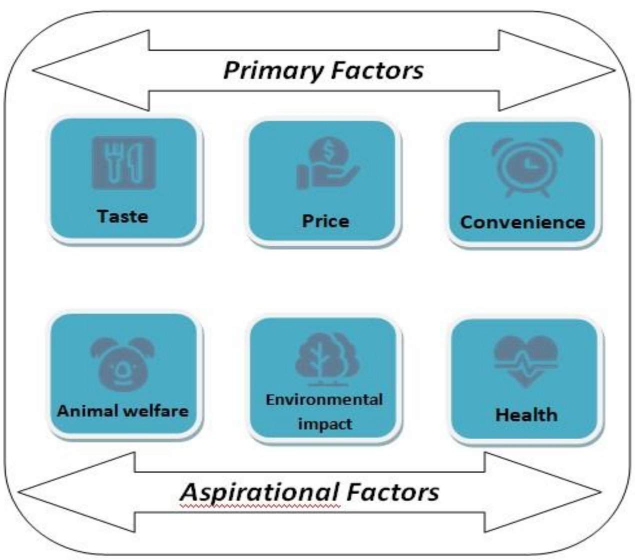

Figure 1: Key factors influencing consumer choice of plant-based foods

A) Primary factors

a) Taste

Novel PBMAs resembles the sensory characteristics of meat, setting them apart from early generation PBMAs like soy and tofu. According to Bryant (2022), PBMAs that successfully mimicked the flavour and texture of processed meat have the best chance of displacing products that are based on meat. Numerous studies have stressed the importance of establishing desirable sensory qualities, such as taste, texture, look, and fragrance, in order to win over and retain customers. However, it is extremely difficult to duplicate desired meat qualities. In meat-based analogues, for instance, the higher lipid content adds flavour and texture that aren't present in PBMAs, making them less juicy.

Legumes as a substitute protein source may also have a detrimental effect on the flavour. Consequently, taste can be seen as both a barrier and a facilitator. Adoption of PBMAs may also be hindered by the influence of hedonic features of pleasure induced in response to perceived sensory characteristics. Consumer linkages between meat and "delicious" as opposed to "disgust" for PBMA were reported by Michel et al (2021). Customer perceptions may provide insightful information, but as they are self-reported, they cannot be directly compared to customer acceptability. High levels of food neophobia and high meat attachment have been identified as major obstacles to the adoption of PBMAs. It's interesting to note that vegetarians and vegans are more likely to accept replacements that don't taste like meat, whereas omnivore/flexitarian subgroups prefer items that do.

b) Price

Consumer engagement is hampered by the PBMAs' allegedly expensive cost (Michel, Hartmann, & Siegrist, 2021). A number of cross-sectional studies have found that PBMA engagement in the present and the future is significantly influenced by affordability. Survey results may be impacted by sociodemographic variables and respondents' annual income, with cost being identified as a key product attribute among low income groups and those with lower educational outcomes, while engagement with PBMAs is reportedly higher among those with higher socioeconomic status (Hoek et al., 2011).. Consumer segmentation may also have an impact on the response: although vegetarians were reportedly more hesitant, meat consumers identified the cost of Quorn as a drawback. While further research into the association between dietary habits and sociodemographic traits is necessary, it is evident that innovative PBMAs' pricing is a critical factor in determining whether or not they will be adopted by a variety of consumer sectors.

c) Convenience

Convenience and its alleged impact on self-efficacy may also limit consumption of plant-based diets. Elzerman, van Boekel, and Luning (2013) investigated consumer experiences and contextual factors related to meat substitutes. According to the study, people believed that preparing a desirable dinner using PBMAs would take substantially longer than preparing a similar meal using meat. Since flexitarians and meat eaters are more frequently found in households with children and prioritise time convenience more than meat avoiders, demographic factors may be significant confounders. It is possible to hasten the adoption of plant-based dietary patterns by creating and promoting widely accessible PBMAs that are quick to prepare and contextually suitable meat alternatives.

B) Aspirational factors

While the three main determinants of food choice—taste, price, and convenience—are substantial, animal welfare, environmental impact, and health also play a considerable role.

a) Animal welfare

Animal welfare has consistently served as a motivator for meat avoidance, even while questions about disparities in global meat production standards and problems with the transportation of live animals continue to have an impact on the progressive decline in meat consumption. Neff et al (2018). discovered that, in contrast to other factors like cost and health, just 12% of respondents in the USA mentioned reduced meat intake as a result of concerns about animal welfare. Varying outcomes could stem from consumer subgroup disparities, with rural individuals less impacted than urban counterparts, influenced by animal husbandry experiences or limited access to large supermarkets. Additionally, vegetarians and vegans have a tendency to value animal welfare more highly.

b) Environmental impact

36% of respondents to a recent food standards agency study indicated they would be open to trying plant-based proteins for sustainability-related reasons as opposed to health (39%) and safety (44%). This reinforces the findings that omnivores and semi-vegetarians' adoption of a plant-based diet is more influenced by their own health than by environmental sustainability. Therefore, when it comes to consuming less meat and more plant-based diets, personal health benefits could prevail over altruistic considerations. Age and sex are noted to influence both the level of awareness and importance of the environmental impact of meat consumption, with these effects appearing to be greatest among younger adults, Millennials, and females as compared to older adults and males. Demographic characteristics of study respondents predict consumer behaviour.

c) Health

Excessive intake of red and processed meat has been linked to negative health effects, including a higher risk of type 2 diabetes, colorectal cancer, and a shorter life span. Because of this, consumers have changed their eating habits to consume fewer foods derived from animals and more plant-based meals as a result of increased consumer awareness of potential health benefits. Consuming plant-based foods is thought to have health benefits due to their predicted nutritional profile (low energy density, low saturated fat content, rich micronutrient profile), as well as the likely physiological effects of diet adoption (altered cardio-metabolic risk and decreased risk of obesity).

Health benefits for novel plant-based meat substitutes

Regarding the health benefits of innovative PBMAs and their ability to match the nutritional profile of meat-equivalents, the published scientific information is unclear. In their investigation of Australian supermarkets, Curtain and Grafenauer (2019) reported that the majority of PBMAs had a healthier nutritious profile than meat-based analogues. For instance, PBMAs had much higher levels of dietary fibre and significantly lower levels of calorie density, total fat, and saturated fat. However, just 4% of PBMA products were designated as "low in sodium," indicating that the sodium level of these items was unusually high (Alessandrini *et al.*, 2021). In fact, meat sausages contained considerably more salt than PBMAs, whereas plant-based mince had a 6-fold higher sodium load than the meat-based equivalent. According to several researches, PBMAs often contain less saturated fat, more dietary fibre, and much more sodium than their meat-based counterpart. Non-haem iron, which is mostly found in plant-based foods and has a significantly lower bioavailability than haem iron, which is the main form of iron found in foods originating from animals, is another reason why PBMA fortification is necessary.

Conclusion

Food producers are now acknowledging the need for thorough studies that take into account a variety of factors, such as level of processing and nutritional composition, in order to create products with healthier nutrient profiles. Understanding how prolonged processing affects health impacts may serve to support the implementation of novel techniques intended to maintain linked health benefits. Additionally, expanding our understanding of the nutritional benefits of PBMAs will help us spot ways to improve their health profile and encourage consumers to make wise food decisions.

Finally, a better knowledge of the variables affecting target consumer subgroups' involvement with PBMAs could aid in the manufacture of appealing, healthier plant-based foods. Such an evidence-based approach to food production has the potential to improve both human and planetary health in the future.

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Advancement in Food Processing and Preservation Techniques

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In a world where the focus is on achieving environmental sustainability and ensuring food security, the food industry's continuous growth relies heavily on innovation. Moreover, responding to the demand for intricate and varied food products requires constant product innovation. Contemporary food technology offers a range of fresh processing possibilities to consider, potentially leading to a broader array of food industry products and processes that are both more competitive and resource-efficient. Numerous of these inventive technologies present novel avenues for creating new food items and enhancing the safety and quality of traditionally produced foods using gentler processing methods.

Novel processing technologies come with several challenges that must be tackled throughout their journey from conception to practical implementation. Specifically, ensuring the correct utilization, advancement, and fine-tuning of appropriate machinery and procedural parameters demand a substantial increase in knowledge and comprehension. Food processing technologies cover a wide array of methods and approaches used to transform raw agricultural resources into safe, nutritious, and easily consumable food items. These technologies encompass a range of procedures including cleaning, sorting, categorizing, heating, cooling, drying, fermentation, extraction, packaging, and preservation. These techniques not only improve the taste and extend the shelf life of food but also guarantee adherence to safety regulations.

Food safety guarantees that food items are devoid of impurities, harmful microorganisms, poisons, and any other dangers that might endanger consumers' well-being. Quality pertains to the sensory qualities, nutritional composition, and overall superiority of food products, encompassing factors such as flavor, visual appeal, consistency, fragrance, and nutritional significance. Moreover, sustainability concentrates on diminishing the environmental consequences of food manufacturing, curbing waste, conserving resources, and advocating ethical procedures across the entirety of the food distribution network. Through preventing spoilage, decreasing microbial presence, and maintaining the nutritional integrity of food, these processing technologies play a vital role in enhancing worldwide food security and public health.

Overview of Food Processing and preservation Technologies

Food processing technologies involve a diverse set of methods, procedures, and machinery employed to convert raw agricultural resources into safe, user-friendly, and enhanced food products with added value. The emergence of new and contemporary trends in food processing methods stems from the consumer desire for foods that promote health and offer elevated nutritional and nutraceutical benefits. Throughout history, the food industry's primary focus was on creating safe products with extended shelf-lives. However, in today's landscape, meeting consumer demands goes beyond mere safety. Consumers now expect food products to offer substantial nutritional benefits, bioactive compounds, and pleasing sensory characteristics. The desirable qualities of food, including its taste, texture, appearance, and nutritional content, are heavily influenced by the methods of food processing employed.

Microorganisms have long been the primary culprits behind food spoilage and contamination, prompting various preservation techniques to combat them. Industrial food processing methods generally involve either eliminating these microorganisms or impeding their growth. Conventional heat-based approaches like thermization, pasteurization, and in-container sterilization have the downside of potentially compromising taste, nutritional value, and appearance. In response to consumer demands for higher quality and more tailored food products, the industry has shown keen interest in non-traditional methods of food processing. These innovative techniques, often referred to as "novel" or "emerging," aim to overcome the limitations of traditional thermal processing, ensuring that food products maintain their integrity and better cater to consumer preferences.

Novel Food Processing Technologies

Thermal treatment is a widely employed method for prolonging the shelf life and ensuring the microbiological safety of food items due to its capability to deactivate microorganisms and spoilage enzymes. However, this approach can have adverse impacts on the excellence and nutritional aspects of fruit-based consumer goods. The components responsible for color, flavor, and taste are generally sensitive to heat, making thermal processing capable of significantly altering the caliber of commercial fruit products and influencing consumer acceptance. As a result, the quest for alternative approaches to thermal food processing, which can yield safer products with enhanced quality, nutritional value, and sensory characteristics, prompted food scientists to explore alternative methods of deactivation.

Presently, there are two primary categories of food processing technologies being investigated: non-thermal methods, which rely on physical barriers like pressure, electromagnetic fields, and sound waves to deactivate harmful elements, and innovative thermal processing methods that primarily harness energy from sources such as microwaves and radio frequencies. However, inactivating microorganisms and enzymes in food by using such novel technologies is not enough. Ensuring product safety also involves eliminating toxic substances and preventing any contact between food and specific materials during the processing phase. Thus, evaluation of the overall quality of food products processed by innovative technologies is an essential requirement before a product can be commercialized.

Table 1: Novel food processing technologies

Thermal technologies	Non-Thermal Technologies
Microwave	High hydrostatic pressure
Radio Frequency	Pulsed electric fields
Ohmic - Heating	Irradiation
Inductive Heating	Ultrasound
	Inductive heating
	Cold plasma
	Ozone
	Supercritical water

A) Advancements in thermal processing methods

Thermal processing plays a critical role within the food industry by offering efficient solutions for transferring heat in a range of food processing tasks. Modern advancements in food processing technologies have introduced novel thermal methods that bring notable advantages in enhancing food safety, quality, and sustainability.

Microwave processing involves the utilization of electromagnetic waves within the microwave frequency spectrum to heat and cook food items. This approach presents numerous benefits, including quick and even heating, retention of sensory characteristics and nutritional integrity, as well as reduced processing durations in comparison to established techniques. Microwave processing has effectively been employed across diverse food categories, encompassing fruits, vegetables, meats, and baked goods. Nonetheless, addressing obstacles related to heat transfer constraints in specific products, managing moisture movement, and ensuring the use of suitable packaging materials is necessary to promote broader adoption of this method.

Ohmic heating, also referred to as Joule heating or electrical resistance heating, encompasses the application of alternating electric current through food items to generate heat. This approach presents merits such as accurate and manageable heating, decreased processing durations, and enhanced product excellence attributed to minimal temperature differences. Ohmic heating has effectively found application in diverse food categories, including soups, sauces, and beverages. Nevertheless, addressing issues like electrode fouling, regulating electrical conductivity in varying food compositions, and enabling scalability for industrial usage remain areas requiring attention.

Radio frequency (RF) heating entails the utilization of high-frequency electromagnetic waves to generate heat within food items via molecular friction. This technique provides benefits like swift and thorough heating, energy efficiency, and heightened product quality and safety. RF heating has effectively found application in a variety of food products, ranging from grains, nuts, seafood, to confectionery goods. Nonetheless, addressing hurdles such as uneven heating, managing moisture retention, and the necessity for specialized machinery and packaging materials is essential to facilitate wider adoption of this approach.

B) Advancements in non-thermal processing technologies

Alternative to conventional thermal processing, non-thermal processing technologies have garnered notable interest within the food industry. These groundbreaking methods provide a range of advantages concerning food safety, quality, and sustainability.

Ultraviolet (UV) light treatment is a non-thermal approach that utilizes UV-C radiation to deactivate microorganisms present on the surfaces of food items. It presents merits such as brief treatment durations, efficacy against a wide range of pathogens, and its non-thermal character. UV light treatment has been effectively employed in a variety of food items, spanning fruits, vegetables, juices, and water. Nevertheless, addressing obstacles connected to depth of penetration, inconsistent treatment, and potential alterations in sensory qualities and nutritional content is necessary to broaden its application.

Cold plasma technology entails the utilization of ionized gases at low temperatures to create reactive species capable of deactivating microorganisms and altering the surface characteristics of food items. This non-thermal technique offers benefits like quick treatment durations, adaptability to both solid and liquid foods, and its non-thermal nature. Cold plasma has found application in diverse food items, spanning fruits, vegetables, meats, and packaging materials. Yet, addressing challenges like intricate equipment requirements, management of plasma parameters, and the necessity for extended research on its enduring impacts is crucial for its broader incorporation.

Ultrasound processing employs high-frequency sound waves to disturb cellular structures, improve mass transfer, and streamline diverse food processing tasks. This non-thermal method presents advantages such as limited influence on sensory characteristics and nutritional content, enhanced extraction effectiveness, and its non-thermal characteristic. Ultrasound processing has effectively been employed in numerous food operations, encompassing extraction, emulsification, and preservation. Nevertheless, addressing issues like fine-tuning process parameters, managing cavitation effects, and ensuring scalability for industrial usage is essential for wider implementation.

C) Advancements in preservation techniques

Ensuring the safety, excellence, and sustainability of food products relies heavily on preservation methods. Recent progress in food processing technologies has introduced inventive preservation approaches that bring noteworthy advantages compared to conventional methods.

High-pressure processing (HPP) involves subjecting food items to elevated pressures, typically between 100 and 900 mega pascals, effectively deactivating spoilage microorganisms and extending product shelf life. HPP presents several benefits, including minimal impact on sensory qualities and nutritional content, as well as the capacity to neutralize pathogens without resorting to heat or chemicals. It has found successful application across a diverse array of food products, including juices, meats, seafood, and ready-to-eat meals. However, addressing issues like equipment expenses, limited penetration in larger items, and potential alterations in product texture and appearance is essential for its widespread adoption.

Pulsed electric field processing (PEF) encompasses the application of brief, high-voltage electrical pulses to food items, leading to the disruption of cellular membranes and microbial structures. PEF provides benefits such as limited heat production, preservation of sensory and nutritional attributes, and suppression of enzymatic activity. It has effectively been utilized in an array of products, spanning fruits, vegetables, dairy, and liquid foods. However, addressing issues such as restricted implementation on an industrial scale, refining process parameters, and managing electrode fouling is crucial for its broader acceptance.

Hurdle technology integrates a range of preservation methods, such as regulating temperature, adjusting pH, reducing water activity, and applying antimicrobial treatments, to collectively create a synergistic impact that retards microbial proliferation and extends the lifespan of food items. This approach provides versatility in customizing preservation factors to suit individual food products, guaranteeing safety while upholding quality traits. Hurdle technology has been effectively utilized across different product types, including processed meats, sauces, and ready-to-eat meals.

Implication and Future Scope

The progress in food processing technologies carries notable consequences for how consumers perceive products, the direction of market preferences, regulatory evaluations, and the overall uptake of these innovative methods. The evolution of food processing technologies significantly shapes how consumers perceive products and steer market trends. Consumers are progressively recognizing the significance of food safety, excellence, and sustainability. The integration of pioneering processing techniques that elevate these dimensions holds the power to sway consumer choices in the marketplace. Approaches like high-pressure processing, novel preservation methodologies, and intelligent packaging systems have the capacity to offer consumers safer and superior food items. Moreover, incorporating sustainable practices into food processing, including the adoption of energy-efficient machinery and environmentally friendly packaging, aligns with the escalating consumer desire for products that reflect environmental responsibility.

The potential for future advancements and areas of extended research and development within food processing technologies is substantial. Sustained exploration and inventive efforts are imperative to tackle emerging hurdles and maximize the potential of these innovations. A notable realm for exploration lies in crafting integrated strategies that amalgamate various technologies to attain synergistic outcomes in the realms of food safety, quality, and sustainability.

Conclusion

These pioneering processing technologies have played a significant role in elevating the quality, safety, viability, and bioactivity of functional elements in food. The adoption of novel and inventive processing methods is expanding extensively due to their positive influence on health, resulting in fewer consumer grievances. In the foreseeable future, traditional thermal processing is anticipated to be entirely substituted by innovative food processing techniques, as these methods are swiftly gaining traction on the global stage. These technologies are of utmost importance in fulfilling consumer expectations, molding market dynamics, and steering the trajectory of the food industry moving forward.

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Packaging of Milk and Milk Products

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The art of using the best possible materials for carrying, identifying, and merchandising any product is known as packaging. It serves as a crucial link between the producer and the final consumer to ensure the product is delivered safely through all the pathways including manufacturing, storage, transport, distribution, and marketing stages. Protective packaging is required to withstand the risks of climate changes, shipping, handling, etc. in order to offer fresh, sound, and convenient forms of milk and to minimise losses (Paine& Paine, 2012).

Currently, milk production is increasing at a global pace of 2%, while it is increasing at a rate of over 6% in India. India has substantially higher per capita milk availability than the rest of the globe (Boland& Hill, 2020). When compared to the global average of 322 grammes per day in 2021, the country's daily milk consumption increased from a low of 107 grammes per person in 1970 to 427 grammes per person in 2020–21 during three decades (the 1980s, 1990s, and 2000s).

Packaged, branded pasteurised milk makes up just 12% of the milk sold today. The proper packaging of dairy products is crucial not only to maintain nutritional content and reduce waste, but also to increase marketability and generate higher profits. There are many different forms of milk that provide packaging manufacturers in the fields of glass, metal, paper, plastics, etc. with a wealth of difficult chances to innovate and introduce packaging solutions that may be readily adopted in our nation (Muehlhoff& Bennett, 2013).

The packaging industry's challenge is to provide consumers with nutrient-dense dairy products in the most cost-effective, hygienic, secure, and environmentally responsible packages possible (Kawabata et al., 2020).

Selection of packaging material

Milk and dairy products are packaged using a variety of materials depending on the type of product, the processing and storage circumstances, the handling requirements, and the intended use. Most often used containers are laminates (multilayer materials), pouches, plastic tubs, cans, and glass and/or plastic bottles. All of them must give all product information mandated by law, which is something they all have in common (Mirza Alizadeh et al., 2021).

There is no "one size fits all" solution or good or terrible packaging material; instead, it all depends on striking the right balance between the required packaging function and the least possible environmental impact. Although it is normally necessary for a packaging material to be inert and not interact with the dairy product being packed, current trends are moving in the direction of developing packaging that does interact in order to increase the shelf life (Millican& Agarwal, 2021).

Types of packaging materials used for packing of milk and milk products (Atanu Jana, Food packaging technology)

Dairy product	Packaging material used
Packaging of fluid milk • Pasteurized milk	Glass / plastics (LDPE) / tetra packs
Packaging of cream	Polyethylene / Polystyrene / Polypropylene
Packaging of fermented dairy products • Yogurt	Polystyrene tubs covered with aluminium foil LDPE sachets, polystyrene cups,
• Buttermilk / sour cream/ lassi	polypropylene cups, wax coated paper Aseptic tetra packs,
• Dahi	Polystyrene / polypropylene cups with aluminium foils-based lids
• Shrikhand	Polystyrene / polypropylene cups
Packaging of ice cream	Liner less bleached sulphate board carton coated with wax / polyethylene wax blends Aluminium container Plastic container
Packaging of milk-based sweets • Khoa	Polypropylene containers with lids
• Peda	Paper board lined with polyethylene /
• Paneer	Polypropylene Vegetable parchment paper / polyethylene bags
• Rasogolla	Tin cans

The necessary characteristics of packaging materials for packing of milk and milk products are:

- Compatible with the product.
- Protection from mechanical risks, particularly those related to transportation.
- Work well with production lines.
- Advertising potential.
- Attractive appearance.
- Simple to handle while manufacturing, storing, and distributing
- Resistant against moisture.
- Enough mechanical strength to withstand shock, compression, vibration, etc.
- Resistance to acids and bases.
- Resistance to oil and grease.
- Product resistance to photochemical modifications.
- Tolerance to rodents and insects.
- Fireproof and water, fume, and smoke resistant.
- Inert: Has no impact on scent or flavour.
- Safe for human health.
- Economical
- Easy accessibility.
- Take precautions against climatic risks.
- Provide microbial protection.

Microbes should not live there; instead, it should govern growth factors to limit their proliferation.

