Chapter 17
Film-Based Packaging for Food Safety and Preservation: Issues and Perspectives

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Introduction

Packaging is one of the last food processing operations at the manufacturing end and the first impression at the consumer end. The food packaging enables the containment in cost-effective manner with the quality and preservation of the food. The packaging of foods is advancing with technological advancements. The introduction of petrochemical polymers has impacted the food packaging industry to the extreme end. Almost in all the food and food processing sectors, synthetic polymeric or non-biodegradable packaging is introduced. The features such as flexibility, gaseous impermeable, strength, printability, and light weightiness have made it an efficient material for food packaging. In almost all the food sectors such as beverages, dairy, confectionary, meat, fruits, and vegetables, packaging plays a key role. Transportation, convenience, and the preservation of the foods are the major roles of a packaging display. The packaging designs and creation is determined according to the contents and the technology employed for the package. The correct variety of the packaging material determines the keeping quality of the contents (Francis et al., 2022). Commercially traditional food packaging materials such as metals, paper, paperboard, glass, etc. are partially or wholly replaced by plastic packaging. Plastic packaging comes in different forms such as PVC, PET, polystyrene (PS), polypropylene (PP), and polyamide (PA), mainly in rigid and flexible ones (Emblem, 2012). The concept of food packaging is evolving day by day,

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determined by consumer demand, market strategy, and product features. The new trends in packaging have not only revolutionized the food processing sector but also created a huge environmental hazard. The non-biodegradability and improper waste management made plastic a curse on the planet. Scientists and researchers are looking for the proper biodegradable technology and substation for petrochemical polymeric substances. Biopolymers of plant and animal origin are seen to have various film-forming properties (Diyana et al., 2021). The research is now to advance the commercialization and enhance the mechanical and barrier properties. The presence of biopolymers in nature is in abundance, which can act as a cheap raw material for packaging development (Ortega et al., 2022). The seaweed-based and agricultural waste are also utilized for the development of such biopolymers (Puglia et al., 2021). This can act as a cost-effective methodology to attain the goal of sustainability, safety, and waste utilization. The historical view on the use of such packaging started with the sausage casings. Nowadays different organic materials such as carbohydrates, proteins, and lipids are utilized for the development of the packaging (Wróblewska-Krepsztul et al., 2018). The films or coatings are made from carbohydrates, proteins, or lipids and can be directly applied to food products. To date carbohydrates are significantly developed for food packaging material for their ease of availability, biocompatibility, and polymeric property. Protein-based films are used in the pharmaceutical industry for capsule making (Gerna et al., 2023). Similarly, the gelation from the fish sources is exploited for food packaging at the lab scale as well (Rigueto et al., 2022). Cellulose is one of the most significantly used polymers to date for making wooden containers, but nowadays cellulose fibers are used for polymer development with molecular modifications (Aziz et al., 2022). Different types of papers are made by the utilization of cellulose from soft tissue to the toughest paper board. Different biopolymers from plant-based materials are now introduced as intact or primary packaging of food products. Such packaging is edible and can be consumed as part of food products (Chhikara & Kumar, 2021). It can be made from a variety of materials including starches, proteins, and polysaccharides, and it is often used as an eco-friendly alternative to traditional packaging materials such as plastic. Biopolymers reduce waste and environmental pollution by eliminating the need for disposable packaging. The quality and safety of food are maintained from external contamination and microorganisms. In marketing, it can add value to food products by providing an innovative and unique packaging solution (Agarwal et al., 2023). Several studies are going on to establish its integrity and effectiveness for the duration of the product's shelf life, and also for transportation and handling (Abdullah et al., 2022).

Despite certain challenges, there is growing interest in biodegradable film packaging as a potential solution to the problem of plastic waste and environmental pollution (la Fuente et al., 2023). Researchers and companies are exploring new materials and technologies to create safe, effective, and appealing edible packaging solutions that can help promote sustainability and reduce the environmental impact of food packaging.

Edible Coating

The edible coating is a layer provided on the fruit and vegetable artificially to give a barrier property to it and at the same time can be consumed with the food (Moeini et al., 2022). The important barrier properties are moisture barrier, oxygen barrier, and solute barrier properties. When moisture loss occurred from the fruit and vegetables it causes quality loss and oxygen diffusion cause oxidation, hence the deterioration of color, texture, and flavor (Chavan et al., 2023). Now these days' chemicals and synthetic materials are in use to increase the shelf life of fruit and vegetables. So, it is an initiative to replace synthetic material in the food sector. The edible coating and films are getting more attention due to the readily biodegradable nature and environmental consciousness of people (Kolybaba et al., 2006). There is also an advantage that if it is disposed of then it won't harm the environment. It also can carry some important attributes to the primary food like anti-oxidant properties, anti-microbial properties, vitamins, and nutrients (Robles-Sánchez et al., 2013). Other than these coating materials can carry flavoring agents, color enhancers, and taste improvers (Quezada Gallo et al., 2004). It can help in the fortification of food. There is a simple difference between coating and films. The coating is the direct application of coating material on the fruit or vegetable. It can be achieved by dipping, brushing, and spraying (Ganduri, 2020). But in the case of edible films preparation process is different. Continuous sheets are prepared and used as edible films on fruits and vegetables.