Disposal of dairy packages

The empty packages that remain after product use must be thrown away, and they make up a sizable amount of the solid waste generated by the community. Authorities in the ministry or the department of public health are responsible for the garbage collection and proper disposal. The principal packaging materials that mix with municipal trash and pose a concern for proper disposal are glass, paper, plastic, and tin cans. Because many packaging materials cannot be properly disposed of in the environment without disrupting its stability, it is significantly more difficult.

Hierarchy of waste disposal

1. **Prevention:** Using proper packaging material might also aid in reducing waste.
2. **Minimization:** During the process of designing a package, one of the factors to be minimised is the mass and volume of the packing.
3. **Reuse:** Reusing a packaging material for several uses is recommended and hence long economic life.
4. **Recycling:** Reprocessing resources (packaging material) into new goods or new packaging material reduces the cost of final product.
5. **Energy recovery:** The heat from the packaging components can be used in permitted facilities for waste-to-energy from recycled materials.
6. **Disposal:** Some materials require incineration or deposit in a sanitary landfill (Patel et al., 2017)

Standardization in packaging of milk and milk products

There is a need to raise packaging standards as a result of rising industrialisation, increased milk output, value addition, better storage facilities, and advancements in transportation techniques. Modernising packaging standards will preserve food product quality, extend shelf life, satisfy market expectations, and maintain consumer trust.

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Powering Up Your Plate: The Nutrient-Packed Future of Biofortification

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Biofortification increases food crop nutrition using traditional breeding, genetic engineering, or agronomic methods. Biofortification boosts crop vitamin, mineral, and nutritional levels to promote consumer health. Biofortification is a sustainable and cost-effective way to address micronutrient deficiencies in two billion people worldwide, including vitamin A, iron, and zinc. This article discusses biofortification, its methodologies, success stories, pros, cons, and possibilities for world health and nutrition.

Biofortification History

Biofortification began in the early 20th century when scientists realized that specific nutrients were vital for human health. Vitamin A, vital for vision and immunological function, was discovered in the 1930s. Researchers discovered the importance of iron and zinc in reducing micronutrient deficits. Biofortification began in the 1970s when researchers began developing crops for nutritional content. The first successful biofortification effort was breeding corn with high lysine levels, which are needed for human growth and development. This led to high-protein wheat and rice biofortification efforts. IPNI promoted biofortification in the 1990s. Iron, zinc, and vitamin A-rich crops were the IPNI's focus. This research produced vitamin A-rich orange-fleshed sweet potatoes and iron-fortified beans. The Harvest Plus program developed and promoted biofortified crops in underdeveloped nations in the early 2000s. The program developed local, consumer-friendly crops. High-iron beans, zinc-enriched wheat, and vitamin A-enriched maize have been biofortified by the initiative. Biofortification research is still significant. Biofortification is a promising way to address micronutrient deficiencies in vulnerable people worldwide, since good nutrition is increasingly recognized as essential to health and well-being.

Why Biofortification Needed?

Micronutrient deficits afflict two billion individuals worldwide, necessitating biofortification. Micronutrient deficiencies, which result from not getting enough vitamins and minerals, can cause anemia, immunological dysfunction, and cognitive decline. In underdeveloped nations, where people eat rice, wheat, and maize, micronutrient shortages are common. Heavy users of these crops may be deficient in micronutrients such iron, zinc, and vitamin A. Micronutrient deficits can be dangerous, especially for pregnant women and small children. Vitamin A insufficiency can cause blindness and infectious illness death, whereas iron deficiency can cause anemia, weariness, and cognitive impairment. Food fortification and supplementation schemes have difficulties in addressing micronutrient deficits. In places without processing facilities or stable supply chains, food fortification and supplementation initiatives can be costly and difficult to deliver. Biofortification addresses micronutrient shortages sustainably and cheaply. Biofortification can improve staple crop nutrition over time by breeding crops high in critical micronutrients like iron, zinc, and vitamin A.

Locally farmed biofortified crops are cheaper and more accessible to vulnerable populations. Micronutrient deficits, especially in vulnerable populations, necessitate biofortification. Biofortification breeds crops naturally abundant in critical micronutrients to improve staple crop nutrition.

Biofortification Methods

Several biofortification technologies improve crop nutrition. These are:

1. **Conventional breeding**: Plants with favorable features are selected and crossbred to develop new types with better nutrition. This approach has increased micronutrient levels in crops like iron, zinc, and vitamin A (Goel et al. 2018).
2. **Genetic Engineering**: Transferring genes from one organism to another creates a new plant variety with higher nutritional value. Scientists transferred the gene that produces beta-carotene, a precursor to vitamin A, from a daffodil plant to rice, creating a vitamin A-rich rice variety (Kaur et al. 2019).
3. **Agronomic Practices**: These farming methods boost crop nutrition. Micronutrient-rich fertilizers can boost crop iron and zinc levels (Ali et al.2019).
4. **Microbial biofortification**: Bacteria and fungi are used to improve crop nutrition. Some bacteria can transform atmospheric nitrogen into a form that plants can use, increasing crop protein (Hoekenga 2014).
5. **Transgenic Biofortification**: Inserting genes into a plant's genome creates a nutritionally superior variant. Unlike genetic engineering, this approach inserts genes from the same plant species (Shreya et al. 2013).

Each biofortification approach has pros and cons, depending on the crop, nutritional goal, and local farming practices. All strategies aim to increase crop nutrition and consumer health.

Success Tales

Gold Rice

Golden Rice, a genetically modified rice, combats vitamin A deficiency, which affects millions globally. Genetically altered rice grains produce beta-carotene, a vitamin A precursor. Golden Rice can provide most of a person's vitamin A needs. A team lead by Drs. Ingo Potrykus and Peter Beyer produced Golden Rice in the late 1990s. Anti-GMO and environmental groups opposed Golden Rice. Recently, Golden Rice has been licensed for production and consumption in various countries as a safe and efficient strategy to treat vitamin A deficiency (Dubock 2019).

Iron-Biofortified Beans

Iron deficiency is widespread, especially in developing nations. Iron-biofortified beans may solve this. Iron deficiency anemia, which can cause fatigue, weakness, and cognitive impairment, can be reduced by breeding beans with increased iron content. CIAT introduced BIO104, an iron-biofortified bean, in 2015. This conventionally bred bean has 50% more iron than others. BIO104 routinely consumed by mothers and children improves iron status and reduces anemia (Beebe 2020).

Zinc-Biofortified Wheat

Poor diets put millions of South Asians at danger of zinc deficiency, a major public health issue. Zinc-biofortified wheat may solve this. Zinc-rich wheat can boost nutrition. Zincol-2016, a zinc-biofortified wheat cultivar, was released by CIMMYT in 2016. Regular consumption of this wheat type improves zinc status. Farmers in South Asia, especially India and Bangladesh, are growing Zincol-2016 (Yaseen et al. 2020).

Orange-Fleshed Sweet Potato:

Millions of individuals in sub-Saharan Africa are at risk of blindness, immunological dysfunction, and other health issues due to vitamin A deficiency. Orange-fleshed sweet potato (OFSP) may solve this issue. Beta-carotene in this sweet potato turns to vitamin A. Dr. Robert Mwanga and his team produced OFSP in the 1990s through conventional breeding. Since then, Uganda, Ghana, and Kenya have pushed and accepted OFSP. OFSP consistently consumed by children and women improves vitamin A status and reduces vitamin A insufficiency.

Biofortification Benefits

Biofortification has various advantages over traditional micronutrient deficiency treatments, including:

Sustainability: Instead of expensive supplementation programs or fortification processes, biofortification breeds crops with naturally higher micronutrient levels.

Biofortification can be integrated into crop breeding efforts, making it cheaper than supplementation or fortification.

Biofortified crops can be cultivated and consumed locally, making them cheaper for vulnerable communities. Farmers can raise and eat locally adapted foods, promoting food security and self-sufficiency.

Biofortification does not need behaviour change, unlike food fortification, which requires consumers to eat processed foods containing critical micronutrients.

Improved Nutrition: Biofortified crops can sustainably improve staple crop nutrition, which can help vulnerable populations including pregnant women and small children.

No Risk of Overdose: Unlike supplementation, which can cause overdose if taken in excess, biofortification is a natural and safe technique to boost micronutrient intake because the nutrients are available in food in their natural form and at safe quantities.

Conclusion/Future Perspective

Biofortification may help micronutrient deficits in populations with little food diversity. Biofortification involves breeding crops with more iron, zinc, and vitamin A. Biofortified crops treat micronutrient shortages in underdeveloped nations in a sustainable and cost-effective manner. Biofortified crops increase crop yields and lower healthcare expenditures, improving population health and economics. Biofortification requires cooperation between farmers, scientists, legislators, and public health advocates. Research on nutrient-dense crops with improved nutritional profiles is promise for biofortification. Biofortified crops with high vitamin content, pest resistance, drought tolerance, and high yield potential are projected to evolve faster due to advances in biotechnology and genetics. More research is needed on biofortified crops' micronutrient-correcting abilities. To reach more communities and combat global malnutrition, biofortification requires public-private partnerships and government funding. In conclusion, biofortification is a sustainable solution to global hunger that requires ongoing research and application.

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Application of Simulation Software's in the Food Industry

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Simulation software has become a valuable tool in the food industry. It allows companies to analyse and optimize processes, develop new products, and reduce costs. In this article, we will explore the various applications of simulation software in the food industry, with examples of specific software programs.

Applications of Simulation Software:

Process Optimization: One example of simulation software for process optimization in the food industry is COMSOL Multiphysics. This software allows companies to model and optimize processes such as cooking, baking, and packaging. By modelling different scenarios and parameters, companies can identify the most efficient way to produce their products. This can lead to reduced production time, energy usage, and waste.

Product Development: Another example of simulation software is Simulink, which can aid in the development of new food products. By modelling the ingredients and production processes, companies can test different formulations and evaluate their impact on taste, texture, and nutritional content. This can help companies bring new products to market faster and with greater success.

Quality Control: For quality control, a software example is Ansys Fluent. This software can be used to identify potential quality issues before they occur. By modeling different scenarios and parameters, companies can identify potential sources of contamination, spoilage, or other quality issues. This can help companies take proactive measures to prevent quality issues and ensure that their products meet regulatory requirements.

Supply Chain Optimization: Simulation software such as Any Logic can be used to optimize the entire supply chain from sourcing raw materials to delivering finished products. By modelling different scenarios and parameters, companies can identify the most efficient and cost-effective ways to transport and store their products. This can lead to reduced transportation costs, improved inventory management, and faster delivery times.

Training: For training purposes, a software example is Virtual Plant by FLSmidth. This software allows employees to practice operating equipment and performing tasks in a safe and controlled environment. This can help reduce the risk of accidents and improve overall productivity.

Benefits of Simulation Software

The use of simulation software in the food industry offers several benefits, including:

Reduced Costs: By optimizing processes and supply chain logistics, companies can reduce costs associated with production, transportation, and storage.

Improved Product Quality: By identifying potential quality issues before they occur, companies can take proactive measures to ensure their products meet regulatory requirements and are of high quality.

Increased Efficiency: By modelling different scenarios and parameters, companies can identify the most efficient way to produce and transport their products, leading to increased efficiency and productivity.

Faster Time-to-Market: By using simulation software to develop and test new products, companies can bring products to market faster and with greater success.

Conclusion

Simulation software is a valuable tool for the food industry, with examples such as COMSOL Multiphysics, Simulink, Ansys Fluent, AnyLogic, and Virtual Plant. By using simulation software, companies can optimize their processes, develop new products, and improve overall productivity. As the food industry continues to evolve, the use of simulation software is likely to become even more important in ensuring the success of food companies.

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A choice between A1 and A2 milk type: A health concern?

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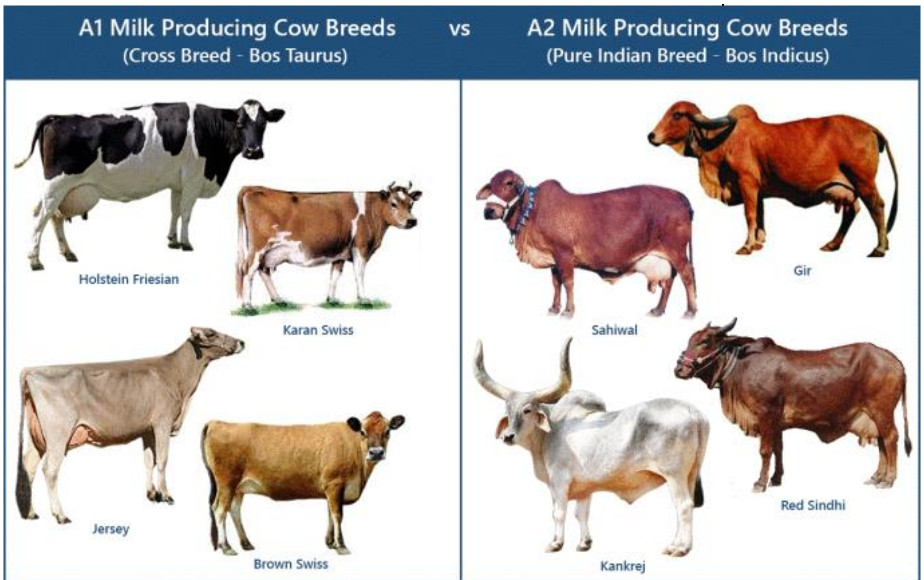
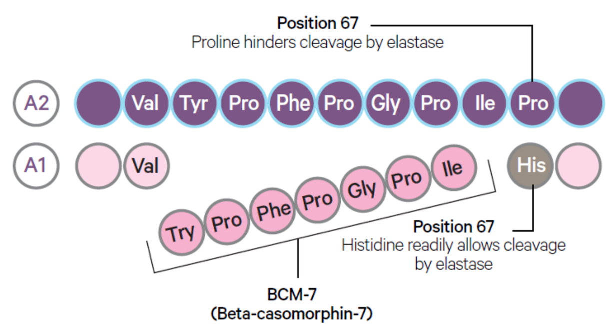


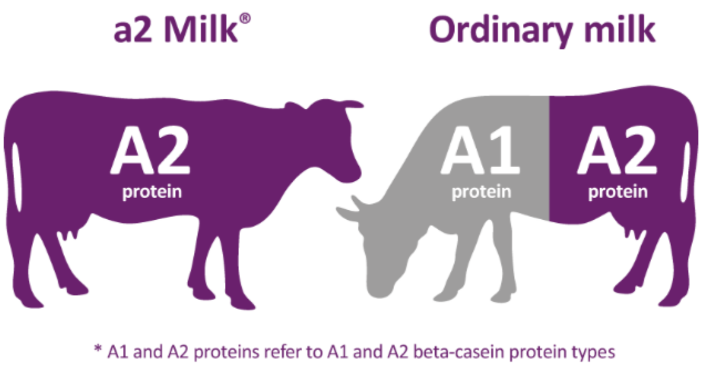
Milk is a wholesome food consumed everyday by large population irrespective of age. Throughout the world, more than six billion people consume milk and milk products. Carbohydrate, protein, fat, vitamins and minerals are important nutrients in milk. Two different types of protein in milk are whey protein and casein protein. Casein constitutes 80 per cent of the total protein present in milk and exists mainly in two forms: alpha-casein and beta-casein. Among the milk casein, beta casein holds special significance. It is reported that beta-casein protein variants not only result in generation of different group of bioactive peptides, but also has an influence on milk protein composition and milk production traits. The most common forms of beta casein in dairy cattle breeds are A1 and A2, while B is less common and A3, C are rare. The recent health concerns rising with respect to choose of milk between conventional and organic milk is related to this A1 and A2 forms of beta-casein.

During digestion of milk, A1 milk releases a 7 amino acid bioactive peptide called beta-casomorphin 7 (BCM-7) in small intestine, while proline (type of amino acid) in A2 milk at 67 position of polypeptide chain prevents the split at this particular site and generates nine amino acid peptide BCM-9. The BCM-7 generated from A1 type milk is further broken down to BCM-5 and BCM-3 by dipeptidyl peptidase IV (DPP IV) enzyme present on surface of enterocytes or in blood. If not degraded, this peptidecross the epithelial layer and then free to exert their physiological effects on various



tissue types and cells by participating in cellular pathway.

There are literatures, which supports positive associations between A1 beta-casein to different diseases such as type I diabetes, cardiovascular diseases, arteriosclerosis, schizophrenia and autism. But there are very less *in vivo* and *in vitro* data supporting the same. There is a need for deep investigations through human and animal trials to arrive conclusions on possible and confirmed effects of BCM-7 or A1 milk on human health. Further



extensive comparative research on the effects of consuming A1 and A2 milk are essential to guide the general public in making best choice between these two types of milk. However, till date there are no guidelines suggested by regulatory bodies to differentiate between A1 and A2 type milk.

Milk produced from foreign breed cow or from the mixed-race cow contains only A1 or mixture of A1 and A2 beta-casein. The percentage of modern European cattle producing A1 beta-casein varies from breed to breed. Asian and African cattle, goats, sheep, yaks and camels all produce A2 milk. Majority of the Indian native cattle produce A2 milk. Most of the crossbred cattle population in India are abundant in A2 variant. This scenario is health supportive, even if the adverse effects of A1 are authenticated.

Recently there is increase in number of dairy processing industries which are marketing organic milk or A2 milk. Though this is the promotional step towards popularizing *desi* cow breeds, the cost of A2 milk is double the price of A1 milk. Facts about possible health effects of A1 milk are unclear.As mentioned earlier, according to the studies, majority of the milk produced in India is from A2 or mixed A1 and A2 genotype cattle, hence instead of debating on A1 or A2,milk safety must be focused, which otherwise a serious health concern.

There are several factors that contribute to the type I diabetes, heart diseases, immune dysfunction and digestive issues, whereas role of consuming milk in occurrence of these diseases is still debatable. Thus, is it necessary for health-conscious consumer to give importance to the selection of A1 or A2 is of concern? or to focus on wide health promoting foods available in Indian culinary and to practice lifestyle modifications for making future days to be healthier.

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Health Spine Gourd: The Impact of The Vegetarian Diet

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The word "Spine Gourd" does not usually relate to a specific plant or fruit. It's possible that you're referring to "Spine Gourd" as a local or regional term for a specific type of gourd or vegetable. The thick skin and fleshy interior of gourds distinguish them. They are available in a variety of shapes, sizes, and colors. Some gourds have spines or prickles on their skin, which may explain the phrase "spine gourd" in some contexts. Spine Gourd fruits are oblong or spindle-shaped, measuring about 4-5 cm in length.

They are covered with numerous little spines or prickles, therefore the common name "spiny gourd." The fruits are green while immature and turn yellowish-orange as they grow. When the fruit is unripe, the flesh is white and crisp, but when fully mature, it becomes soft and red.

The Spine Gourd commonly known as teasel gourd, Adavihagal and Madahagal-Kayi in Kannada and Vahisi in Sanskrit, Kakor, Parora and Golbandra in Hindi, Banzakartoli in Marathi, Kartoli in Bengali, Akakara and Bodakakara in Tamil. It is a perennial climbing vine belonging to the Cucurbitaceae family. It is native to the Indian subcontinent and is widely distributed in tropical and subtropical regions of Asia, including countries like India, Bangladesh, Sri Lanka, Myanmar etc. Spine Gourd has been cultivated in India for millennia, but it is only recently that it has gained popularity due to its numerous nutritional and health benefits. It is dioecious and perennial in nature, but commercially grown as vines and annuals with simple tendrils and fruits in axils and tuberous roots. It is becoming increasingly popular in the country as a result of its great therapeutic value.

Nutritional Value: Spine Gourd fruits are low in calories and high in fiber. They also include minerals such as calcium, potassium, and iron. Furthermore, the fruit is known for its antioxidant capabilities.

Nutrients	Quantity (per 100g)
Energy (kcal)	288.25
Fat (g)	3.1
Fiber (g)	3.0
Protein (g)	3.1
Carbohydrate (g)	7.7
Iron (mg)	14
Zinc (mg)	134
Sodium (mg)	150
Calcium (mg)	50
Potassium (mg)	830

Source: (Sattya and Mohammad, 2014)

Culinary Uses: Spine Gourd fruits are mostly used in cooking. The tender unripe fruits are used in many Asian cuisines, particularly in India and Bangladesh, in dishes like as curries, stir-fries, and pickles. The ripe fruits, with their soft and sweet flesh, are eaten fresh or used in sweets and preserves.

Medicinal Uses: Spine Gourd has a long history of traditional medicinal use in Ayurveda and other traditional healing systems. Different parts of the plant, including the fruits, leaves, and roots, are used to treat various ailments. It is believed to have anti-inflammatory, antidiabetic, and antimicrobial properties.

Antioxidant Activity: Spine gourd contains antioxidant substances that can limit the generation of oxygen-derived free radicals and protect cells (Anant *et al*., 2019). Fruit extracts are diuretic, alexiteric, stomachic, laxative, hepatoprotective, and antivenomic. It is used to treat asthma, leprosy, and excessive salivation (Bawara *et al*., 2010), as well as to avoid inflammation caused by lizard and snake bites, fever, mental and intestinal diseases, and cardiac problems. Fruits are used to treat pimples and acne on the skin because of these qualities.

Anticancer activity: According to (Anjana *et al*., 2020), root extracts have several constitutions with anti-cancer properties. Spinasterol-3-o-a-D-glucopyranoside is a significant chemical that inhibits cancer cell growth (Jha *et al*., 2017).

Allelopathic activity: Spine gourd seed oil is naturally insecticidal. Spraying the extracted oil on cereal grains gives anti-feed effect against cereal-feeding insects (Anjana *et al*., 2020).

Ayurvedic values: Other than the vegetable, ancient peoples employed spine gourd as a folk medicine. Spine gourd root fluids have anti-diabetic and anti-inflammatory properties, and applying extract of spine gourd leaves to the skull is an effective headache cure. When applied to the entire body, root extracts give a superficial effect for high fever. Oral administration of the leaf paste is used to treat a variety of skin problems such as pimples, acne, and skin softening (Talukdar *et al*., 2014). Spinach is the most beneficial nutrient vegetable for children, lactating moms, and pregnant women because it strengthens the immune system in the body (Salvi and Katewa, 2015).

Other Uses: Spine Gourd is planted as an ornamental plant due to its lovely leaves and distinct fruit appearance, in addition to its culinary and medicinal benefits. Spiny gourds can be utilized in flower centrepieces and offer aesthetic appeal to gardens.

Health Benefits of Spine Gourd

Insulin Secretion: Spine Gourd has been shown to increase insulin production by pancreatic beta cells. Insulin is a hormone that regulates blood sugar levels by allowing glucose from the bloodstream to enter cells. Spine Gourd extracts has been demonstrated in some trials to increase insulin release from beta cells, potentially contributing to better glucose control.

Digestive Health: Spine Gourd has long been utilized in Ayurveda and traditional medicine to support digestive health. It is thought to aid digestion, increase appetite, and treat constipation.

Weight Management: Spine Gourd can help with weight loss because to its low calorie and high fiber content. It promotes feelings of fullness, suppresses hunger, and promotes healthy digestion.

Immune System Support: Spine Gourd has vitamins and antioxidants that can help boost the immune system. They help the body's defence against infections and improve immunological function generally.

Anti-inflammatory Effects: Chronic inflammation is linked to insulin resistance and poor glucose metabolism, both of which play important roles in the development of type 2 diabetes. According to certain research, Spine Gourd has anti-inflammatory qualities. These qualities may assist to reduce inflammation and maybe enhance insulin sensitivity.

Slows ageing: Anti-aging components found in spiny gourd include antioxidants, beta-carotene, alpha-carotene, lutein and zeaxanthins. Their ingestion inhibits the onset of aging.

Conclusion

Plants were mostly used by ancient humans and our ancestors to recuperate from ailments. However, the recent tendency of avoiding natural sources of sickness rather than artificial sources is discouraging. Because ongoing reports of antibiotic resistance and synthetic medication adverse effects all throughout the world indicate a worldwide health emergency. Spine gourd contains a large number of secondary metabolites. Furthermore, the use of Spine gourd is beneficial to the environment and has less adverse effects than other synthetic medications. It will also be safer and less expensive than man-made medicine formulation.

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Innovative Techniques to Assess Adulterated Ghee

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Over six billion people worldwide consume milk on a daily basis, despite it being considered a complete food for millennia. Among the essential milk components are fat, SNF, protein, lactose, and ash. A variety of adulterants, including urea, detergents, ammonium sulphate, and neutralizers, were assessed using physicochemical properties

In order to increase profits for dealers, ghee adulteration refers to intentionally mixing pure ghee with inexpensive components of the same type to increase its profits. Ghee is prone to adulteration because of its high price, which includes animal fats, vegetable oil, hydrogenated fats, esterified fats, and mineral oil that is not edible. There are serious issues that need to be properly dealt with in order to identify the adulterations in ghee. Utilising these cheap oils and fats has detrimental health impacts in addition to being prohibited. Media outlets, both print and electronic, routinely report on the adulteration of ghee in India. Adulterations in ghee can be identified using techniques such as chromatographic analysis, spectroscopic analysis, thermal analysis, and physicochemical analysis. These established techniques are pricy, time-consuming, and need substantial sample processing before regular laboratory analysis. Innovative techniques are being utilised more frequently to detect ghee adulteration due to their speed and accuracy.

ATR-FTIR and Chemometrics

ATR paired with transmission, often known as attenuated total reflectance, is one of the most widely used sampling techniques for Fourier transform infrared spectroscopy. In this method, which is based on total internal reflection, infrared (IR) light only interacts with a sample at the point of refraction. Transmission, on the other hand, depends on IR light passing through the sample. An FTIR spectrometer is an extremely useful instrument for determining the chemical composition of organic substances in solid, liquid or gaseous form. Pre-treatment of the samples is necessary for a number of sampling techniques in order to produce high-quality spectra. Measurements of solid or liquid samples can be made using ATR FTIR spectroscopy with only minimal sample preparation.

ATR FTIR spectroscopy requires sample interaction with the ATR crystal. The ATR crystal allows IR radiation to pass through it, which has an impact on the sample surface that is in touch with it. Due to the two materials' differing refractive indices, total internal reflection occurs. This reflection results in the formation of the so-called "evanescent wave" that travels further into the sample. Depending on how the evanescent wave interacts with the sample, a little amount of the infrared light is absorbed, resulting in an attenuated total reflection.

The technique is rapid, non-destructive, and affordable; however, chemometrics expertise is necessary to properly utilise ATR-FTIR's potential.

Recent studies have reported the addition of coconut oil, goat body fat, and pig body fat to ghee using ATR-FTIR and chemometrics. First, spectra of pure ghee and the powerful adulterant, coconut oil, were taken in the wavenumber range of 4000 to 500 cm-1, together with samples that had been spiked. Furthermore, a wavenumber range of 1170-1141 and 1117-1100 cm-1 was selected, and principal component analysis (PCA) of the samples showed distinct groupings for pure ghee and contaminated samples. Soft independent modelling by class analogy (SIMCA) was successful in classifying the pure ghee and coconut oil samples of the confirmation set using both the principal components regression (PCR) and partial least squares regression (PLS) models. The study found that it is possible to detect counterfeit coconut oil samples in ghee at a concentration of just 2%.

Electronic Nose System

An electronic nose (e-nose) based on MOS gas sensors was developed to detect adulterated ghee with hydrogenated fat (vanaspati). To find ghee adulteration, the data from the e-nose system was analysed for pattern recognition and classification. Principal component analysis (PCA) and discriminant function analysis (DFA), two techniques for multivariate chemometric analysis, were examined. The PCA and DFA each explained 98.10% of the variance in the e-nose dataset. The accuracy of cross-validation results and training data was found to be 98.18% and 97.27%, respectively. Based on the e-nose signals that were received, the DFA model was successful in identifying adulteration in 90.90% of the sample. It indicates that the developed e-nose system successfully differentiated between pure and contaminated ghee samples based on the e-nose data, PCA, and DFA results.

Gas Chromatography

Researchers generated samples of cow and buffalo ghee using milk gathered from areas in the eastern, western, southern, and northern sections of the nation. The triglyceride content of ghee that had been made in this way was determined using gas-liquid chromatography, and S-limits were computed using the equations outlined in the ISO technique. Cow and buffalo ghee samples from all four locations both fell outside of all five S- limits, as stated in the standard for cow milk, on both the lower and upper sides of the limits.

It was discovered that samples of buffalo ghee had a greater. In samples from all four regions, the maximum S-total (ST) limit ranged from 109.34 to 118.21, but the lower value for buffalo ghee samples from the eastern, northern, and southern region samples was a little lower (94.06 to 94.59) than the lower range indicated in the standard. When the S-limit (S4) required for the detection of palm oil and beef tallow was used, a similar pattern was seen. The S- values in cow ghee also displayed a tendency to deviate from the norm.

Chromogenic Test

To evaluate the quality of ghee in routine quality control analyses, simple and quick tests are currently utilised. Currently, a DPPH-based chromogenic test is being utilised to detect palm oil in ghee. The experiment used a 50 mg/100 ml (ethanol) DPPH solution. This assay's specificity was evaluated using pure ghee and palm oil. Up to 5% of adulterated palm oil in ghee appears to be detectable by the technique. A platform test for routine quality analysis may be used because the designed procedure was effective, reliable, and sensitive. milk food testing facility.

Conclusion

The current issue has impacted the dairy industry's reputation both domestically and internationally. The different instances of adulteration documented in the literature were utilised to gauge the severity of the issue. Finding adulterants in ghee utilising a variety of quick, creative methods could raise awareness of the need to preserve the ghee's typical quality. Their methods might be put to use in research labs or other labs, which could generate financial resources. Even though the initial expenditure is more for some techniques, such FTIR and electronic systems, it is a quick way to find adulteration in ghee.

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Kiwi Fruit (*Actinidia Deliciosa*)- Therapeutic Benefits and Application in Dairy and Food Industry

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Fruit, the fleshy or dry ripened ovary of a flowering plant, enclosing the seed or seeds. Fruit is usually classified as simple fruit, aggregate fruit, composite fruit. Kiwifruit is a non-citrus exotic fruit. The genus Actinidia is known for the famous 'kiwifruit' (A. deliciosa). Kiwifruit is native to the Yangtze Valley of China, and was originally called “mihoutao” that is monkey peach in China and "Chinese gooseberry" in the rest of the world. When kiwifruit farmers in New Zealand decided to market the fruit overseas, they gave it the name “kiwi” to identify it better with New Zealand. The name "kiwi” (*Ateryx australis*) or “kiwifruit" comes from the kiwi, a flightless bird and New Zealand's national symbol, and also a colloquial name for the New Zealand people.

The genus Actinidia belongs to the Actinidiaceae. The four infra-generic sections in this genus are: Leiocarpae, Maculatae, Stellatae, and Strigosa. This classification is based on the characteristics of the fruit (presence or absence of lenticels), pith (lamellate or non-lamellate), and hair (simple or stellate). Although kiwifruit is now an important crop in many parts of the world, much fruit is collected each year from the wild in China. The most widely planted kiwifruit cultivar is the fuzzy kiwifruit A. deliciosa- ‘Hayward’. ‘Hayward’ accounts for about half of kiwifruit cultivation throughout the world. ‘Hayward’ kiwifruit also represents about 90% to 95% of the kiwifruit traded internationally. The fuzzy kiwifruit A. deliciosa is commercially the most important crop and its total production accounts for about 1.8 million tons per year. However, internationally kiwifruit is a minor crop representing about 0.2% to 0.3% of total fresh fruit production. In terms of "marketable gross production" (essentially, crop value), kiwifruit is the sixth most valuable fruit crop after citrus, apples, table grapes, peaches/nectarines, and pears. (David *et al*., 2018)

It contains high levels of bioactive compounds such as vitamin C vitamin E, flavonoids, carotenoids and minerals. Kiwifruits show a wide diversity in size, shape, fuzziness, flesh and peel color and flavor. The species Actinidia deliciosa has a smooth, bronze skin, with a beak shape at the stem attachment. Flesh colour varies from bright green to a clear intense yellow. This species is sweeter and more aromatic in flavor. The yellow fruit fetches a higher market price and, being less hairy than the fuzzy kiwifruit, is more palatable for consumption without peeling. But it has a short storage life which limits its commercialization.

Kiwi fruit is a one of the multipurpose fruits and it has a lot of therapeutic benefits and applications, these therapeutic benefits it is used in dairy, food, chemical, pharmaceutical industries (Guroo *et al*., 2019).

History

Kiwi fruit is traditionally used for various treatments in Ayurveda. Ayurveda, the traditional scientific system of Indian It contains high levels of bioactive compounds such as vitamin C vitamin E, flavonoids, carotenoids and minerals. Worldwide evidences have been observed for its therapeutic action by many scientists. As per many scientists' Black plum contains various phytochemicals present in seeds and fruits which possess many therapeutic actions Antidiabetic, Antibacterial, Antioxidant, Antidiarrhea, Antihyperlipidemic, Free radical scavenging. Thus, this small fruit has lot of potential to be used as nutraceutical and therapeutic food

Year	**Development**	**Scientist**
12th C	1st recorded description – Kiwi Fruit dates	Song Dynasty
1700s	Species was first found at border of Yangtze River valley	Huang (China)
1750s	1st botanical specimens were sent to Europe	Jesuit priest
1847	1st plant sent for England and America	E.H. Wilson
1886	1st species was preserved in spirit in Kew, London	Robert fortune
1904	Introduction of Kiwi fruit to New Zealand	Isabel Fraser
1922	Listed kiwi plant as "a wonderful fruiting climber"	Hayward Wright
1960	kiwi was 1st planted in India	Bangalore
2005	Anticancer activity in kiwi fruits	Lippi
2009	Antioxidant activity in kiwi fruits	Park *et al.,*
2018	Kiwi fruit enzyme is replaced as rennet in cheese preparation	Sharma *et al.,*

Status of kiwi fruit

According to agriculture and processed foods export and development authority, China stands first in production of kiwi fruit of 2196.7 metric tons and major producer are New Zealand of 558.19MT, Italy of 524.49MT, Iran of 344.19MT, Greece of 285.86MT, Chile of 177.21MT. In India produce around 13000 tones and major producer are Arunachal Pradesh, Nagaland, Mizoram, Himachal Pradesh, Jammu and Kashmir. Percentage contribution for total production in India is Arunachal Pradesh of 56.83%, Nagaland of 22.92%, Mizoram of 9.58%, Himachal Pradesh of 3.19%, Jammu and Kashmir of 0.09% (APEDA, 2019).

Scientific classification of kiwi fruit

Domain	Eukarya
Kingdom	Plantae
Phylum	Magnoliophyta
Class	Magnoliopsida
Order	Ericales
Family	Actinidiaceae
Genus	Actinidia

Plant description

Kiwi fruit plant is borne on vigorous, woody, climbing shrubs or twinning vines. Height of the plant is 9 meters and plantation done at the time of January, Leaves are Deciduous, Alternate, and long petiolate and length of leaves is 7.5 to 12.5cms, Flowers are Fragrant, 5-6 petalled, white at first that changes to yellow, the best time to harvest is during September to October. Rate of Yield is for 3 year that is 4 tons per acre and for 8 year that is 25 tons per acre, yield rate per vine is 50-100 kg per vine.

VARIETY	CHARECTERISTIC
Abbott	The oblong, medium sized, fruits are covered with dense hairs. They are very sweet in taste Fruit weight of 45 - 50gms Ascorbic acid (50mg/100gm fruit) Yield of 12 kg/vine
Bruno	Medium sized with 60gm weight Completely cylindrical, dark drown with long and hard hairs Ascorbic acid - (50mg/100gm fruit) Yield of 29 kg/vine
Hayward	Most popular cultivar of the world, Large, ellipsoidal shape with 80gms weight Skin is brown with thin hair Ascorbic acid – (62mg/100gm fruit) Yield of 32kg/vine
Monty	Characteristic vertical striations have tendency to produce 3 fruits per peduncle Weights about 80 – 90gms Ascorbic acid of 70mg/100gm fruit Yield of 10kg/vine
Allison	Resembles to those of Abbott, except slightly broader in proportion to its length. Medium sized with 60 – 70 gms weight Ascorbic acid – 48mg/100gm fruit Yield of – 13kg / vine
Jing gold	Smaller in size with weight 40-45 gms. . It has yellow pulp and sweet in taste Ascorbic acid 45mg/100gm fruit Yield of – 10kg / vine

Kiwi fruit plant

Farmers put fruit or seed into the soil gently they water it often and kiwi requires lot of water because it is very moist fruit, there should be 200 square feet for a kiwi farm and There must be protection from wind and frost in order for kiwi fruit to grow. For kiwi plant soil pays important role that's why it requires deep rich well drained sandy loam soils. Annual rainfall requires of about 150 cm and temperature is less than 15°C.

Classification of kiwi fruit

Constituents	**Quantity (Gms/100gm Fruit)**
Moisture	83.1
Fat	0.52
Protein	1.14
Carbohydrate	14.7
Sugar	9.0
Ash	0.61
MINERALS (mg/100g)	
Potassium	312
Phosphorus	34
Calcium	34
Magnesium	17
VITAMINS (mg/100g)	
Vitamin C	92.7
Vitamin A	122µg
Vitamin K	40.3µg

Composition of kiwi fruit

(David *et al.*, 2018)

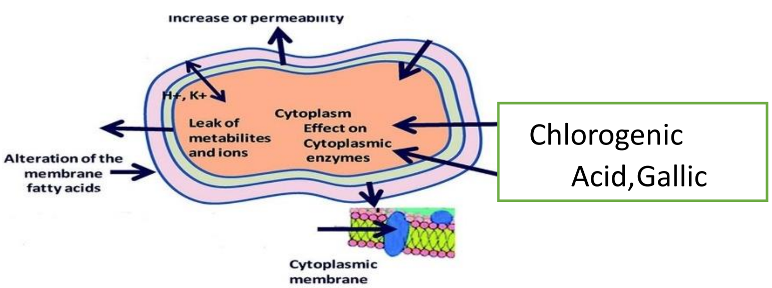
Therapeutic benefits of kiwi fruit

1. Anti-bacterial
2. Anti-cancer
3. Anti- diabetic

Antibacterial activity

Compound	Mechanism	Spectrum of activity
Phenolic compound (0.39g/100gm)-	Dissolves the fatty acids of cell membrane - increases cell permeability - leaking of cell constituents.	*Escherichia coli*
chlorogenic acid, gallic acid-		Staphylococcus aureus
Hydrophobic in nature		Listeria monocytogenes

Mechanism of action



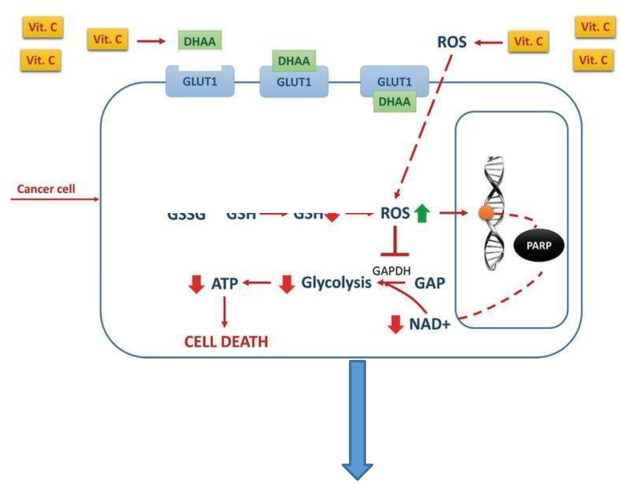
The sites or structures of the bacterial cell that are considered targets for action by the components of natural products. The action mechanisms of natural compounds are related to disintegration of cytoplasmic membrane, destabilization of the proton motive force (PMF), electron flow, active transport and coagulation of the cell content. Not all action mechanisms work on specific targets, and some sites may be affected due to other mechanisms. Important characteristics responsible for the antimicrobial action of phenolic compounds include hydrophobic components that allow the participation of lipids from the bacterial cell membrane, which disturbs cell structures and make them more permeable, changes the internal ph which significantly affects the cell membrane by dissolving the fatty acids and creates pores in the cell membrane and leaking of cell constituents occurs and finally leads to death of bacteria.

II. Anti-cancer activity

Active component	Activity
Vit. C (ascorbic acid) - 92.7mg /100g	ANTI CANCER act – ROS

Mechanism of action

High amounts of DHAA enter the cancer cells, thanks to the overexpressed GLUT-1 receptors. DHAA is then reduced again to vitamin C inside the cells. The reduction of DHAA to vitamin C scavenges



DHAA-Dehydroascorbicacid
ROS- Reactive oxygen species
PARP- Poly ADP ribose polymerase
GAP- Glyceraldehyde 3 phosphate
NAD- Nicotinamide adenine dinucleotide

glutathione (GSH), thus inducing redox imbalance and oxidative stress. Oxidative stress, in turn, leads to inactivation of GAPDH, vitamin C, functioning as a prooxidant, would induce an increase in the intracellular reactive oxygen species (ROS), which leads to increased DNA damage, with consequent activation of poly ADP-ribose polymerase (PARP), an enzyme necessary to repair damaged DNA. PARP activation would in turn consume NAD+, with NAD+ depletion and consequent ADP depletion inhibition of glycolysis, and energetic crisis, which leads to cancer cell death.

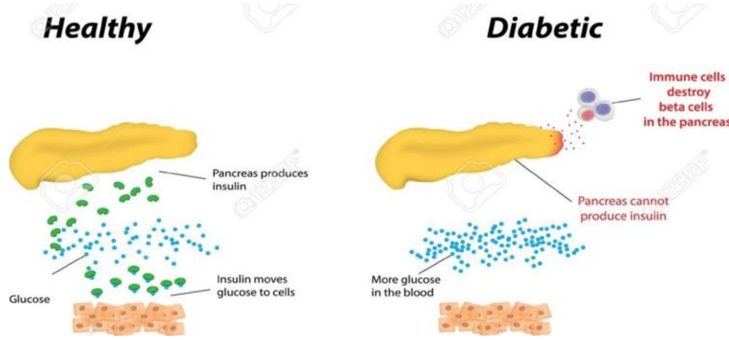
III. Antidiabetic activity

Active Compound	Mechanism
Zinc (0.14 mg/100gm) and Magnesium (17 mg/100gm)	Beta-cells of pancreas – improves production of insulin

Mechaism Of Action

Diabetes mellitus, a complex syndrome is characterized by the imbalance in blood glucose homeostasis leading to hyperglycemia (high blood glucose) and a series of secondary complications caused by an absolute or relative lack of insulin which moves glucose to cells.

Normally beta cells of pancreas release insulin which moves glucose to celss present in blood. But in case of diabetes, the destruction of pancreatic beta cells occurs which affect the release of insulin. So, glucose level increases in blood causing diabetes. Normally Streptozotocin selectively destroys pancreatic insulin secreting β-cells causing diabetes close to type-2 diabetes of humans. Streptozotocin induces a wide variety of animals species by damaging the insulin secreting pancreatic β-cells, resulting in a disease in endogenous insulin release, which paves the ways for the decreased utilization of glucose by the tissues.



Applications of kiwi fruit

Kiwi fruit enriched dahi ingredients:

Milk: 4.5% and 8.5% SNF

Sugar: 6%

Kiwi fruit juice:8%,10%,12%

Culture: 2%

Standardized milk (4.5% and 8.5% SNF)

↓

Heated to 90°C/5min & cooled to 30°C

↓

Addition of sugar (6%) & kiwi fruit juice (8,10 and 12%)

↓

Homogenization 65°C/ 2stage, 2500psi and 500psi

↓

Addition of Starter culture @ 2% (*Lactococcuslactis* ssp.*lactis*, *L. lactis* ssp *cremoris*, *L. lactis* ssp. *diacetylactis* along with *Leuconostoc* species.)

↓

Packaging and incubation (30°C / 10h)

↓

Cooling and storage (7°C)

Fresh sweet good quality standardized milk (4.5% and 8.5% SNF). The standardized milk was heated to 90 °C for 30 minutes; it was cooled to 30 °C. Addition of sugar (6%) and kiwi fruit juice (8,10,12%). Homogenization is done at 65°C by two stage ,2500 and 500 psi and then inoculated by starter culture @ of 2% and incubated, at 30 °C for 8 to 10 hours until a firm coagulum (Dahi) was formed.

Sensory analysis of kiwi fruit enriched dahi

Parameter	**Colour and appearance**	**Body and texture**	**Flavour**	**Overall acceptability**
Control	8.33	8.33	8.50	8.50
Kiwi fruit (8%)	8.33	8.16	8.33	8.16
Kiwi fruit (10%)	8.66	8.50	8.66	8.60
Kiwi fruit (12%)	8.16	8.33	8.00	8.16

Result: Good quality, value added Dahi with more acceptability can be prepared by addition of Kiwi fruit juice. The treatment containing 10% Kiwi fruit juice was most acceptable in terms of sensory score however the treatment containing 8% & 12% Kiwi fruit juice also obtained satisfactory results as they were within the acceptable limit. (Nikhil, 2017).