Classification of Edible Coating and Film

Edible film is formed by biopolymers which have other food grade plasticizer, additives to support its structural stability (Kaur et al., 2022). There are 3 types of edible films used for fruits and vegetable coating. Eg- Polysaccharide based, protein based, lipid based (Dhaka & Upadhyay, 2018). Each class of film-forming material provides different properties to the coating. These materials could be used alone or in combination with other materials to provide the required properties. All edible coating materials are formed from biopolymers only lipid-based edible coating materials are the exception. All edible coating materials are biodegradable in nature, which is consumer-friendly and environment-friendly also. It is very important to choose a perfect material or combination of materials to increase the shelf life of fruits and vegetables.

Polysaccharide Based Coating

Generally, polysaccharides are high in molecular weight and form hydrogen bonds when mixed with water, which makes them a good material for coating formation. Some polysaccharides are dissolved in cold water, some are in warm water and some are even in neutral water (Zhang & Huang, 2022). Before making any film, it is necessary to check the mixing of the polysaccharides in the solvent. Some polysaccharide-based materials showed a huge improvement in the storage quality of fruits and vegetables, from which chitosan is a material which prevents microbial activity in the storage product (Fernandes et al., 2020).

Chitosan

It prevents the growth of Escheria coli and Staphylococus aureus, which are the major microbes in the food industry (Pavinatto et al., 2020). Not only just the antimicrobial property, but it also showed the ripening delay in some fruits and vegetables. It also promotes the actions like low respiration rate, low ethylene emission, and less weight loss (Pagno et al., 2018). Again, chitosan is a hydrophilic coating material, which made it a bad moisture barrier. That is why chitosan is used with other coating materials.

Aloe Vera

It is also come under polysaccharide-based coating material and with chitosan, it gives extra mechanical barrier and antifungal properties (Pinzon et al., 2020). Aloe vera also enhances its texture, taste, and visual properties. This is proved in the case of peach fruits (Hazrati et al., 2017). As it is a polysaccharide, it has hydrophilic nature too. So, using only aloe vera gel is not effective, so composite coating material is used to reduce the water vapor transfer. So, an additional layer of lipid should be used. It is also proved that the use of aloe vera gel with rosehip oil reduces ethylene production and moisture loss in plums (Martínez-Romero et al., 2017). It is also mentioned that the use of rosehip oil with aloe arborescence has a better effect on the firmness, total acidity, and weight loss of the fruit. The concentration of the lipid layer also plays a huge role. When the aloe vera gel is used with 0.1% sage essential oil on a tomato shows a better effect than the 0.5% sage essential oil (Tzortzakis et al., 2019). So, the proportion of the coating material is also important to reduce the respiration rate and ethylene emission. Aloe vera has generally less effect on respiration rate and weight loss but it helps to decrease the emission of ethylene. A similar result is shown by the composite coating of aloe vera, papaya leaf, and lemongrass leaf on papaya fruit (Lin & Zhao, 2007). The coating of aloe vera gel can increase the shelf life of papaya by up to 14.3 days when it is compared with non-coated papaya (Parven et al., 2020). Firmness is one of the important parameters in the case of a fruit, which shows consumer acceptance. It is affected by respiration rate and metabolic activity which causes ripening. In the case of mango, it is shown that the composite coating of aloe vera can increase the shelf life but the firmness gradually decreases (Ebrahimi & Rastegar, 2020).

Alginate

It is also known as sodium alginate. It is generally extracted from brown seaweed species and used as an edible coating on food material. It is available in the form of salts (Sarkar & Maity, 2023). It needed a conversion process from salt form to sodium alginate form. Alginate is the good barrier of oxygen, but fails to prevent moisture loss like chitosan. It has experimented that in the case of pansies there is no significant difference between the water losses in cold storage (Fernandes et al., 2018). But using sodium alginate with other compounds enhances its properties also. The extract of Ficus hirta enhances the antifungal properties of sodium alginate. Again, it shows a greater level of antioxidants in Nanfeng mandarin than the only use of sodium alginate coating (Chen et al., 2016). In blueberry fruit, the alginate-coated sample incorporated with pectin shows development of yeast after 10 days of storage whereas the control sample shows after 2–4 days of storage (Mannozzi et al., 2017). The red color of sweet cherry shows the quality of the fruit. Alginate-coated sweet cherry shows less change in color and phenolic compounds during storage (Díaz-Mula et al., 2012). There is also evidence that using 2% sodium alginate incorporated with 1% grape seed extract can decrease the fungal decay in grapefruit (Aloui et al., 2014). It can decrease the weight loss by about 25% compared with the uncoated control samples. Alginate forms a thick layer on the fruit and vegetables. So that it also helps to preserve freshly cut fruits as it is vulnerable to rapid decay. Freshly cut watermelon coated with alginate shows a result of less weight loss and preserving the texture for up to 13 days (Sipahi et al., 2013). Again, the fruits like peach which ripe faster than other fruits needed to delay the ripening process. Alginate incorporated with salicylic acid delay the post-harvest ripening and maintain the phytochemical concentration (Bal, 2019).