Parameters	**Appearance**	**Odor**	**Taste**	**Texture**	**Overall acceptability**
Control	8.94	8.50	8.56	8.93	8.90
5% KFP	8.88	8.69	8.69	8.81	8.75
10% KFP	8.38	8.75	8.75	8.76	8.38
15% KFP	7.75	8.81	8.37	8.44	8.19
20% KFP	7.44	8.31	7.31	8.13	7.56

Development of biscuit with incorporation of kiwi fruit powder Ingredients:

Wheat flour :80g

Kiwi fruit powder: 20g Sugar: 35g

Sodium chloride:0.5g Baking powder:0.6g

kiwi fruit powder: wheat flour 5:95,10:90,15:85,20:80

↓

Sugar (35g), Butter(40g), Sodium chloride (0.5g), Baking powder (0.6g)

↓

Mixed in Moulinex mixer (2 min)

↓

Cookies dough was sheeted, cut into shapes

↓

Baking (170-180°C for 20 min)

↓

Packaging and storage

The formula used for cookies preparation [wheat flour and different proportion of kiwi fruit powder. The dough was made from 35g sugar, 40g butter, 0.5g sodium chloride, 0.6g baking powder and water using Moulinex mixer (model Super mix 150). Butter and sugar were creamed in a mixer for 2min at slow speed. Wheat flour containing various proportions of kiwi fruit powder with baking powder was added and mixed for 3 min at medium speed. The cookies dough was sheeted, cut and baked at 170-180°C for 20 min. The baked cookies were cooled at room temperature.

Sensory parameter of biscuit prepared from kiwi fruit powder

Cookies production by substitution with kiwi fruit powder which was considered as a good source of phytochemicals components like crude fibers, bioactive compounds and antioxidant activity. It could be concluded that substitution of wheat flour with kiwi fruit powder improved the antioxidant activity and nutritional quality with acceptable sensory characteristics of produced cookies at 10 and 15% substitution level of kiwi fruit powder, respectively. So, it is possible to maximize the benefit of the kiwi fruit and its powder as a preferred functional product for consumers, especially children who like cookies. (Zahrat**, 2017**).

Future prospects

In future there is a need for further innovations in the manufacture of kiwi fruit products and there use in food products, perfect validation is need to imposed that gives a value addition to the products. Research and development is essential for effective utilization of the underutilized kiwi fruit and its by products in food industry and dairy industry because it have a good therapeutic benefits. Promotion and Commercialization need to be emphasized and Legal Standards need to be implemented for proper utilization kiwi fruit.

Conclusion

Kiwi fruit it is power house of nutritional components such as vit c, fiber, protein, minerals it helps provide good health to human. Scope for Value addition in dairy and food products that helps enhance of human health & increase the nutritional value. In dairy industry especially in cheese industry, the kiwi fruit enzyme is suitable alternative to rennet that helps to reduce the use of calf rennet. Greater awareness is needs to be created for better commercialization.

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Significance and Strategies to Reduce Sodium in Processed Foods

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Sodium chloride is used as a food additive in food processing from long period. In addition to its influence on the taste of products, it has a significant role with regard to texture and storage. It is an essential nutrient for the maintenance of human health. Less than 5 grams per day salt intake has been recommended by the World Health Organization (WHO), which is equivalent to 2 grams of sodium. Recent report in Brazil has shown that most sodium source is derived from the table salt (NaCl)(Collucci, 2013). Though it is a vital nutrient for maintenance of health (regulates extracellular volume, maintains acid-base balance, neural transmission, renal function, cardiac output and myocytic contraction), but the excessive intake is associated with the cardiovascular diseases, hypertension, neurological diseases, osteoporosis, gastric cancer, kidney disease, asthma, and obesity(Doyle and Glass, 2010). WHO recommendations indicate that, in order to prevent chronic diseases, an adult upper daily limit intake of sodium should be less than 87 mmol Na/day (<5 g NaCl/day). Accordingly, there is a great interest in producing low-sodium foods. Despite low-sodium products have been found in some markets, the production of these items with satisfactory sensory acceptance and technological performance is still a challenge. Several alternatives enable to keep the same functionality, but with a partial decrease or even total elimination of sodium from formulations.

Low Sodium Foods

The food that has 140mg or less sodium in one serving is considered "low-sodium" product. A "very low-sodium" product has 35 mg or less per serving, and any food that supplies fewer than 5 milligrams per serving is "sodium-free". Table 1 represents the list of low sodium foods and Table 2 represents the nutrient content claims for sodium.

Table 1. List of low-sodium foods

Sources of low sodium foods	Examples
Fresh and frozen vegetables	Greens, broccoli, cauliflower, peppers, etc.
Fresh, frozen or dried fruits	Berries, apples, bananas, pears, etc.
Starchy vegetables	Potatoes, sweet potatoes, butternut squash and parsnips.
Fresh or frozen meat and poultry	Chicken, turkey, beef or pork.
Fresh or frozen fish	Cod, sea bass, tuna, etc.
Eggs	Whole eggs and egg whites.
Healthy fats	Olive oil, avocado and avocado oil.
Low-sodium snack foods	Unsalted pretzels, unsalted popcorn and unsalted tortilla chips.

Health benefits of low sodium foods

- Controls blood pressure
- Reduces cardiovascular diseases
- Certain medications work more efficiently with a low sodium diet
- Reduces or prevents swelling of the extremities, such as the legs
- Decreases the risk of kidney stones
- Decreases the risk of developing Osteoporosis.

Strategies for reducing salt in processed foods

Nowadays Sodium reduction is a priority for public health because of negative health consequences and associated health care costs of high sodium consumption. For this reason, a range of strategies to reduce sodium in different foods have been applied. The technological or strategic approach to the reduction of salt in food products are affected by various factors(Mitchell, 2019), but the basic strategies that uses ingredient solutions for sodium reduction are discussed below.

1) Remove: This strategy involves the removal of sodium chloride without replacement or compensation from a formulation and it does not require much investment but applies to a limited number of processed food products. Sometimes, salt concentration in a formulation exceeds the amount required to meet its function (taste, preservation, texture, or appearance). Where salt concentration exceeds the quantity required to meet its functions, salt can be removed.

2) Reduce: This strategy involves two methods for reduction of sodium chloride content in processed foods.

i. **By stealth:** Some food manufacturers demonstrated that reducing salt in formulations by small steps over time is a feasible approach. When small salt reductions are made, by stealth over time, large reductions can be achieved as long as there are no changes in product quality or microbiological safety. It has been demonstrated that 15 to 20% of salt can be reduced this way.

ii. **By using taste enhancers or modifiers:** Using taste enhancers or modifiers, salt content can be reduced without changing taste profile, when used in combination with other salts. In this way, it is possible to reduce 30-50% reduction in sodium. A taste enhancer is a substance that does not modify the taste but increases the intensity of how the taste is perceived and works by activating receptors in the mouth and through stimulating receptors linked to umami taste. In practice, there are several types of salt enhancer available including mineral salts, yeast extracts, hydrolysed vegetable proteins, autolysed dry yeast, monosodium glutamate, guanylate or inosinate, peptide-based compounds, etc. are used to accumulate taste profile based on either primary taste, enhancement of taste or specific flavour.

3) Replace: Complete replacement of added salt is possible through the use of commercially available salt substitutes. Use of physically modified sodium chloride crystals, mineral salts (potassium chloride, magnesium chloride, calcium chloride, etc.), phosphates, or mixtures of taste enhancer/modifier ingredients and mineral salts are used to replace the salt. These salt substitutes may not necessarily completely replace sodium chloride, but salt reductions of 50–60% are possible when using this method.

Conclusion

Low sodium foods possess various health benefits in reducing or preventing swelling of the extremities, decreasing the risk of kidney stones, decrease the risk of developing osteoporosis. Changing the dietary sodium content of a population that has adapted to a high sodium diet will not be easy, and will entail a number of strategies. Currently, the best success is achieved, when multiple approaches based on a wide range of ingredients and technologies are used to reduce the sodium in processed foods.

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Table 2. Nutrient content claims for sodium

Nutritional claim for sodium	India (As per FSSAI)	United States	European Union
Sodium free	Product contains not more than 0.005g of sodium per 100 g for solids or 100 ml for liquids.	<5 mg serving	≤5 mg/100 g
Very low sodium	Product contains not more than 0.04 g of sodium per 100 g for solids or 100 ml for liquids.	≤ 35 mg/serving	≤40 mg/100 g
Low sodium	Product contains not more than 0.12 g of sodium per 100 g for solids or 100 ml for liquids.	≤140 mg/serving	≤120 mg/100 g
Lightly salted	-	At least 50% less sodium (than the regular product) / At least 25% less sodium (than asimilar product)	At least 25% less sodium (than a similar product)
No salt added	-	No salt added during processing	No salt added
Reduced sodium	-	At least 25% less sodium (than the original product)	At least 25% less sodium (than a similar product)

* * * * * * * *

An Overview on Protein-Based Fat Replacer

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Excessive consumption of calories in the form of high fat western diets which drive weight gain as fat being the densest source of calories having more than double that of the carbohydrates and proteins. Obesity is a growing health concern and socio-economic crisis globally (WHO, 2016). In the US, most adults are predicted to be overweight and 50% obese by 2030 consistently rising since 1999 (Wang *et al.*, 2020). With the prevalence of obesity and obesity-associated chronic diseases such as cardiovascular diseases, cancer and type 2 diabetes, consumers become increasingly aware of the calorie intake of their diet. Nowadays consumers are more health-conscious and aware than ever before. They look forward for healthier alternatives and psychological satisfaction at the same time. The Dietary Guideline for Americans, 2020–2025, encourages the public to consume low- or non-fat foods for healthier diets. As a result, policy-makers and consumers are addressing dietary and associated health issues and, consequently food industries are attempting to accelerate their innovations in creating lower calorie food products (Bigliardi & Galati, 2013). Nevertheless, the commitment to consuming low-fat foods or maintaining a low-fat diet remains challenging because of their deteriorated texture and sensorial properties compared to those of full-fat ones. Hence, there has been motivation in the food industry and research community to design fat replacers that mimic the functional and sensory properties of fat. These include two classes of materials: fat substitute (FS) and fat mimetic (FM) ingredients, with an attempt to replicate the physicochemical and sensorial properties of fat in food products. Typically, FS involves direct replacement of fat with a substance that attempts to provide similar organoleptic properties to fat, these can be synthetic in nature or structured lipid moieties that provide little to no calories (O'Connor & O'Brien, 2016).

Dietary fat: Harmful effects

Dietary fat provides flavor, sensory qualities, mouthfeel, creaminess, palatability, satiety and other psychological benefits to the consumer. It is energy-dense major macronutrient in the human diet and provides 9 cal/g of energy upon consumption, which is double than that of carbohydrates and proteins (Peng and Yao 2017). The regular consumption of fat contributes to a number of chronic diseases, such as cardiovascular diseases, type 2 diabetes, cancer, and obesity (Mozaffarian 2016). Obesity in itself is a challenging problem to treat ever since its emergence, so the primary prevention of weight gain is a promising strategy for individuals as well as the population. Owing to the detrimental health effects and economic repercussions of high dietary fat consumption, reduced-fat meals are a realistic and feasible option. FSSAI has also announced regulations to limit the content of trans-fat in food as research has shown that consuming large amount of industrially produced trans-fat is associated with an increased risk of high cholesterol and heart diseases. Under this regulation, FSSAI limited industrial TFA (trans-fatty acids) to not more than 3% in all fats and oils by January 2021 and not more than 2% by January 2022. It also stated that all food products in which edible oils and fats are used as an ingredient should not contain industrial TFA of more than 2% by mass of the total oils/ fats present in the product, on and from January 1, 2022. With this India has joined the group of over 40 countries around the world that have already implemented policies to remove trans-fats. However, low-fat food can lack taste, mouthfeel and psychological properties which decreases the acceptability of food (Marchetti and Andrés 2021). To address this general problem, fat replacers are applied to compensate the loss of fat related properties and improve the overall acceptability of a low-fat diet (Peng and Yao 2017).

Why protein-based fat replacer gaining importance?

Protein-based fat replacers have received increasing attention. They boost the protein nutrition of food products with a low-calorie contribution. As compared to other macronutrients proteins are often considered as a suitable macronutrient to replace fat as it contributes to only 4 kcal per gram with more satiation, per calorie, (Benelam, 2009). In fact, the protein content of foods correlates positively with Satiety Index scores (Holt et al., 1995). This benefit has been used by scientific community for considering protein-based fat replacers. In addition, protein is also a highly tuneable structuring agent by virtue of its responsiveness to pH, ions, temperature and enzymes. Fig. 1 shows the reported bibliographic data for fat replacers and protein-based fat replacers showing the growth of scientific literature and citations with the highest number of publications being produced since 2017, highlighting the topical nature and importance of this field in the period (1998–2018). A substantial yearly increase can be observed from 2012 for both total FR and protein-based FRs, with the latter contributing to nearly one-third of the total FR publications to-date indicating this as a priority area in the food science community (Kew *et al.,* 2020). The protein-based fat replacements have advantages over carbohydrate-based ones in terms of flavor interactions and the amount of fat that could be replaced.

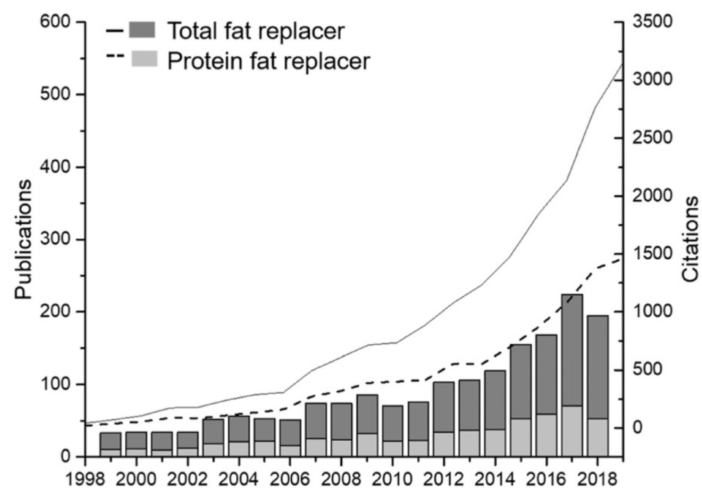


Fig. 1. Number of publications (bars) and citations (lines) of fat replacers (black bar, solid line) and protein-based fat replacers (white bar, dashed line) using search engine, Web of science (ISI) from 1999 to 2018. Adopted from Kew *et al.*, 2020

Fat Replacers: Definition and Classification

A fat replacer is an ingredient that can be used to provide some or all of the functions of fat yielding fewer calories than fat. According to the American Dietetic Association fat replacer means "an ingredient that can be used to provide some or all of the functions of fat, yielding fewer calories than fat". A wide range of products in the food industry uses fat replacers, major being meat, dairy and bakery and confectionery industry (Colla *et al.,* 2018). Fat replacers need to be able to replicate all or some of the functional properties of fat in a fat-modified food. It is worth to mention that the term of fat replacer implies that a substance has certain desirable physical or organoleptic attributes of fats which it replaces without any of the undesirable properties of fats (Hassel, 1993). There are several categories of fat replacers, and there is often confusion regarding how the categories are defined. Fat replacers are either fat substitutes or mimetics. Fat substitutes are lipid-like substances intended to replace fats on a one-to-one basis. Fat mimetics are protein or carbohydrate ingredients which function by imitating the physical, textural, mouth feel and organoleptic properties of real fats (Owusu-apenten, 2005).

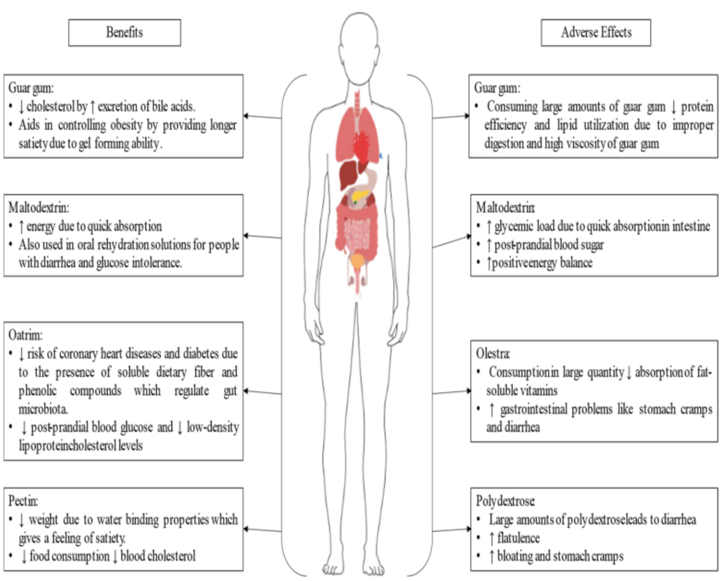


Fig. 3 Beneficial and adverse effects of different fat replacers

Fat Substitutes

Fat substitutes are usually produced by enzyme-modified oils and fats and can also be synthesized chemically (O'Sullivan 2016). They resemble as like with conventional fat and oils and can replace fat on a gram-for-gram basis. As compared with fat mimetics, they are stable to cooking, baking and frying temperatures. Sugar or sugar alcohol fatty acid esters such as sucrose polyester (olestra), sorbitol polyester and raffinose polyester are among the most studied fat substitutes (Zheng et al. 2015).

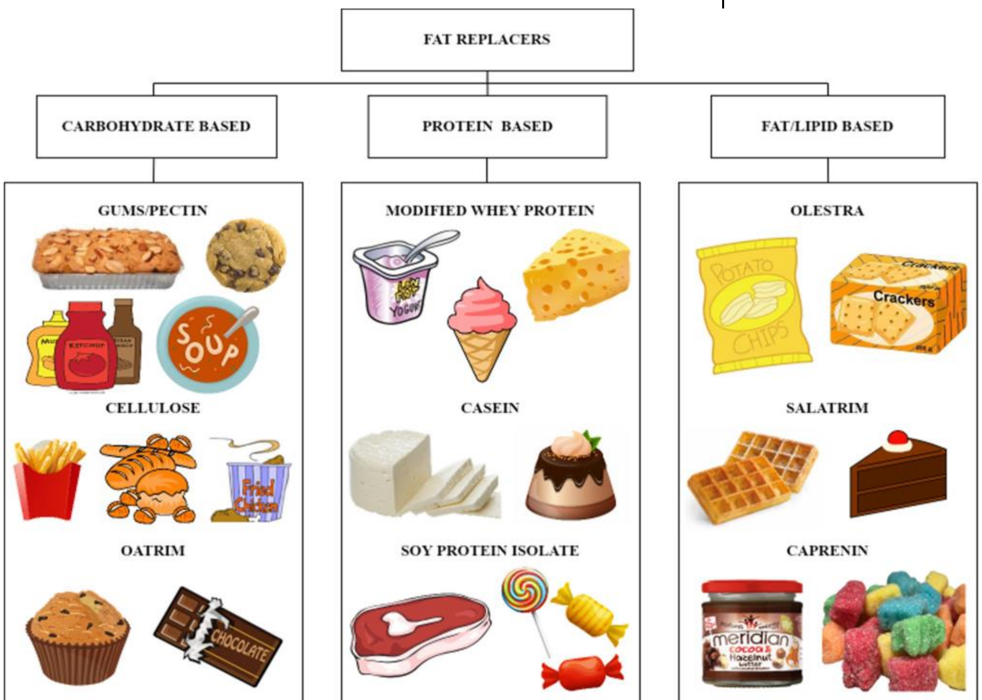
Fat Mimetics

Fat mimetics are ingredient that mimic one or more of the sensory and physical functions of fat in the food. They are generally protein or carbohydrate based and also provide lubricity, mouth feel, and other characteristics of fat by holding water. These are substances that imitate the organoleptic or physical properties of triglycerides but cannot replace fat on a one-to one or gram-for-gram basis (Solanke et al. 2016). Though fat mimetics have distinct microstructural and rheological properties than fat, when they are employed to substitute fat in food products, the end products have similar qualities to that of the normal formulation (Patel et al 2020). They are also referred to as 'texturizing agents' and require a high water content to achieve their functionality. They provide lubricity, mouth feel, and other characteristics of fat by holding water which makes them unsuitable for frying and baking. In some cases, extreme heat may lead to excessive browning (Oreopoulou 2006).

Classes of Protein-Based Fat Replacers

Protein Concentrates and Isolates

The most commonly used fat replacer is protein concentrates or isolates. They may be slightly denatured during the manufacturing process. The protein concentrate contains ~30–80% protein, whereas the protein isolates reach 90–92%. Extensive research has been conducted on developing low-fat dairy products including yogurt, ice cream, and cheese using protein concentrates/isolates, especially whey protein due to its high compatibility with other dairy ingredients and a matching flavor profile.



Microparticulated Proteins

Protein microparticulation is a process of aggregation and size of the particles commonly ranges within 0.1–10 μm. Protein particles with a size larger than 5 μm can be detected by oral mucosa; thus, a smaller size is preferable to provide the smoothening mouthful feelings. The most widely used microparticulated proteins is from whey proteins, which was patented in 1988 and later commercialized with the brand name Simplesse®. Some other proteins, such as soy protein, bovine serum albumin, egg white protein, gelatin, zein, wheat protein, pea protein, and potato protein, have also been used to produce fat replacers. Due to their spherical shape and size, they were claimed to mimic fat droplets and create a smooth and creamy mouthfeel through a "ball bearing" mechanism.

Protein–Polysaccharides Hydrogel

Either proteins or polysaccharides have the capacity to form hydrogels. Protein-based hydrogels are mainly particle type, whereas those from polysaccharides are "thread or linear" type. When mixing the two, complexation could occur, which tailors' protein functionality in foods by altering its surface chemistry and aggregating behavior. Many studies have confirmed that the addition of polysaccharides prevented the coalescence and interaction between microparticulated proteins, either by shielding charged groups or by decreasing the collision rate between molecules through an increase in the viscosity of the system. The presence of polysaccharides can also bind a large amount of water to provide a creaminess sensation through the oral process. Thus, a protein-based fat mimetic in combination with polysaccharides is usually formulated to replace fat to develop low-fat products. The polysaccharides used in complexation with protein are gum arabic, pectin, alginate, and xanthan. Nowadays, there is a growing trend to develop plant protein–polysaccharide hydrogel from peas, lentils, and soybeans to increase their sustainability.

Conclusion

Fats play a very significant function in food matrices and impart physical and sensory properties to the food products. Fat replacers have facilitated the emergence of low-fat and fat-free foods that mimic the flavor and texture of high-fat foods. Although using fat-modified foods can help to avoid weight gain and related chronic diseases but they still don't replace the need for practicing good nutritional habits. The fat replacers currently available in the market do not contribute to all the sensory and functional properties of conventional fats. An ideal fat replacer must be safe for consumption, cost-effective, low-caloric, suitable for cooking, contribute to sensory properties and at the same time play functional role in the food products. Nonetheless, it can be claimed that fat replacers may help in meeting the required aims of current dietary recommendations as long as they are coupled with physical activity and mindful eating. Further research is needed in order to explore other potential sources of fat-replacers which can be successfully utilized for the development of new and healthy products in food industries as an effective alternative of fats.

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Nutraceuticals Fortification in Milk and Milk Products

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The Codex Alimentarius defines food fortification as the addition of one or more necessary nutrients to a food, whether they are typically present in the food or not, in order to prevent nutrient deficiencies in the population. Food enrichment is the practice of adding necessary micronutrients to food to replace those that are lost during preparation. In order to lower the risk of nutrient insufficiency and related disorders among individuals of all ages, vital nutrients such as vitamins, minerals, omega-3 fatty acids, probiotics, prebiotics, and phytochemicals are added to dairy products through the process of "milk fortification." The fortification is favoured by the variety of dairy products such whole milk, yoghurt, cheese, yoghurt drinks, dairy-based beverages, milk powder, butter, and buttermilk. Any food (or component of a food) that promotes medical or health advantages, such as the prevention and/or treatment of disease, is referred to as a nutraceutical. Even though milk is one of the healthiest foods, it is lacking in a number of micronutrients and several nutraceuticals (Nagarajappa& Battula, 2017). Therefore, adding nutraceuticals to milk is necessary for physiologic benefits or disease prevention.

Nutraceutical Components Used for the Fortification of Milk and Milk Products

Fortification of different nutraceuticals components is receiving more attention these days in order to improve the technological and nutritional quality of milk and milk products. Probiotics, prebiotics, phytochemicals, fruit purees or pulp, conjugated linoleic acid, omega-3 fatty acids, milk fat globule membrane, herbs, and other nutrients are frequently added to fortify milk and milk products.

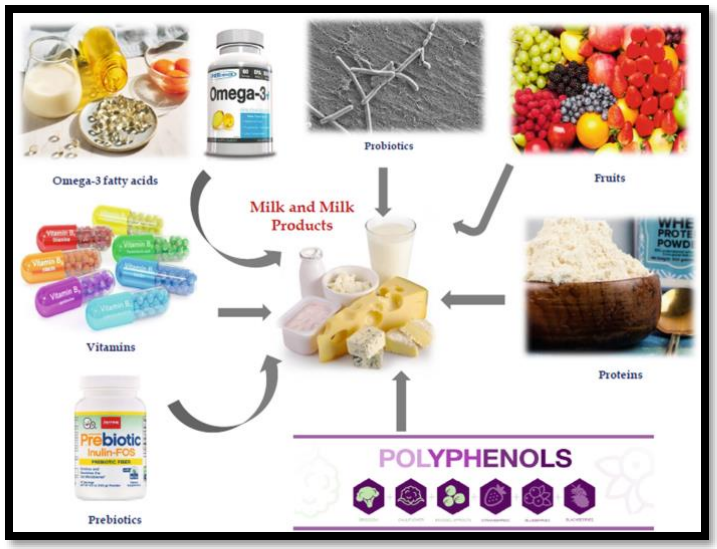

Figure1: Nutraceuticals Components Used for the Fortification in Milk and Milk Products

1. Probiotics

Value-added dairy products can be manufactured by addition of live and active micro-organisms known as probiotics. Probiotic fortified dairy products not only improve the gut health but also have many more beneficial health effects.Cheese, yoghurt, milk drinks, and frozen dairy products are examples of fermented dairy products that make excellent probiotic delivery vehicles. These products safeguard the probiotic bacteria's viability in addition to provide a favourable environment for their growth and development. However, it serves as a vehicle for delivering a certain quantity of live bacteria into the gut. The most important factors to take into accountthat probiotic bacteria must be present at an effective level in all products and that level must be maintained during the whole product's shelf life.The capacity of live probiotic bacteria to survive can be impacted by a variety of variables, such as pH, processing conditions, presence of inhibitory components, storage temperature, and more. There are numerous manufacturers who are currently engaged in manufacturing the dairy products with added nutraceuticals. Unilever's Culture Republick probiotic-fortified light ice cream asserts that it contains three billion live probiotic bacteria (https://www.culturerepublick.com/). Similar claims are made for Dannon YoCream frozen yoghurt by Danone North America, which states that each gram of the product contains 100 million cultures.

2. Prebiotics

Prebiotics are dietary fiber which is helpful in the growth and promotion of probiotic bacteria in the gut mainly lactobacilli and bifidobacteria. The International Scientific Association for Probiotics and Prebiotics (2016) defines prebiotics as "A substrate that is selectively utilized by host microorganisms conferring a health benefit". The most common prebiotics inulin, galacto-oligosaccharides (GOS), fructo-oligosaccharides (FOS), lactulose, and xylo-oligosaccharides (XOS) have been studied for their functional aspects (Boehm and Moro, 2008). Prebiotic inulin also promotes the growth and viability of National Collection of Dairy Cultures (NCDC) yoghurt cultures which can be further used to make functional fermented milk products (Minj and Vij, 2017). Prebiotic components also improve the technological and nutritional properties of the food (Farias *et al.,* 2019). The IASPP suggested dietary recommendation for prebiotic or dietary fiber is 28 g/day (source: ISAPP).

3. Phytochemicals or Plant-Based Ingredients

Natural ingredients derived from plants have long been known to improve the human health. There are numerous potential health advantages of substances including polyphenol, flavonoids, phytosterols, catechin, phytoestrogens, phytostanols, and carotenoids. These plant-based substances have a reputation for being possible antioxidants that can boost milk and milk products' natural antioxidant capacities. Despite the fact that synthetic antioxidants are also available for food fortification, their use has the potential to have harmful and cancer-causing consequences. Regular use of foods high in natural antioxidants can lower the prevalence of numerous illnesses like cancer, heart disease, and hypertension. The functional qualities of yoghurt have been enhanced by fortification with phytochemicals such peppermint essential oil, basil, and zataria (Azizkhani and Tooryan, 2016).

4. Fruit/Fruit Pulp/Fruit Purees

Fortification with fruit and fruit pulp to the dairy products not only improves its biofunctional properties, but it also contributes to the technological properties of the product. Fruits are rich in vitamins, minerals, fibers, and polyphenols, and they are an excellent source of antioxidants. Fortification with fruit, fruit pulp, or purees also provides various options to the consumer to buy the products. Yoghurt fortified with fruits improves its flavor (Ndabikunze et al., 2017), taste, and nutritional properties. Many antioxidant-rich fruits like blueberry, strawberry, raspberry, cherries, apricots, pineapples, orange, and peaches are used for the dairy product formulation.

5. Omega-3 Fatty Acids

Some essential fatty acids, including omega-3 fatty acids, have long been recognized for their significance in a variety of physiological processes, including cognitive growth and maintenance, cardiovascular disease prevention, and anti-inflammatory properties. Linoleic acid (LA), eicosapentaenoic acid (EPA), and docosahexaenoic acid (DHA) are three of the most popular Omega-3 fatty acids (Gruenwald, 2009). The market for dairy products containing Omega-3 fatty acids has been expanding steadily over the past few years and has already overtaken all other functional food categories in the US (Mellema and Bot, 2009). According to Goyal et al. (2016), fortification of microencapsulated flaxseed oil powder for omega-3 supplementation in dahi (Indian yoghurt) has been proposed as a viable delivery method.

Dairy-Based Omega-3 Beverages

Milk is an efficient vehicle for fat absorption. In addition to fresh milk, fermented milk, and yogurt drinks are the popular dairy beverages suitable for omega-3-enrichment. Omega-3 fortification of milk can be done broadly using two types of methods:

- **i.** Preharvest biofortification of milk.
- **ii.** Postharvest fortification of milk

Challenges in Omega-3 Fortification of Beverages

a) Due to the large number of C-C double bonds in their molecular structure, omega-3 FAs are susceptible to oxidation which results in to lowering of the nutritive value and off smell. EPA and DHA have more double bonds than ALA; therefore, they are more susceptible to oxidation leading to typical fishy smell.

b) As omega-3 fats are water immiscible, to fortify aqueous beverages with omega-3 fats, emulsification of these fats is a must. Emulsification is achieved using different types of surfactants/emulsifiers. In emulsion oil, water, and surfactants are mixed to form a single homogenous phase. But there are two main challenges in this area, first is emulsion stability, and the second is flavor stability. Several methods have been used for the preparation of stable emulsion such as phase inversion, phase titration, high-pressure homogenization, and sonication (Puranik, 2016).

6. Conjugated Linoleic Acid (CLA)

Conjugated linoleic acid (CLA), a beneficial milk component, has recently attracted particular interest from the Canadian dairy sector and researchers. Many linoleic acid isomers that don't have a methylene (CH_2) group in-between the two double bonds are collectively referred to as conjugated linoleic acid (CLA). The two primary CLA isomers with known biological activity are cis-9, trans-11 and cis-10, cis-12, and their mixture (50:50) has been allowed for use in food as GRAS (generally regarded as safe) in the United States since 2008. CLA, which is naturally produced by ruminant animals, may lower the risk of obesity, diabetes, cardiovascular disease, and cancer while also strengthening the immune system. By giving cows a diet enriched with CLA, the CLA level in milk can be increased even more.

7. Dietary Fibre

Plants cell wall contains many compounds including cellulose, hemicellulose, lignin and pectin collectively known as dietary fibre. Humans cannot digest dietary fibre due to lack of enzymes.

Importance Of Fortified Dairy Products with Dietary Fibers:

One of the greatest ways to increase the overall nutrient intake of food while minimizing adverse effects is to fortify dairy products using natural resources (fruits, grains, etc.). Consuming high-fiber foods and beverages may prevent or lessen cancer, hypertension, hypercholesterolemia, obesity, gastrointestinal diseases, and coronary heart disease. Together with grains, legumes are the primary source of plant-based protein in the human diet. Additionally, they are typically high in carbs and dietary fiber. Lipids, polyphenols, and bioactive peptides are the minor constituents of legumes. It is becoming more popular to add fiber to yogurt or other dairy products to make them more functional and to give them health advantages. Yogurt's beneficial qualities would be complemented by adding dietary fiber.Inulin is a prebiotic fiber that is fermented in the lower intestine by the beneficial bacteria, Bifidobacterium. Because inulin is a lower calorie carbohydrate, it is beneficial in formulating reduced and low-calorie foods. Inulin has little or no impact on blood sugar making it a quality sugar substitute in low-glycemic foods.

Effect of plant fiber fortification on dairy products properties

The importance of food fibers coupled with the fact that milk and milk products are devoid of dietary fiber has led to the successful development of various dietary fiber fortified dairy products such as yoghurt, Ice-cream, dairy-dessert and lactic-beverage. Fiber of various sources is added to dairy products because of its water-holding capacity and its ability to increase the production yield, reduce the lipid retention, improve textural properties and structure, and reduce caloric content by acting as a bulking agent. Native inulin, such as Oliggo-Fiber® Instant inulin, is an extremely versatile product for fiber fortification. As a soluble source of fiber, it can be easily incorporated into dairy products, including yogurt, ice cream and cheese. It also allows for fiber fortification into beverages, such as meal replacements, dairy-based beverages.

8. **Herbs**

The term herb is used loosely to refer not only to herbaceous plants but also to bark, roots, leaves, seeds, flowers and fruits of trees, shrubs and woody vines and extracts that are valued for their savory, aromatic or medicinal qualities. In different herbs, a wide variety of active phytochemicals including the flavonoids, terpenoids, lignans, Sulfides, polyphenols, carotenoids, coumarins, saponins, plants sterols, curcumins and phthalides have been identified. Table 1. Represents the some of the examples of herbs-fortified dairy products.

Product	Reference
Herbal ghee	Rainikant *et al.*, 2006
Pueraria tuberosa + milk	Sawale *et al.*, 2011
Ashavganda + milk	Moharkar *et al.*, 2011
Satavari + milk	Veena *et al.*, 2011
Sandesh+ herb	Bandopadyay *et al.*, 2008
Milk based wolfberry	Feng *et al.*, 2010

Influence of Herb Components on Health Attributes

Immunomodulatory activity

Herbal products are known to possess immunomodulatory properties and generally act by stimulating both specific and non-specific immunity. Many plants are identified by rasayanas in the Indian Ayurvedic system of medicine having various pharmacological properties such as immunostimulant, tonic, neurostimulant, anti-ageing, antibacterial, antirheumatic, anticancer, adoptogenic and antistress.

Antioxidant activity

Antioxidant activity plays an important role in pharmacological activities such as anti-aging, anti-inflammatory, anti-atherosclerosis, and anti-cancer activities. Inhibition of free radical induced damage by supplementation of antioxidants has become an attractive therapeutic strategy for reducing the risk of diseases (Brash and Harve, 2002). Several synthetic antioxidants are available, but are quite unsafe and considerably toxic.

Major Challenges in Development of Herbal Fortified milk products:

a) Awareness
b) Sensory acceptance (Color and Taste)
c) Optimized extraction medium
d) Process stability
e) Product Stability
f) Geographical Variation

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Human Milk Oligosaccharides: The Bridge Between Human Milk and Infant Formula

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Breastfeeding is commonly regarded as the gold standard for supplying nutrition to infants and has been a natural method of feeding infants since ancient times. The World Health Organization (WHO) recommends exclusive breastfeeding for the first six months after birth. On one hand, breastfeeding supplies infants with essential nutrients for their healthy growth. On the other hand, it offers protection against infections, particularly gastrointestinal and respiratory ones, and lowers the risk of various conditions like obesity, diabetes, atopy, and asthma.The structure of breast milk is complex and dynamic, comprising macronutrients (carbohydrates, proteins, and fats), micronutrients (such as calcium, thiamine, and zinc), hormones, insulin-like growth factors, and cytokines.Human milk oligosaccharides (HMOs), the third most abundant solid component in human milk, are resistant to digestion in upper small intestine and the majority of HMOs reach the large intestine (Zhang *et al.,* 2021).

HMOs, a class of non-digestible carbohydrates, constitute a significant component of human breast milk. The concentration of HMOs varies, with levels ranging from 20 to 25 g/L in colostrum and 5 to 15 g/L in mature human milk. One of the defining features of HMOs is their resilience against processes such as pasteurization and freeze-drying. Structurally, HMOs are built upon a lactose base that elongates through the addition of N-acetyllactosamine units, accompanied by fucoylation and/or sialylation. This intricate process results in three major categories: fucosylated neutral HMOs(35-50%), non-fucosylated neutral HMOs(42-55%), and sialylated acidic HMOs (12-14%).Neutral HMOs make up over 75% of total HMOs, with 2'-fucosyllactose (2'-FL), a trisaccharide consisting of glucose, galactose, and fucose, being the most prevalent (accounting for almost 30% of all HMOs).HMOs have a fundamental structural design, despite the fact that they come in several forms and perform a range of tasks (Figure 1). The basic building components of HMOs are five monosaccharides: glucose, galactose, N-acetylglucosamine, fucose, and N-acetylneuraminic acid(Ray *et al.,* 2019).

Functions and health benefits of HMOs

Numerous research endeavors have supported the positive impacts of HMOs. HMOs have been recognized as active prebiotics that withstand digestion by human enzymes and foster the proliferation of advantageous bacteria. For instance, *Bifidobacterium longum subsp. infantis* (B. infantis) thrives on HMOs as its exclusive carbohydrate source.Furthermore, various strains of bifidobacteria have demonstrated the capability to utilize HMOs for their growth stimulation. The proliferation of bifidobacteria results in the production of short-chain fatty acids that create an environment conducive to the expansion of beneficial bacteria, thus discouraging the growth of potential pathogens.

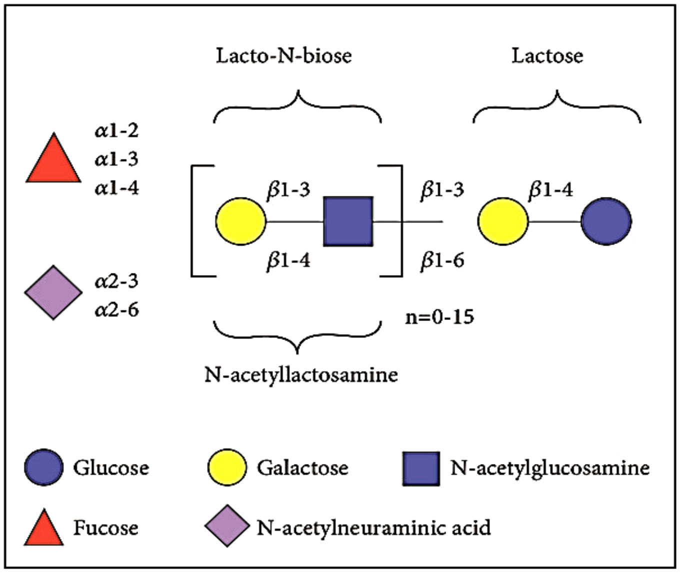

Fig 1: Structural blueprint of HMOs (adapted from Ray *et al.*, 2019)

HMOs possess a significance beyond merely being "nutrition for microorganisms". Evolutionarily, it is speculated that oligosaccharides in milk might have played a role in the antimicrobial defence system. Research indicates that certain specific HMOs can directly impede the growth of group B Streptococcus (GBS), a predominant cause of invasive bacterial infections in newborns typically acquired during childbirth due to maternal vaginal colonization. Moreover, HMOs exhibit the ability to modulate GBS growth and the formation of biofilms. Detailed microscopic analysis revealed disruptions in the arrangement of biofilm cells in bacterial cultures treated with particular HMOs, indicating the bacteriostatic impact of HMOs by hampering bacterial growth kinetics (Asakuma*et al.*, 2011).

HMOs also exhibit an antiadhesive effect. Pathogens like viruses, bacteria, and parasites often require adherence to mucosal surfaces to colonize and cause diseases. HMOs function as decoy receptors, thwarting microbe attachment to epithelial cells. Notable studies in animals demonstrated HMO-mediated inhibition of Campylobacter colonization and protection against infectious diarrhoea. Another HMO, lacto-N-neotetraose (LNnT), administered intratracheally alongside pneumococcus, exhibited the potential to mitigate the progress of pneumococcal pneumonia and prevent nasopharyngeal colonization in animal models.

Apart from shaping the gut microbiota composition, HMOs directly influence the responses of host intestinal epithelial cells. They can curtail cell growth while inducing differentiation and apoptosis in human intestinal cells. Some HMOs are also implicated in promoting the maturation of intestinal cells and enhancing barrier function. Another significant role of HMOs is their capacity for immunomodulation.HMOs have a dual impact on the immune system: they exert direct effects on immune cells systemically upon absorption into the bloodstream, while also indirectly influencing immune responses by altering the gut microbiota. Following ingestion, most HMOs resist intestinal digestion and reach the distal small intestine and colon, with a small fraction, approximately 1%, being absorbed and detected in the systemic circulation and urine. The exact mechanism of HMO absorption into the bloodstream remains partially understood; however, studies indicate that HMOs bind to endothelial cells, leading to interactions with monocytes, lymphocytes, and neutrophils, thereby exerting systemic effects (Bode *et al.,* 2004).

HMOs possess a direct impact on intestinal epithelial cells, governing gene expression and prompting changes in cell surface glycans and other cellular responses. Lymphocyte cytokine production can also be influenced by HMOs, possibly leading to a more balanced Th1/Th2 response. Notably, one of the primary HMO components, 2'-fucosyllactose (2'-FL), plays a role in restraining inflammation during the invasion of enterotoxigenic *Escherichia coli* into intestinal epithelial cells. This is achieved through the attenuation of CD14 induction, which mediates the lipopolysaccharide-Toll-like receptor 4 stimulation of an inflammatory pathway.

Furthermore, the influence of HMOs extends to neurodevelopment and cognitive function. Animal studies have revealed that oral supplementation of 2'-FL enhances memory and learning. Human cohort studies have also indicated that increased early exposure to 2'-FL might contribute to infant cognitive development. Moreover, metabolic byproducts of HMOs, such as sialic acid, play a role in promoting brain development, neuronal transmission, and synaptogenesis(Cheng and Yeung, 2021).

Synthetic methods for HMO production

Research efforts have been concentrated on acquiring access to thesemacromolecules via synthetic pathways since scientific evidence strongly supports the role of HMO in a number of beneficial physiological effects in newborns.Indeed, by attracting new customers or by incorporating HMOs into other products, the need for HMOs may increase over the next years. As of now, four possible synthetic pathways—chemical synthesis, whole-cell biotransformation, enzymatic, and chemo-enzymatic pathways—have been suggested for the generation of HMOs(Pérez-Escalante*et al.,* 2022).

Incorporation of HMO to infant formula

Only 38% ofthe worldwide infant population has been exclusivelybreastfed. Presently, the composition of milk formulas for newborns has evolved, moving away from the conventional fortification with oligosaccharides like FOS and GOS, which were more prevalent in previous years. As a result, a novel approach to infant formula has arisen, with the industry striving to create formulations that closely resemble human milk. This is achieved by incorporating fats, proteins, and HMOs.

When maternal production of certain HMOs is insufficient or to provide additional disease protection in early childhood, integrating HMOs into milk formulas is recommended. Research supports the idea that well-formulated HMO compositions can yield similar microbiome profiles as those found in breastfed infants. For instance, a cow protein-based infant formula containing 2'-fucosyllactose (2'FL) and lacto-N-neotetraose (LNnT) at specific concentrations showed promising microbiome similarity to breastfed infants.Furthermore, studies have highlighted the good assimilation and tolerance of infants fed with formulas containing 2'FL and LNnT.

Studies investigating the safety and tolerance of HMOs in infant milk formulations have yielded positive results. Formulas enriched with 2'FL and LNnT were well-tolerated, with favorable absorption rates and no significant differences in anthropometric measurements when compared to formulas fortified with other oligosaccharides. Moreover, infants fed with 2'FL and LNnT-enriched formulas exhibited a lower incidence of respiratory infections and reduced use of antipyretics and antibiotics.

Currently, HMOs are present in infant formulas developed by Nestlé and Abbott, mainly 2'-fucosyllactose (2'FL) and lacto-N-neotetraose (LNnT) incorporation (Bych *et al.*,2019). Eventhough many foreign countries have legally permitted HMO addition to infant formulas; Indian standards does not permit the same. Hence, formulas with HMOs are not available in Indian market (Pérez-Escalante*et al.*, 2022).

Conclusion

In conclusion, breast milk stands as the gold standard for infant feeding and nutrition, offering a range of benefits essential for optimal growth and development. Human Milk Oligosaccharides (HMOs), a distinctive component of breast milk, constitute a critical factor in differentiating between human milk and formula. While breastfeeding remains the optimal choice for infant nutrition and well-being, the incorporation of HMOs into infant formulas emerges as a viable alternative when breast milk is inadequate or unavailable. Although challenges in synthesizing certain HMOs persist, the continuous research and progress in this area hold the promise of further refining infant formulas and improving the overall well-being of infants in need. In coming years, HMOs will be considered as gold standard for premium infant formulas.

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Quality Changes in The Fruits and Vegetables After Processing

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A crucial factor that directly affects the desirableness, nutritional value, and general consumer satisfaction of fruits and vegetables is their quality. A healthy diet must include fruits and vegetables because they offer a variety of vitamins, minerals, fibre, and antioxidants that promote overall wellbeing (Arshad et al., 2021). The cultivation of these natural goods as well as their handling, storage, and processing after harvest are all aspects that have an impact on their quality (Nicastro &Carillo, 2021).

Fruits and vegetables can undergo a variety of quality changes as a result of processing, both positive and negative. The precise alterations depend on the kind of processing techniques employed, how long it takes, and the environmental factors involved.

The quality of fruits and vegetables encompasses several attributes

- Nutritional value: The existence of necessary vitamins, minerals, and nutrients that support the health and vigour of humans. A wide variety of essential nutrients should be present in high-quality fruits and vegetables(Uthman& Garba, 2023).
- Freshness: The quality of having just been picked or newly harvested, which guarantees the best possible flavour, texture, and appearance. The flavour and texture of fresh fruits and vegetables make them very enticing (Agarwal).
- Fruits and vegetables are distinguished by their appearance, which includes their colour, size, form, and lack of blemishes or other flaws. Consumer choices are frequently influenced by attractive looks (Mohamed et al., 2021).
- Texture: A fruit or vegetable's ability to be felt, such as its crispiness, juicy, tender, or firm it is. The experience of eating is substantially influenced by texture (Szczesniak, 2020).
- The various flavours and aromas that give fruits and vegetables their overall sensory appeal is known as flavour and aroma. A high-quality produce's distinctive flavour combination is its defining characteristic.
- Safety: the assurance that the produce is free of dangerous infections, chemicals, or toxins that could endanger the health of customers.
- Fruits and vegetables preserve their quality and freshness without suffering significant deterioration throughout the duration of their shelf life. Better distribution and less food waste are made possible by longer shelf life.
- Processing Suitability**:** It's critical that fruits and vegetables are suitable for processing without sacrificing quality if they're going to be turned into juices, canned foods, or frozen goods.

Factors affecting quality of fruits and vegetables

A number of interrelated elements, such as product type, minimal operations (such as slicing, washing, antimicrobial, and anti-browning treatments), exposure duration, packaging, and storage temperature conditions, affect the quality of fresh fruits and vegetables.

Product type: Each product type has a unique combination of physical and compositional traits, as well as growing, harvesting, and processing procedures and storage requirements. Size, colour, flavour, texture, nutritional content, insect resistance, processing appropriateness, eating quality, and yield are just a few of the characteristics that differ between cultivars. The cultivar chosen for fresh cut processing has a significant impact on the shelf life and general quality of the final product (Liu et al., 2022).

Processing operations: Peeling, slicing, and shredding are examples of unit operations used in the processing of minimally processed produce. These operations damage surface cells, stress tissues, and in the case of fruits, remove natural barriers like cuticles and skins. This leaves tissues more vulnerable to water loss and decay.Due to processing-related damage, there is an increase in respiration rate and ethylene generation, which could hasten the deterioration of non-climacteric tissues and encourage fruit ripening in climacteric fruits (Giannakourou & Tsironi, 2021).

Packaging: The best strategy for increasing the shelf life of fresh and little processed produce is thought to be modified environment packaging. A decrease in respiration rate, ethylene generation, enzymatic processes, and other physiological problems are of MAP's advantageous impacts, which improve product quality and shelf life (Yadav et al.,2022).

By actively flushing a gas mixture through the packaging prior to sealing, MAP tries to actively construct an optimum gas composition within the packaging, which can be directly generated by the commodity inside the package.

Transport and storage: One of the most important aspects in preserving the quality of minimally treated produce is storage temperature. To preserve fruits and vegetables at the ideal temperature from the point of processing to the destination, cold chain management is crucial (Oberoi & Dinesh, 2019). As a result, physiological processes are slowed down and microbial growth is decreased, maintaining freshness and nutrient content.

Positive attributes of processing of fruits and vegetables

Preservation: By lowering microbial activity, enzymatic reactions, and moisture content, processing can increase the shelf life of fruits and vegetables while maintaining their freshness for a longer period.

Safety: Some processing techniques, including pasteurisation and canning, can eliminate dangerous microorganisms, making the food safer to eat (Ariyamuthu et al., 2022).

Convenience: For the benefit of consumers, processed fruits and vegetables frequently come in ready-to-eat or simple-to-prepare formats.

Nutritional Retention: Some processing processes, such as freezing, can help fruits and vegetables maintain their nutritional value more effectively than other approaches (Waghmare et al., 2022).

Enhancement of Flavour: Certain processing techniques, such as dehydration and drying, can concentrate the inherent flavours of fruits and vegetables, making them more potent and palatable.

Negative attributes of processing of fruits and vegetables

Nutrient Loss: Heat-sensitive nutrients, such as vitamin C and several B vitamins, can be lost during certain processing techniques, such as high-temperature cooking and lengthy storage (Coe & Spiro, 2022).

Changes in Texture: Fruits and vegetables' textures might change as a result of processing. For instance, freezing and canning could make some veggies mushy or softer.

Changes in Colour: Fruits and vegetables' colours may fade or alter as a result of processing, which affects how appetising they appear (Gençdağ et al., 2022).

Flavour Loss: While certain processing techniques improve flavours, others may cause the loss of volatile chemicals that give fruits and vegetables their distinctive flavours and aromas.

Additives: Some processed foods may contain additives like preservatives, sugars, or sodium to improve flavour or shelf life, which may not be appealing to consumers who are concerned about their health (Ukwo et al., 2022).

Conclusion

To preserve the nutritional value and quality of fruits and vegetables to the greatest extent possible, it is crucial to select the right processing techniques and ensure correct handling and storage. A balanced and nutritious diet can also be maintained by consuming a range of fresh, minimally processed fruits and vegetables.

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Diverse Approaches to Microencapsulation in Food Processing

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Microencapsulation can be defined as a process of enclosing or enveloping wherein solids, liquid or gaseous material (core particle) are compactly packed with thin polymeric coatings (matrix) to form small particles referred to as microcapsules in the micrometer (µm) to millimeter (mm) range (2-5000 µm) (Gibbs *et al.*, 1999).Microencapsulation is a versatile technology that has gained significant attention in the food industry due to its potential to enhance the stability, bioavailability, and controlled release of various bioactive compounds and ingredients. Microencapsulation involves the encapsulation of active ingredients, such as flavours, aromas, vitamins, minerals, probiotics, enzymes, and functional lipids, within a protective matrix or shell. This encapsulation process offers numerous advantages, including improved ingredient protection against degradation caused by environmental factors like light, heat, and oxygen, as well as the ability to mask undesirable tastes or odours. Several microencapsulation techniques are employed in the food industry to achieve these goals. Spray drying is a widely used technique that involves atomizing a liquid formulation into droplets, which are then rapidly dried to form encapsulated particles. Coacervation involves the phase separation of polymers around the active ingredient, leading to the formation of microcapsules. Inclusion complexation, electrostatic deposition, freeze drying and extrusion are other techniques that offer unique ways to encapsulate ingredients. The choice of microencapsulation technique depends on factors such as the nature of the ingredient, the desired release profile, and the intended application. Microencapsulation finds applications in a variety of food products, including beverages, baked goods, dairy products, and functional foods. The technology enables the controlled release of active compounds during consumption, which can result in extended flavour perception, improved nutrient absorption, and targeted delivery of bioactive compounds to specific areas of the digestive tract.Additionally, it improves sensory quality by reducing unpleasant tastes, aromas, and flavours, prevention of germ's growth (Hasanvand*et al.,* 2015).Various flavourings agents, lipids, antioxidants, essential oils, pigments, probiotic bacteria, and vitamins are several dietary components that are commonly encapsulated (Azeredo, 2005).

Using various protective wall materials that allow them to be released at a particular place, at a specific time, and under specific conditions. Microencapsulation can be a solution to the problems faced in the formulation of complex foods. Such foods have recently been put on display in the food sectors, such as the usage of some volatile flavours in instant mixes and fatty acidsin dairy products, which are especially susceptible to auto-oxidation. The solution to this problem is microencapsulation.

Classification of Microcapsules

The term "microcapsules" describes microparticles with a core surrounded by a coat or wall materials that are distinctly different from the core, payload, or nucleus, which may be solid, liquid, or even gas.

As shown in Figure 1, there are three categories of microcapsules:

a) Mononuclear: Containing the core in a shell.
b) Polynuclear: Having several cores encased in a shell.
c) Matrix type: Evenly distributed throughout the shell material

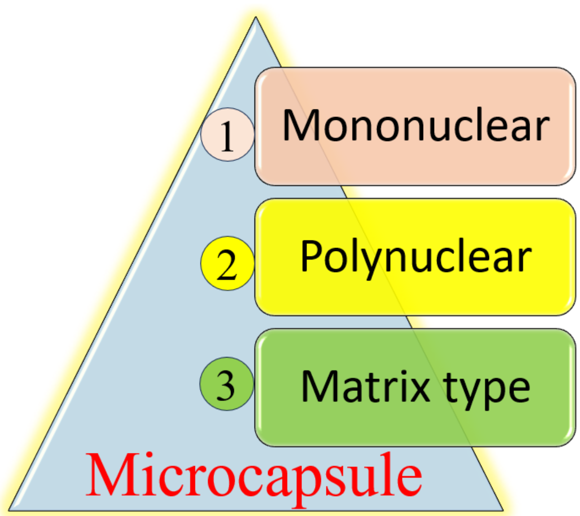

Fig. 1: Classification of Microcapsules

Methods of Microencapsulation Techniques

There are various techniques for microencapsulation, including freeze drying, fluidized bed coating, spray chilling, spray cooling and coacervation.

Spray drying: Probiotic cultures in the dairy and pharmaceutical industries are encapsulated through spray drying. This involves rapidly evaporating water from a suspension solution of microbial cells with wall material in a drying chamber (Fig. 2). The hot, dry air contacts the atomized spray droplets, resulting in the collection of dried solid particles at the chamber's bottom. This technology enables the fast and cost-effective production of spherical powder particles with desired qualities, such as uniform shape, size, and residual moisture content.

Table 1. Microencapsulation Techniques and Their Principle

Microencapsulation process	Principle	Nature of core material
Spray drying	Forming an emulsion or dispersion and atomizing the mixture into the drying chamber.	Solids and liquids
Spray cooling	Condensing the core within a liquid shell and ejecting it through a heated nozzle into a controlled cold setting.	Solids and liquids
Freeze drying	Transforming ice into vapor rapidly.	Liquid and solid
Fluidized bed coating	Core material particles are suspended in an air stream and coated with molten polymer.	Solids
Emulsification	Create an emulsion by mixing core and wall materials, then stabilize it with an emulsion stabilizer.	Solids and liquids
Coacervation	Creating three immiscible chemicals, coating deposition, and coating digitization.	Solids and liquids

Spray cooling: Spray cooling utilizes cold air in the process, distinguishing it from spray drying. The mixture of core and wall materials is atomized in a chamber with cold air, causing the microdroplets to solidify and form microencapsulated powder. This method has great growth potential and has been successfully used for various encapsulation applications. For example, it has been used to achieve high encapsulation efficiency of tocopherols in a lipid matrix (Gamboa *et al.*, 2011) and to create highly stable microcapsules for encapsulating iron, iodine, and vitamin A in hydrogenated palm oil for salt fortification (Wegmüller*et al.*, 2006).

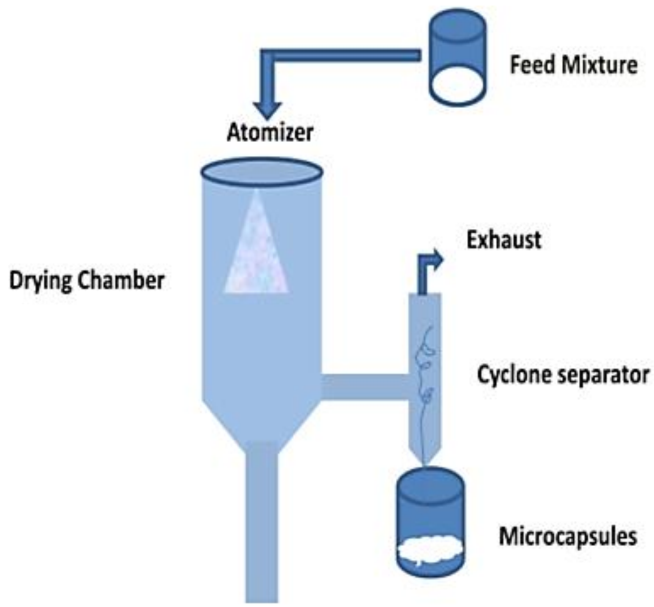

Fig. 2 Microencapsulation by Spray Drying

Freeze drying: Freeze drying operates on the principle of sublimation, where ice rapidly transforms into vapor. The process consists of three steps: freezing, primary drying, and secondary drying. Freezing causes water to crystallize and separate at extremely low temperatures. Sublimation then eliminates frozen water during primary drying, while desorption-based secondary drying removes any remaining non-frozen water. It's important to note that low freezing temperatures can potentially impact protein structures and the physical state of membrane lipids.

Fluidized bed coating: Fluidized bed coating involves covering the fluidized core material with a coating material. Air is used to fluidize the core material, and then the coating material is sprayed onto it, as shown in figure 3. There are three methods for coating a fluidized bed: top spray, bottom spray, and tangential spray. The effectiveness of the coating depends on factors such as the feed rate of the wall material, atomization pressure of the nozzle, temperature, and velocity of the incoming air, etc.

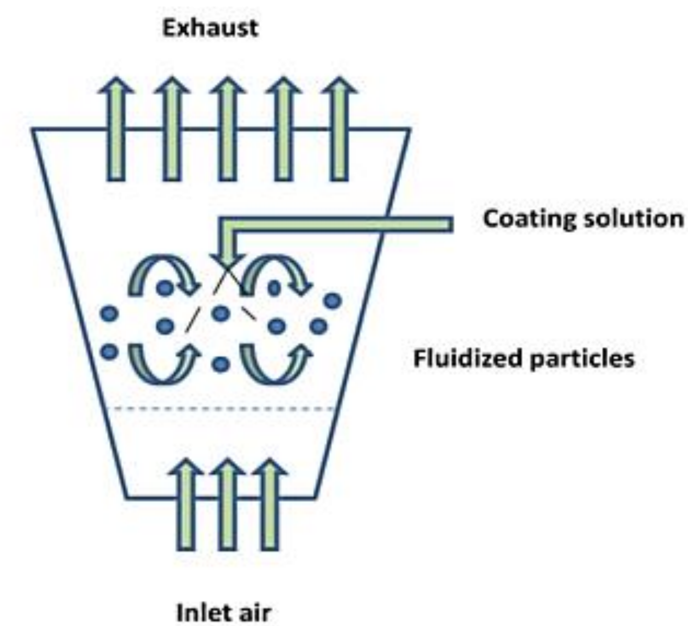

Fig. 3 Microencapsulation by Fluidized Bed Coating

Coacervation: Coacervation involves forming a uniform layer of polymeric wall material around the core (Fig. 4). This is achieved by modifying the physicochemical properties of the wall material through temperature, pH, or ionic strength changes. The wall and core materials are mixed to create an immiscible mixture. By adjusting the ionic strength, pH, or temperature, phase separation occurs, forming dense polymer-rich liquid droplets called coacervates. These coacervates then encapsulate the core substance, creating microcapsules.

Extrusion: The extrusion method of microencapsulation is used to produce highly dense microcapsules. This method requires the core material and the wall material to be immiscible, as shown in figure 5. Using concentric nozzles, the wall material surrounds the core material and is pushed out in the form of droplets. These droplets then solidify either through complex creation in a gelling bath or by cooling. Compared to other methods, the microcapsules produced through extrusion tend to be larger in size. However, the range of materials that can be used for the walls in this method is limited.

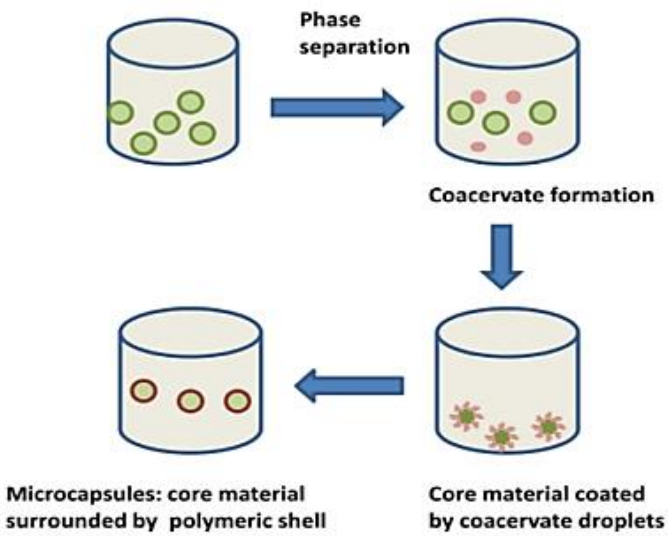

Fig. 4 Microencapsulation by Coacervation

Emulsification: In the emulsification process of encapsulation, the core is dispersed in an organic solvent with the wall material. An emulsion stabilizer is added and the mixture is emulsified in oil or water. As the solvent evaporates, a tight polymer layer forms around the core, enclosing it. This method is commonly used for encapsulating enzymes and bacteria. Song *et al.* (2013) encapsulated probiotics in alginate-chitosan using this technique and demonstrated improved resistance of the probiotics to stimuli in the gastrointestinal tract.

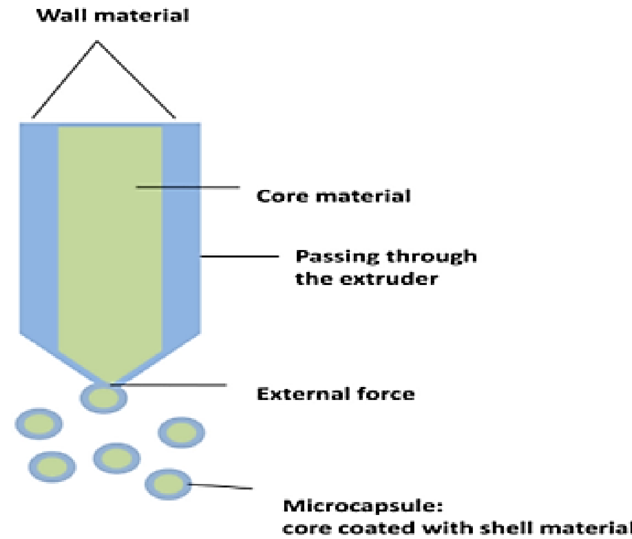

Fig. 5 Microencapsulation by Extrusion

Advantages and disadvantages of the Microencapsulation Process

(A) Advantages of microencapsulation:

a) Providing environmental protection to the encapsulated active agents or core materials.

b) Liquids and gases can be changed into solid particles in the form of microcapsules.

c) Surface, as well as colloidal characteristics of various active agents, can be changed.

d) Modify and delayed drug release from different pharmaceutical dosage forms.

e) Formulation of sustained controlled-release dosage forms can be done by modifying or delaying the release of encapsulated active agents or core materials.

(B) Disadvantages of microencapsulation:

a) Expensive techniques.

b) This causes a reduction in the shelf-life of hygroscopic agents.
c) Microencapsulation coating may not be uniform and this can influence the release of encapsulated materials.
d) There are a number of restrictions when encasing food items since the wall materials must be food grade or generally recognized as safe (GRAS).

Conclusion

Microencapsulation techniques, including extrusion, freeze drying, fluidized bed coating, spray chilling, spray cooling, and coacervation which are help to extend the shelf life of products and improve it improves sensory quality by reducing unpleasant tastes, aromas, and flavours, additionally, it raises food safety to inhibit the growth of pathogenic microorganisms.

Microencapsulation has proven and is further considered to prove as an effective tool in creating novel food products with numerous functional properties. Microencapsulation technology has applications for many commercial food products, including juices, chocolates, meat and poultry products, etc. Microencapsulation has been applied widely in a variety of food and pharmaceutical products. Studies have shown its enormous potential to provide superiorly featured core, resulting in advanced quality products applicable in the food and pharmaceutical industry. It provides an effective protection for active agent against oxidation, evaporation or migration in food as well as facilitate conversion of liquids to powders.

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Role of Water Activity in Food Stability

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Water activity, a thermodynamic parameter, is the ratio of vapor pressure of water in a system to that of pure water at the same temperature or equilibrium relative humidity of surrounding air. It plays a pivotal role in microbial growth inhibition and material stability. The influence of water activity (a_w) on molecular mobility within the matrix affects physical stability, primarily governed by diffusion, a kinetic process influenced by factors like matrix porosity and molecular sizes. Water activity is a vital factor in microbial growth and food shelf life. It significantly impacts food quality, stability, and safety, influencing deteriorative reactions, physical attributes, and microbial growth rates. Methods like concentration, dehydration, and freezing decrease water availability for microbial activity. Additionally, preservation techniques involving solutes restrict microbial water access, further enhancing food stability and safety.

Importance of water activity (a_w) and Growth of Microbes in Foods

The majority of food contains more water than 0.95, which promotes the growth of bacteria, yeast, and mold. It is important to understand a food's water activity when establishing a Hazard Analysis Critical Control (HACCP) plan. When performing a hazard analysis for many items, evaluating the water activity of a product or substance is required.At water activities below 0.8, the majority of enzyme processes are slowed down. During storage, a_w also has an impact on the uniformity, flow and caking of milk powder and other powdery food ingredients. The texture characteristics of food are also affected by a_w.

Hysteresis

Hysteresis, or the difference in equilibrium moisture content between the adsorption and desorption curves, is illustrated in Figure 1. Because a substance could exhibit two different aa_w values at a given water content, two different paths between the adsorption and desorption isotherms are observed. The reason for this is due to a given meal, different amounts of adsorption and desorption may occur at the same vapor pressure. Situated above the adsorption isotherm is the desorption isotherm. Different hysteresis loop shapes appear depending on the food type and isotherm temperature. Further factors influencing hysteresis include product composition, period of storing before isotherm testing, drying time, etc. Although the water usually exists in small capillaries in region II of this figure, it is held less tightly in region III and is either free or held loosely in large capillaries by Fortes *et al.*, (1980). Foods are affected both theoretically and practically by sorption hysteresis. The theoretical implications show that the sorption process is irreversible and that the equilibrium thermodynamic process is correct. Hysteresis' importance for low- and intermediate-moisture foods, as well as its impacts on chemical and microbiological deterioration, are covered in the practical implications by Kapsalis *et al*., (1987). Since food hysteresis loops alter with storage time, Strasser *et a*., (1969) and Wolf *et al*.,1972suggested that changes in hysteresis may be utilized as an indication of quality deterioration.

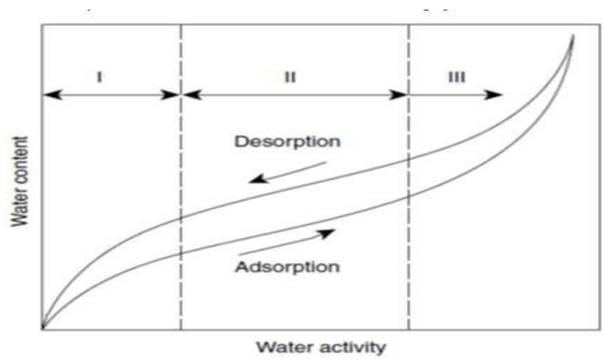

Fig. 1Water Sorption Isotherm Showing a Hysteresis Loop

Water Activity in Food Preservation

Brunauer-Emmet-Teller (BET) Equation

Water activity in food preservation relies on the monolayer concept. The Brunauer-Emmett-Teller (BET) isotherm, developed by Brunauer, Emmet, and Teller in 1938, is used to determine the monolayer value, crucial for assessing food stability. The BET equation can be derived using kinetic, statistical mechanics, or thermodynamic principles. Formula for the equation:

$$\frac{a_w}{(1-a_w)m} = \frac{1}{M_oC} + \frac{(C-1)a_w}{U_oC}$$

where M_o is the monolayer moisture content, C is the constant related to the net heat of sorption. The above equation can be rewritten in linearized form as

where $\alpha = [(C\text{-}1)/(M_oC)]$ and $\beta = 1/(M_oC)$.

α is determined from the slope and β is determined from the intercept of the straight line when $[a_w/(1\text{-}a_w)M]$ is plotted as a function of aw.

The monolayer moisture content (M_o) and the net heat of sorption (C) parameters are then determined.

Above the upper limit of 0.5 aw, the results deviate from the straight-line portion when plotted as a linear equation. For type II isotherms, the value of 'C' varies from 2 to 50. When Qs is very large, as in the case of chemisorption (type I isotherm), the value varies from 50 to 200, whereas for type III isotherms representing crystals, Qs approaches 0 and the constant 'C' is less than 2. Note that the model does not predict adsorption in the capillary region (Region 3 of the isotherm). The BET equation provides the value of monolayer moisture

content. Evaluating water uptake at the monolayer value is important because it determines the level of moisture content at which dehydrated foods can be preserved with the least amount of deterioration due to adsorption and interaction of adjacent polar groups.

The monolayer value usually ranges from 0.2 to 0.4 in terms of water activity by Labuza (1984). Additionally, the BET monolayer computation is a useful technique for determining the amount of bound water at particular polar places in dehydrated food systems McLaren *et al*., (1952) For foods and food components, the BET monolayer values typically range from 0.01 to 0.14 (dry basis). High fat food including avocado, peanuts, and whole milk showed lower BET monolayers than macromolecules like starch, protein, and agar, which typically have greater monolayers. After evaluating 100 foods and dietary components, Iglesias and Chirife (1976) showed that monolayer values became significant with rising temperatures. This could be because higher temperatures enhance gas molecules' propensity to escape, based on thermodynamics.

Guggenheim-Anderson–de Boer (GAB) model

Rahman (1995) has obtained the monolayer values and GAB model parameters for a variety of food items. While GAB offers greater mathematical isotherm prediction across a wide variety of water activities, it is important to acknowledge that the BET monolayer is used for food stability. The equation was independently developed by Guggenheim (1966), Anderson (1946) and de Boer (1968) and is shown below

$$\frac{m}{M_o} = \frac{CKa_w}{(1 - Ka_w)[1 - Ka_w + CKa_w]}$$

C' and 'k' are constants associated with the energies of interaction between the first and the distant sorbed molecules at the individual sorption sites. Mo is the GAB monolayer value. The GAB equation reduces to the BET equation when K = 1. This constant 'K' permits the model to be applicable to higher water activity (at multilayer moisture region).All of the parameters used in GAB equation have physical meaning associated with them.

Methods for Control of Aw and Moisture

Dehydration: is the process in which water is transferred from a food to a gas or air. The gas is then recirculated or allowed to escape.

Spray-Drying: The liquid or slurry is finely atomized and introduced into the drying chamber, where it is brought into contact with a gaseous heating medium such as air. Air transfers the heat to the individual spray particles, evaporating the moisture and leaving the solids as a powder floating in the air stream. The fine droplets of 10-200 microns present a very large surface area per unit volume. Very rapid drying (1-30 s) occurs because of the vast surface area. The product particles may never reach a temperature higher than the wet-bulb temperature of the air. Hence, minimum damage occurs to the product even though higher air temperatures are used for drying. Most of the drying occurs under constant rate drying conditions. The air stream in spray dryers may be co- or counter-current, with a variety of air-flow patterns.

Drum Drying: Ideal for slurries, pastes and solutions. The material to be dried is spread onto the surface of the drum and heated by condensing steam inside the drum. The heat is transferred to the product through the metal thickness of the drum. Drums varying from 0.3 to 3 m in diameter are used. The surface temperature of the drums may be much higher than that of the product film due to evaporative cooling. The speed of revolution of the drum is 1-5 rpm, while the dried product is in contact with the drum for less than one complete revolution. Properties that affect drum adherence are viscosity, surface tension, and wetting power. The product is distributed over the drum surface by splash or dip feeders. The time of drying is in seconds. The dried product is removed using a doctor's blade as a continuous sheet. The capacity of a drum dryer is a function of the drying rate of the thin layer of material and the amount of product that adheres to the drum surface. The drying rate depends on the type of feed device, steam pressure within the drum, and the drum speed. Drum drying is relatively inexpensive and efficient, but may yield products with burnt flavor.

Belt and Tunnel Dryer: Both types of dryers are very similar in design except that in belt dryers, the product is distributed uniformly to a thickness of 30-150 mm on a porous belt through which air circulates in an upward or downward pattern. In the tunnel dryer, layers of food are dried on trays, which are stacked on carts or trucks programmed to move at a specified rate in a tunnel. The airflow in the tunnel is horizontal and may be co- or counter current. The final finishing of the product is done in bin dryers. Both dryers have the ability to dry large quantities of material within relatively short times.

Fluidized Bed Drying: Commonly used for drying potatoes, peas, carrots and selected vegetables. The moist product is introduced continuously at one end onto a grate or porous plate. Beneath the grate lies the air distributor and heater, from which hot air is blown up. As the product moves slowly over this plate in a continuous bed, it becomes gently suspended by the hot air, which facilitates mixing and faster drying. The rapid mixing of the product provides nearly isothermal drying conditions. The air exhaust system is connected to a dust recovery system and an exhaust fan. The bed depth is not greater than the bed diameter.

Freeze Drying: In freeze-drying, water is sublimed directly from ice crystals in the frozen product and the ice is not allowed to melt. The frozen food is placed on heated shelves within a vacuum chamber, and heat is applied to the shelf to provide the latent heat of sublimation by conduction or radiation. The sublimed ice, now as a vapor, is pulled from the vacuum chamber by vacuum pumps or steam jet ejectors. As sublimation proceeds, the ice front within the food recedes at a progressively slower rate. The final moisture content may be approximately 2-8%. Principal advantages are the elimination of product shrinkage, improved flavour and colour retention, and superior rehydration characteristics.

Conclusion

To prevent the growth of microorganisms and enhance the shelf life of dairy products, it is essential to determine the water activity of food and dairy products. Most foods are spoilage due to higher water activity causing oxidation, non-enzymatic browning, and hydrolytic rancidity and bacteria, yeast and mold growth. The preservation of foods based on water activity to retard the growth of microorganisms and also extend the shelf life of foods. The water activity in food preservation is using the two equations as Brunauer-Emmet-Teller (BET) Equation concept and Guggenheim–Anderson–de Boer (GAB) model that is based on the monolayer and food stability diagram. The methods used to control the water activity and to prevent the growth of microorganisms such as freeze drying, dryers, concentrations and dehydration process.

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Table 1. Limiting Water-activity for Microorganisms in Different Food Products

Food Products	Water activity (a_W)	Inhibited microorganisms
Highly perishable (fresh) foods as well as canned fruits, vegetables, meat, fish, and milk; foods containing with up to 40% (w/w) sucrose or 7% sodium chloride	1.00–0.95	Pseudomonas, Escherichia, Proteus, Shigella, Klebsiella, Bacillus, Clostridium perfringens, some yeasts
Certain foods containing 65% (w/w) sucrose (saturated) or 15% sodium chloride; sponge cakes; dry cheeses; margarine; and fermented sausages	0.91–0.87	Micrococcus and many yeasts
Most fruit juice concentrates; sweetened condensed milk; flour; rice; pulses containing 15–17% moisture	0.87–0.80	Most molds, Staphylococcus aureus, most Saccharomyces (bailii) spp., Debaryomyces
Jam, marmalade	0.80–0.75	Most halophilic bacteria, mycotoxigenic aspergilli
Rolled,oats,fudges marshmallows, jelly, some dried fruits, and nuts containing10% moisture	0.75–0.65	Xerophilic molds, Saccharomyces bisporus
Dried fruits containing 15-20% moisture; honey	0.65–0.60	Osmophilic yeasts, few molds
Pasta and spices containing 12% and10% moisture	0.50	No microbial proliferation

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Tribology and Its Significance in Food Industries

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The perception of food texture is influenced by the arrangement and properties of food components at molecular, microstructural, and macroscopic levels. It is experienced through the senses of sight, taste, touch, and hearing. While seeing, hearing and touching all contribute to texture perception, the most valuable and dominating signal comes from oral sensation. From the oral perspective, food texture can generally be defined as the "sensation from the ingestion, mastication and swallowing of the food, which is influenced by the physical properties of the food being masticated" (Chen, 2009; De Wijk et al., 2006).

The act of eating is a constantly changing experience, just like sensory perception. While consuming food, the intensity of specific sensory attributes varies, and the overall profile of the dominant sensory characteristic may shift accordingly. Textural aspects detected early in the oral processing process are primarily dominated by bulk phase qualities, whereas textural features detected later in the process are related to a thin film of product and/or a product-saliva combination that impacts oral surface properties and lubrication (Engelen and De Wijk, 2012).

Tribology-Principle, Operation and Types of Tribometers Used for the Measurement of Lubrication Properties

Generally, the word Tribology is obtained by the combination of two different greek word, "tribo" and "logy". The word "tribo" means rubbing whereas "logy" means to study. Thus, it is defined as "science of rubbing" or "study of rubbing". In other word Tribology is the science of friction, wear and lubrication between the interacting surfaces which are in relative motion, with or without them and the instruments used to measure the tribological properties are called tribometers (Sangeeta et al., 2016). Tribometers in food industries are important to determine the oral perception of food products between the tongue, palate and tooth with or without the lubricants (or saliva) between them (Dresselhuis, 2008).

Nowadays, tribometers are becoming more important due to its ability to measure certain food properties during oral processing which are usually cannot determined by the textural as well as rheological measuring instruments. Generally, there are many techniques or instruments has been developed to measure the Mechanical deformation and flow (rheology) behaviour of food products. But properties like comminution, lubrication, creaminess, and change in surface roughness of foods occurred during oral-processing are usually neglected. Hence here comes tribometers to measure these above properties. Consider an example of biscuit, Mechanical properties like hardness, crunchiness, etc usually determined but mouthfeel properties such as graininess, smoothness, slipperiness, cohesiveness usually neglected. However, some of the above properties can be measured by rheometer, but others properties like smoothness, slipperiness, creaminess, and fat-perception can be measured with the help of tribometers.

As discussed above, tribology is the science of friction between two interacting surfaces with or without lubrication. In the given fig.1.1, two bodies is in relative motion where body A is moving with a velocity 'v' and 'F_L' is the normal force acting perpendicular to the surface. Also 'F_R'is the frictional force acting opposite to'v'. Hence,

$$F_R = \mu \times F_L,$$

where μ = coefficient of friction

$$\mu = F_R / F_L$$

Coefficient of friction (μ) is mainly depended on - surface properties, surface load, moving speed, and lubricant property.

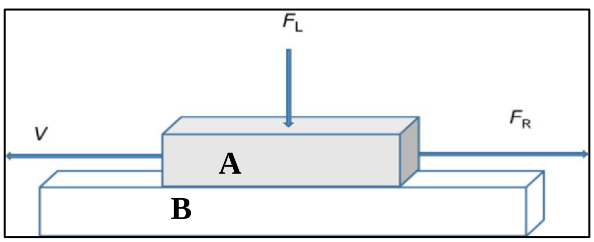

Fig 1. Body A and B are in relative motion (*Source: Sangeeta et al., 2016*)

Conclusions

To understand & quantify a range of different aspects of mouthfeel by using various type of instruments known as tribometers. These tribometers play important role to develop food with improved formulations having low calories with improved consumer acceptability. It is useful to analyse sensory perception which is usually not determined by rheometers. These instruments are able to mimic the fat related sensory perception which includes creaminess as well as fattiness. There is no risk of hazard.

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Table 1. Types of tribometers used to measure the lubrication properties of food

Tribometer	Attachments	Working principle	Food application	Reference
Friction tester	Consist of rubber band, a load cell and a metal cylinder along with an electric motor	Spherical ball revolving against in-house developed rubber band	Roughness and creaminess of Vanilla custard with varying starch type, starch concentration and fat concentrations were measured	de Wijk et al. (2006)
Optical tribological configuration	Consists of two interacting surfaces, a glass platform and a confocal scanning light microscopy (CLSM)	In-house developed detachable surface that applies force against an oscillating glass surface	Roughness and fatty mouthfeel of Emulsions prepared from whey protein isolate and sunflower oil was measured	Dresselhuis et al. (2008)
Mini-traction machine	Consists of a rotating ball and disk in enclosed insulated chamber	Spinning disk against rotating ball	Slipperiness and fattiness ofGuar gum solutions and sunflower oil was measured	Malone et al. (2003)
Mounted tribological device	Consists of a spherical ball attached to a shaft which rotates on three small motile plates	Ball rotating on three motile plates	Creaminess of Heavy cream, milk with different fat percentage, skim milk, dairy emulsions thickened with maltodextrin and xanthum gum was measured	Baier et al. (2009)
Tribology cell	Consists of a rotating disk, two cylinders having same contact point and it can be attached to a rheometer	Two cylindrical contact points rotating against annular disk developed in–house	Different concentrations of corn syrup	Goh et al. (2010)

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Natural Food Colorant Based pH-Sensitive Smart Way for Food Quality and Safety Monitoring

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Food packaging is one of the most significant aspects of a product from the consumer's point of view, and it is extremely vital in modern commercial commerce because it aids transportation, allows for secure storage, avoids damage and loss, cuts down on monetary losses, aids in product promotion, and indirectly keeps consumers safe (Bahrami et al., 2020). Petroleum-based food packaging is usually inert. It protects food against microbial/physicochemical deterioration, ambient conditions, and external stimuli, extending its shelf life. However, the extensive usage of petroleum-based plastic packaging is a global environmental issue due to its manufacture and disposal. The design and manufacture of biodegradable packaging materials from natural and biological resources has grown in popularity.While one of the roles of food packaging is to protect food quality and safety, current packaging must additionally inform the customer about food quality and appropriateness for consumption. Several smart packaging solutions based on colorimetric indications are capable of providing customers with real-time quality monitoring for packaged goods via quality sensor/indicators, particularly pH-sensing indicators, which are currently extensively developed.

An overview of smart packaging

As a novel technology in food packaging, smart/active and intelligent packaging has been developed in response to customers' expanding worries regarding the quality and safety of food items. In order to protect food products, control the environment, detect changes in the headspace and track product history smart packaging systems are typically designed based on the beneficial interaction between food and the packaging environment (Biji et al., 2015). In contrast, intelligent food packaging refers to a packaging system that possesses the capability to continuously monitor the quality of food and promptly communicate this information to consumers through the emission of signals, such as colorimetric, optical, chemical, or electric responses. These signals are triggered by variations in both the packaging environment and the food quality, enabling real-time assessment (Rai et al., 2019). Furthermore, intelligent packaging systems can aid in the development of Hazard Analysis and Critical Control Points (HACCP) and Quality Analysis and Critical Control Points (QACCP) systems, which are designed to identify possible risks and prepare countermeasures or prevention plans for them. Consumers and businesses can now track product information through key stages in the food supply chain thanks to smart packaging technology. Different types of indicators and sensors, such as freshness sensors and time-temperature integrators, have been created for smart packaging systems to monitor the integrity of goods. These intelligent packaging systems measure pH variations, gases (CO2, O2, H2S, ethylene, NH3, etc.) and volatile compounds, pathogens or their metabolites and toxins, time-temperature changes, and humidity to keep an eye on the product's freshness, microbial development, and any chemical changes in the product (Xiao-wei et al., 1018).

Among the various freshness indicators and sensors used in food packaging systems, smart packaging based on natural colours and biodegradable films has recently emerged as an appealing alternative for use in food packaging due to their low or non-toxicity, eco-friendliness, ease of preparation, biodegradability, low cost, availability, renewable, and pollution-free properties. These natural colourants incorporated in the biopolymeric film matrix change colour in response to shifts in the food's physiological circumstances as it spoils, giving the buyer an indication of the product's freshness and safety (Sonar et al., 2019).

Natural food colourant properties with packaging film and pH response

In general, there are four main factors to take into account when choosing a chemo-responsive colourant: The detection of results would be repeatable and reliable if

(i) Strong reaction between the colourant and the desired analyte
(ii) Colour difference following the reaction and a very strong colour interaction to an intense chromophore
(iii) Primarily a group of different pH-responsive colourants that are cross-responsive in an indicator/sensor array
(iv) Detection of findings would be reproducible and reliable

The most common indication for determining the stability of colours, especially natural colourants, is pH. The kind of pigment determines how well-behaved and responsive natural colourants are to pH fluctuations and other conditions. In fact, the main sensing components of a smart system like colorimetric sensors are chemo-responsive colourants. Depending on the surroundings, these substances can change colour. Due to their low price, abundance, simplicity of production, availability, and stable halochromic capability, natural colourants are now the focus of extensive research into pH indicators in the form of optical sensors i.e. colorimetric (Martins et al., 2016).

The instability of carotenoids in acidic settings is commonly ascribed to several factors, including the protonation of carotenoids, duration of exposure to acidic conditions, acid concentration, cis-trans isomerization and supplementary degradation mechanisms which is demonstrated that the degradation of carotenoids occurred at acidic conditions (pH = 3–3.5) by sulfuric acid. Ion pairs that can dissociate the carotenoid carbocation are thought to be responsible for the clear colour of carotenoids at low pH levels. On the other hand, the trans- to cis-isomer transition of carotenoids can result in turbidity of colour since the isomers are highly unstable and induce colour deterioration (Boon et al., 2010).

It is necessary to immobilise these pigments by integrating them into a base material such as polymer/biopolymer matrices in order to fully utilise the potential of these pH sensitive natural colourants for halochromic packaging. A crucial component of the design of colorimetric sensors and smart packaging systems is the selection of chemo-responsive colourants. Because of their inexpensive cost, simple preparation, wide availability, and dependable halochromic, weak acids and weak bases are typically used as pH sensors or indicators. They are effective and affordable alternatives. According to Park et al. (2015), pH indicators typically consist of two parts: a solid base and a colourant that reacts to pH variations. These sensors/indicators can be affixed to the inside or outside of a box or integrated in packaging materials (Balbinot-Alfaro et al., 2019). Several studies have investigated the color changes of natural pigments as pH indicators, including anthocyanins, carotenoids, betanins, anthraquinone, curcumin and chlorophylls in pH-responsive packaging/films (Alizadeh-Sani et al., 2020).

Applications of natural colorant-pH responsive films in food products

The application of natural colorant-responsive films in real food models especially protein foods and fruits and vegetables. Natural colorant-responsive films are most frequently used in the creation of intelligent packaging and other food quality indicators, such as time-temperature, gases and volatile compounds, freshness, integrity, chemical array, toxin and microbial sensors as well as development of colorimetric sensors. Using smart packaging to replicate a pH indicator in pasteurised milk at ambient temperature. Colorimetric pH indicator film based on agar/potato starch/anthocyanins extracted from sweet red potatoes. The films were applied to pork, and the film color altered from red to green according to the pH changes and consequent deterioration of the samples (Choi et al., 2017). The creation of optical indicators/sensors and colorimeters, the design of freshness and integrity indicators, and the detection of poisons, pollutants, residual medications, and microbes may all be done using pH-sensitive films based on natural food colourants.

To improve the stability of natural pigments, packaging techniques like MAP (Modified Atmosphere Packaging) and CAP (Controlled Atmosphere Packaging) or nanotechnology (nanoencapsulation) may be used. The investigation of the films response to various factors, such as gases and volatile vapours, temperatures; evaluating the pigment stability in the packaging/film; developing films with improved physical and mechanical characteristics, moisture resistance, UV-vis light barrier, the analysis of colour changes via simulator solutions and then, applications in various foods; and correlating the pH values to food degradation and sensory evaluation are additional future developments.

Conclusion

Traditional packaging, as previously said, is often made from petroleum resources and is intended to shield food from elements and contaminants including moisture, gases, bacteria, and off flavours and tastes. However, they are unable to advise the buyer about the product's purity and safety. Currently, there is a high demand for and widespread interest in the usage of smart packaging (active and intelligent systems) based on biopolymers and fitted with colorimetric indications/sensors, notably natural colourants (in this case, pH indicators). Smart packaging and films based on natural colourants do more than only keep food secure from danger; they also improve the quality and safety of packaged goods, keep them fresh for longer, and keep consumers up to date on the state of their purchases. Food waste, foodborne illness, spoilage, and deterioration may all be reduced with the use of smart packaging based on chemo-responsive natural colourants, and this method may even prove more effective when combined with nanomaterials. However, smart packaging that displays a pH shift in packaged food may be used as a visual pH detection label, and monitoring the freshness, safety, and quality of packaged foods in real-time through the colour changes of the packaging/film is a quick and easy process.

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Food Fortification Techniques

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Micronutrient deficiencies form a serious world health issue, with deficiency disease affecting key development outcomes as well as poor physical and mental development in kids, vulnerability or exacerbation of the illness, mental retardation, visual impairment, and general losses in productivity and potential. In contrast to energy-protein malnourishment, the health impacts of micronutrient deficiency aren't continually acutely visible; it's so generally termed 'hidden hunger'.

It is widespread within developed countries as well as developing countries. It affects all age groups; however, young kids and ladies of reproductive age are among those most in danger of this malnutrition.the main vitamin deficiencies nowadays are most likely vitamin A, vitamin D, and folic acid, though niacin deficiency in maize intake populations, vitamin B1 deficiency in rice-eating populations, and scurvy disease caused by lack of eating fresh fruits and vegetables.Globally, the one-third population is affected by the 3 most common varieties of malnutrition, micronutrient iron, vitamin A, and iodine deficiency.

Food fortification

According to FAO/WHO (1994) Food fortification has been defined as the addition of one or more essential nutrients to a food, whether it is normally contained in the food, for the purpose of preventing or correcting a demonstrated deficiency of one or more nutrients in the population or specific population groups.

Advantages of fortification

- Since staple foods that are normally consumed are enriched with nutrients, this is a splendid technique to enhance the health of a population with lesser effort.
- Fortification may be a safer means of making certain higher nutrition among people. Since fortification is done as per tips by approved standards, an overdose never happens.
- It is not necessary for folks to form changes in their routine food habits.
- It is socio-culturally acceptable thanks to delivering nutrients to folks.
- Food characteristics don't seem to be altered by fortification.
- Implementation of fortification programs will be fleetly done. The positive impact on organic process status is quickly evident too.
- If the present technology and delivery platforms are taken advantage of, fortification will be cost-efficient.
- It has a high benefit-to-cost ratio. The Copenhagen agreement estimates that each rupee spent on fortification leads to an advantage of Rs 9.

Types of food fortification

1. Conventional fortification:

e.g., Staple foods (flour, cereals, oil, rice), dairy (milk, yoghurt, milk powder), spreads (margarine, butter), condiments (salt, sugar).

2. Home fortification:

e.g., Crushable/ soluble tablets, powder, spread.

3. Bio-fortification:

e.g., Agricultural products (rice, maize, sweet potato)

Food vehicle for fortification

The carrier material is required for food fortification which carries the micronutrient and is commonly consumed by the target population. These carrier materials are daily-use foods like cereal and grain products, milk and dairy products, fats and oils, infant formula and substitution foods, and condiments like salt and sugar. There are specific foods which are used to fortify the different micronutrients like edible oil is used to fortify with vitamins A, D and E; Milk with vitamins A and D, Ca; Cereals with Fe, Zn Vit. B1, B2, B3, B6, B12 Folic acid Vitamin A; salt with Iodine and Fe, Sugar with vitamin A.

Technologies for Food Fortification

The primary requirement for any fortification strategy is, the food should be centrally processed and distributed, where the nutrient should be added at the point of processing. It needs uniform mixing of micronutrients into the food product under processing. For this, we use various techniques for the fortification of diverse types of foods. Like dry blending, microencapsulation, micronutrient premixes etc.

Dry Blending Process

In the dry blending process, the ingredients are completely dehydrated powders. Micronutrients are mixed to achieve a uniform blend of macro and micronutrients. Two or more vitamins can be added at the same manufacturing stage. Micronutrients are added to the food and mixed with the help of blenders like Tumble Blenders, Ribbon Blenders, and Vertical Blenders.

The challenge of blending ingredients with different particle sizes is that bulk density and variable particle sizes can lead to segregation. Therefore, for the homogeneous product, micronutrients are first mixed with the carrier and made into a blend, and then this blend is mixed into the product.

Premix fortification technique

It is a fortification practice to add multiple vitamins and minerals using a single ingredient called a premix. Premixes are either in dry powder, oily liquid, or water-miscible liquid forms. In premixes, these micronutrients are blended with an inert carrier like starch or dextrose, and a water-dispersible powder forms by emulsification. In the case of flour fortification, premixes contain diluents (starch, calcium salts, maltodextrin, or other bulking agents) and free-flow agents (tricalcium phosphate, silica) along with micronutrients.

There are 3 types of feeders that are commonly used to meter premix into product

a. Screw type feeder
b. Revolving disk feeder
c. Drum feeder

Microencapsulation

During the storage of encapsulated foods, there will be more loss of micronutrients such as vitamins and minerals due to oxidation or heat degradation. Due to this, encapsulation is the best approach for delivering two or more micronutrients simultaneously in a stable and bioavailable form without interaction and degradation. It also improves the properties of fortified food by hiding the unwanted colours and tastes of fortification by preventing the interaction between the fortification and the food carrier.This technology overcomes the instability of vitamins and reactivity of minerals in the processed products. It maintains the active ingredients in a stable environment, separated from other food components and thereby preventing undesirable changes in fortified foods. This technology can be the best approach for delivering two or more micronutrients simultaneously in a stable and bio-available form.

Microencapsulation consists of mixing the active material with the encapsulant material, making an emulsion. The mixture can be made with one or two agents. The mixture is then dried, producing microcapsules of different diameters and forms depending on the preparation method and materials used.

Benefits associated with encapsulation.

- Microencapsulation is a method for preventing the compounds, which are volatile and vaporize at room temperature.
- The microencapsulation process can also help to mask undesirable odours and flavours in the final product.
- Protection of active components from factors that can cause oxidation and hence prolong shelf life.

Methods of microencapsulation

- Physicochemical methods (separation of the organic phase, simple or complex coacervation, and liposomal wrapping),
- Physical methods (spray-drying, spray chilling, spray coating, fluidized bed, extrusion, centrifugation with multiple orifices, co-crystallization, and lyophilization),
- Chemical methods (interfacial polymerization and molecular inclusion) have been developed for microencapsulation.

Bio-fortification

Bio-fortification is the process of breeding crops to increase their nutritional value. This can be done either through conventional selective breeding or through genetic engineering (Table 1). Instead of adding nutrients to the meals after they are processed, bio-fortification concentrates on enhancing the nutritional value of plant foods while the plants are still growing.

Micronutrient deficiency is a problem in the developing world, and bio-fortification is being considered as a potential solution. According to WHO estimates, the bio-fortification of iron could help treat two billion cases of anemia brought on by an iron shortage. Similarly, in one trial in Mozambique, eating sweet potatoes biofortified with beta-carotene reduced the incidence of vitamin A deficiency in children by 24 per cent.

Table1. Crops are being investigated for bio-fortification.

Nutrient	Crop
β-carotene/provitamin A,	Banana, sweet potatoes, 'Orange' Maize, Cassava
β-carotene/ pro-vitamin A, iron, zinc	'Golden Rice'
Iron,	Beans, Pearl millet
Zinc	Wheat

Conclusion

Micronutrient malnutrition has been a major problem in the world. That should be reduced, and the best and convenient method to reduce this problem is fortification. Fortification is the addition of micronutrients to the food that is consumed on the daily basis. The main purpose of fortification techniques is that the micronutrients should be properly blended and stable with the product. So Nowadays many techniques have been developed to fortified different products.

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A Novel Approach to Identify Foodborne Pathogens through Surface Plasmon Resonance Biosensors

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Detection methods for food-borne pathogens have advanced from traditional culture techniques to faster and more specific immunological assays, as well as methods based on nucleic acid probes and the polymerase chain reaction. However, these methods can still be time-consuming, taking 24 to 48 hours for results, and may require specialized training. While various biosensors have been developed for direct measurement of biological samples, their application in detecting food-borne pathogens is underexplored.Biosensors are analytical tools with a reactive surface, called a capturing molecule, placed near a transducer. This setup converts the binding of an analyte to the capturing molecule into a measurable signal. An example is the BIAcore instrument, which uses surface plasmon resonance (SPR) to monitor molecular interactions in real time. The instrument's sensor chip has a gold film on a glass backing, with a carboxymethyl dextran matrix attached to the gold. Users link the interactant (ligand) to the dextran layer on the chip's surface. When a molecule (analyte) is captured, it leads to a mass increase that alters the refractive index near the sensor surface.

This refractive index change is translated into optical signals called resonance units (RU), displayed as a sensorgram. This allows continuous monitoring of the association, dissociation, and regeneration processes of the sensor chip's surface(Park *et al.*, 2022; Topor *et al.,* 2023).

Principles of Surface Plasmon Resonance Biosensing

SPR affinity biosensors are designed for sensing and consist of a biorecognition element that interacts with an analyte, along with an SPR transducer that converts this interaction into a signal. These biosensors employ biorecognition elements near a metal film that supports surface plasmons. When analyte molecules in a liquid sample contact the sensor, they bind to the biorecognition elements, leading to a refractive index increase at the sensor's surface. This change in refractive index affects the surface plasmon's propagation, influencing properties of the interacting light wave such as angle, wavelength, intensity, and phase. SPR sensors are classified based on how they measure these light wave modifications, using angular, wavelength, intensity, or phase modulation(Homola *et al.*, 2009).

Plasmon Resonance: Plasmons are collective oscillations of electrons on the surface of a metal, typically gold or silver. When light (usually in the form of polarized laser light) hits the metal surface at a specific angle, it can excite these plasmons. This specific angle is called the resonance angle or SPR angle. At this angle, energy is transferred from the photons in the light to the electrons in the metal, creating an electromagnetic wave known as a surface plasmon wave.

Sensor Chip and Ligand Immobilization: The sensor chip used in SPR biosensing has a thin metal layer (usually gold) on its surface. The ligand molecules of interest are immobilized on this metal layer. Ligands can be antibodies, proteins, DNA, or other molecules that can bind specifically to the target molecules (analytes) you want to study.

Sample Injection and Analyte Binding: The sample solution containing the analytes is injected over the sensor surface. As the analytes bind to the immobilized ligands, the refractive index near the metal surface changes. This alters the angle at which the plasmons are excited – the resonance angle shifts. The extent of this shift is proportional to the amount of analyte bound to the ligands.

Real-Time Monitoring: The shift in the resonance angle is measured in real time, providing a continuous readout of the binding events occurring on the sensor surface. This allows researchers to monitor the association (binding) and dissociation (unbinding) of analytes from the ligands, and to derive kinetic information such as association rate, dissociation rate, and affinity constants.

Analysis and Applications: By analysing the binding kinetics, researchers can gather information about the specificity and strength of the interactions between ligands and analytes. SPR biosensing finds applications in various fields, including drug discovery, molecular biology, clinical diagnostics, and environmental monitoring. It can be used to study protein-protein interactions, antigen-antibody binding, DNA hybridization, and more.

Label-Free and Non-Destructive: One of the major advantages of SPR biosensing is that it is label-free, meaning there is no need to modify the molecules being studied with fluorescent or radioactive labels. Additionally, the technique is non-destructive, allowing multiple binding and dissociation cycles to be monitored on the same sensor chip.

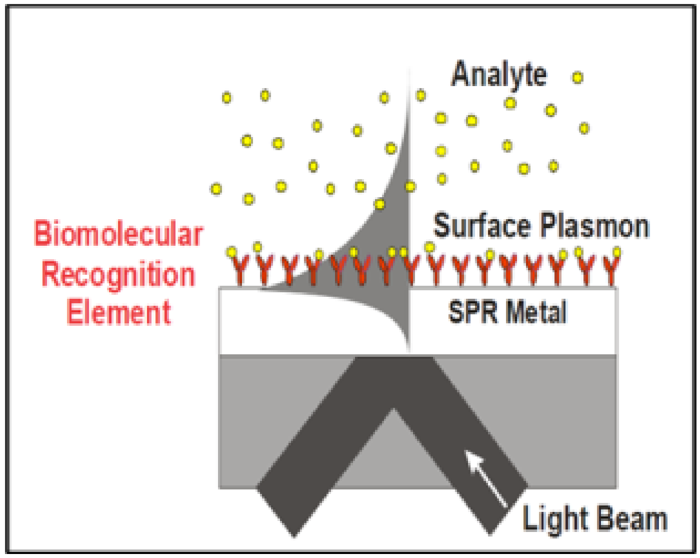

Fig. 1. Concept of SPR Biosensing

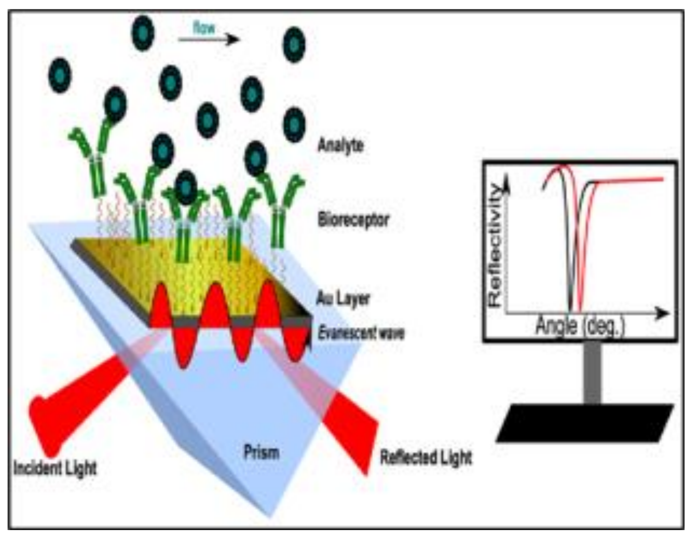

Fig. 2. Principle of Conventional SPR Biosensor

SPR Sensors for Food Safety

The initial application of SPR biosensor for detecting bacterial cells was documented. Their work focused on the identification of *E. coli* O157:H7 using a sandwich assay involving immobilized monoclonal antibodies (MAb) and secondary polyclonal antibodies (PAb). Various methods were explored to immobilize the antibodies, but direct amine-coupling of MAb to the surface proved most effective. The sensor achieved a detection limit of 5-7x10^7CFU/ml(Si *et al.,* 2011). Subsequent developments emerged in 2001, when SPR biosensors were demonstrated for *Salmonella enteritidis* and *Listeria monocytogenes* detection. The system employed a custom-made SPR setup utilizing wavelength modulation and a double layer of antibodies. This design facilitated the detection of heat-killed, ethanol-soaked *S. enteritidis* and *L. monocytogenes* at levels of 10^6 cells/mL and 10^7 cells/mL (Waswa *et al.,* 2006), respectively.

Similarly, (Waswa e*t al.,* 2006) employed a laboratory SPR biosensor (Model: Biacore 2000) to detect *E. coli* O157:H7 in pasteurized milk. They utilized Protein A attachment on a carboxymethylated dextran layer through amine coupling chemistry, achieving a limit of detection of 25 CFU/mL.In a subsequent study, detected *Salmonella enterica* in milk using the same SPR biosensor. They immobilized polyclonal antibodies by attaching protein A via carboxymethylated dextran layer and amine coupling chemistry, with a detection limit of 23 CFU/mL in pasteurized milk.

Conclusion

In conclusion, the utilization of Surface Plasmon Resonance (SPR) biosensors presents a groundbreaking and innovative approach in the identification of foodborne pathogens. This novel technique offers numerous advantages, such as rapid detection, high sensitivity, and real-time monitoring, which are crucial in ensuring food safety and public health. The ability of SPR biosensors to accurately and efficiently detect a wide range of pathogens holds great promise for revolutionizing foodborne pathogen identification, reducing the risk of outbreaks, and facilitating timely interventions. As further research and development continue to enhance the capabilities of SPR biosensors, it is evident that this technology has the potential to become an indispensable tool for food industry professionals, regulatory agencies, and researchers in combating foodborne illnesses. Embracing this novel approach can ultimately contribute to a safer and more secure food supply chain, benefitting both consumers and the food industry alike.

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Molecular Identification of Lactobacilli from Traditional Fermented Dahi Using PCR

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Traditional fermented foods have been an integral part of human diets for centuries and are known to provide numerous health benefits. One such traditional fermented food is "*dahi*," a popular yogurt-like dairy product consumed in many parts of the world. *Dahi* is traditionally prepared by fermenting milk with the help of lactic acid bacteria (LAB), primarily from the genus *Lactobacillus*. These LAB play a pivotal role in the fermentation process by converting lactose, the primary sugar in milk, into lactic acid, resulting in the characteristic flavour, texture, and preservation of dahi. *Lactobacilli* are a diverse group of LAB, and their identification and characterization are essential for understanding the microbiological quality and functionality of traditional fermented *dahi*. Traditional methods of bacterial identification, such as phenotypic characterization, have limitations in terms of accuracy and specificity(Schleifer *et al.*, 1995). In recent years, molecular identification techniques, particularly polymerase chain reaction (PCR), have gained significant attention for their ability to provide rapid and reliable identification of *lactobacilli* at the species and even strain level(Kim *et al.*, 2020). PCR, a molecular biology technique, amplifies specific regions of DNA using DNA polymerase enzymes and a pair of primers that target the desired DNA sequence. The amplified DNA can then be analyzed and sequenced to identify the *Lactobacilli* present in the dahi sample. The advantage of PCR-based molecular identification is that it is highly specific, sensitive, and can detect even low abundance bacterial species in complex microbial communities(Sharma *et al.*, 2020). The identification of *Lactobacilli* from traditional fermented dahi holds great significance in various aspects. In recent years, PCR-based molecular identification techniques have been successfully applied in various studies to identify *Lactobacilli* from traditional fermented foods.

Role of PCR in Molecular Identification

Methods used to identify organisms at a molecular level are developed by studying the genetic makeup of bacteria. Each type of creature has its own special set of genes that create specific traits. One advantage of molecular techniques is that the genetic information remains the same regardless of the environment. Only a small number of genes have different levels of activity, and molecular methods can be used to investigate these differences. Genetic tools have greatly improved the use of PCR, a technique that multiplies a specific part of the genetic material. This has been helpful for molecular research(Kwon *et al.*, 2004). Depending on the approach taken, techniques using PCR and molecular hybridization can be used to find and identify genetic material. In the context of identifying *Lactobacilli* in *dahi*, PCR enables us to target and amplify the DNA regions unique to lactobacilli. By doing so, we can detect the presence of *Lactobacilli* and determine their abundance in the fermented dahi sample.

Step 1: DNA Extraction: To perform PCR, the first step is to extract DNA from the *dahi* sample. This involves breaking open the bacterial cells to release their genetic material. Various methods can be used for DNA extraction, including enzymatic lysis and physical disruption. Once the DNA is extracted, it is purified to remove impurities and contaminants.

Step 2: Primer Design or Selection of Primer: After DNA extraction, specific primers are designed to target regions of the *Lactobacilli* DNA.

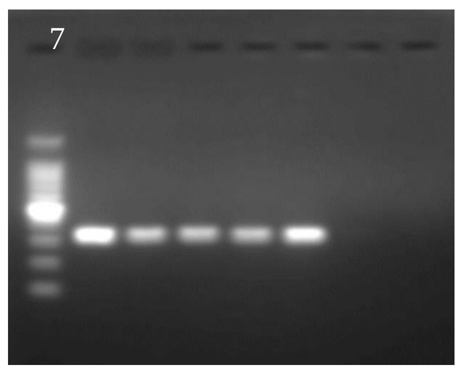
Table 1. Primers used in PCR for *Lactobacillus spp.*Identification

Gene	Forward	Reverse	Amplicon size
Lactobacillus genus	5′-CCTGCCCCCAATCCCTTTATT-3′	5′-CCTGCCCCCAATCCCTTTATT-3′	313

Primer design is a crucial step in molecular techniques, particularly in techniques like polymerase chain reaction (PCR) and DNA sequencing. Primers are short DNA sequences that bind to the complementary sequences of the target DNA. In this case, the primers are designed to bind to conserved regions of the lactobacilli genome, ensuring accurate and specific amplification. Choosen the primer sequence for *Lactobacillus* genus specific for *Lactobacillus spp.* from literature (Balamurugan *et al.*, 2014).

Step 3: PCR Amplification: PCR amplification is carried out in a thermal cycler, a specialized instrument that cycles through different temperatures to facilitate the DNA amplification process. The reaction mixture contains the extracted DNA, the designed primers, nucleotides (building blocks of DNA) and a DNA polymerase enzyme. The thermal cycling process consists of repeated cycles of denaturation, annealing, and extension, resulting in the exponential amplification of the targeted DNA sequences.

Step 4: Gel Electrophoresis: After PCR amplification, the resulting DNA fragments are separated and visualized using a technique called gel electrophoresis. The PCR products are loaded onto an agarose gel and subjected to an electric current(Lee *et al.,* 2012). The DNA fragments migrate through the gel based on their size, allowing us to determine the presence and size of the amplified lactobacilli DNA fragments. By examining the banding patterns on the gel, scientists can gain insights into the genetic diversity within the lactobacillus genus and investigate relationships between different strains.



1 -Ladder 100bp
2 to 6 -*Lactobacillus spp.*
7 - Negative control

Fig. 1 Gel electrophoresis for *Lactobacillus* genus

Step 5: DNA Sequencing and Analysis: For a more detailed analysis of the *Lactobacilli* species present in the dahi sample, DNA sequencing can be performed. DNA sequencing provides the exact sequence of the amplified DNA fragments, allowing us to compare them with known *Lactobacilli* sequences in databases. This analysis helps identify the specific *Lactobacilli* strains and provides valuable insights into their genetic characteristics.

Conclusion

Molecular identification of lactobacilli from traditional fermented dahi using PCR is a powerful technique that allows us to unravel the microbial composition of this popular dairy product. By understanding the specific *Lactobacilli* strains present in *dahi*, we can gain insights into their potential health benefits and tailor fermentation processes to optimize their production. PCR, combined with DNA sequencing and analysis, provides a comprehensive picture of the microbial diversity in dahi, paving the way for further research and advancements in the field of probiotics. Embracing these molecular techniques not only enhances our understanding of traditional food fermentation but also opens doors to the development of innovative and healthier dairy products for the future.

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