Pectin

It is an anionic polysaccharide material, unlike chitosan. It makes a perfect Nano multilayer on the cationic polysaccharide like chitosan. Due to its hydrophilic nature, its water loss is more compared to other coating materials but still less than the non-coated fruit materials (Huang et al., 2021). But when pectin is incorporated with chitosan it shows good gas barrier properties. In the case of mangoes, it results in a decrease in oxygen permeation which delay the ripening (Bartolomeu et al., 2012). But when the fruit is highly perishable due to respiration and vulnerable to weight loss pectin and chitosan show a significant improvement than non-coated fruits. Even it conserves the firmness of it. It helps to increase the shelf-life of strawberries from 6 to 15 days (Treviño-Garza et al., 2015). Not only just the whole fruits, pectin can also improve the shelf-life and sensory characteristics of fresh-cut fruits. Incorporation of calcium lactate shows a shelf life of fresh-cut watermelon up to 14 days which was normally 9 days (Ferrari et al., 2013). But sometimes it decreases the sensory acceptance score as it dilutes the liquid directly. Again, the thinner-coated fruits and vegetables show a greater acceptance and hence get more sensory scores (Martiñon et al., 2014).

Protein-Based Coating Material

Protein can be classified as water-soluble protein and water-insoluble protein. Fibrous proteins are generally insoluble proteins (Sim et al., 2021). As the amino acids present in insoluble proteins are connected with each other with hydrogen bonds. It is the main reason that protein forms fiber and at the same time insoluble in water. It was found that a number of proteins can be dissolved in water, ethanol, and methanol (Bromberg & Klibanov, 1995). So, water and ethanol or their solution can be used as protein carriers in the coating solution. Before using protein in an edible coating, it should be denatured. Due to this process, more sites will be opened to form bonds which will give a cohesive nature to the coating material. Protein is a complex compound that is made of different amino acids. The characteristic of protein-based coating material depends on the nature of amino acids whether it polar or non-polar. On the basis of polarity, the coating material shows a hydrophilic or hydrophobic characteristic. Proteins rich in alanine and leucine create a hydrophobic nature of the protein. Again, protein is categorized under animal source (Casein, whey protein, meat protein, Egg albumin, Keratin protein) and plant source (Soy protein, Corn zein, Wheat protein, cottonseed protein, peanut protein) (Zaritzky, 2011). Some of them are already in use as an edible coating and biodegradable film. Some of them are under research.

Whey Protein

It is generally extracted from milk when sodium caseinate is condensed during cheese making. Like polysaccharide-based coating material, it needs a plasticizer to make the layer more flexible. Without a plasticizer, there is a crack formation on the surface (Song et al., 2022). Whey protein can be a good barrier for gasses if it is used with certain plasticizers. The combination of whey protein isolates and glycerol act as a bad barrier of gases which increases the respiration process (Lerdthanangkul & Krochta, 1996). Hence the ripening process is faster. It has been seen that the use of sorbitol in place of glycerol has a far better barrier effect on gas and water vapor (Chen, 1995). The protein shows amphiphilic nature means it shows both hydrophilic and hydrophobic nature. Hydrophobic nature is the best to protect the primary food from water vapor. The lipid layer is used on the protein layer to prevent it from water vapor. The concentration of whey protein plays a significant role in a barrier property. More the concentration better the barrier properties (Javanmard et al., 2013). Bee wax can also be used to enhance the water vapor barrier of whey protein. It is experimented that 20% Bee wax is better for the edible coating (Soazo et al., 2015).

Soy Protein

It is a product from soybean, which is generally used as a substitute for animal protein. The protein content present in soybean can reach as high as 50%. So, it is a rich source of protein. Besides direct consumption, soy protein can be used as an edible coating material for fruits and vegetables (Momin et al., 2021). Like polysaccharides, it is used with lipid material to improve the moisture barrier property of the material. The main parameters of an edible coating are barrier properties, mechanical properties, and appearance after coating. Experiments have done with 3–5% soy protein isolate 1% olive oil, and 0.40% hydroxypropyl methylcellulose (Nandane et al., 2017). It is applied on pear fruit and results are better than uncoated fruit material. Soy protein isolate is a good barrier of oxygen so it decreases the respiration process and hence decreases the ripening. In phalsa fruit, it is observed that the TSS concentration is low and moisture loss is less in the case of coated samples. The shelf life is increased by 3–5 days than a controlled sample (Dave et al., 2016). Again, in the case of citrus fruit, blue mold is a severe issue now these days. But the addition of antimicrobial agents like limonene in soy protein isolate shows a significant reduction of mold in Persian lime (González-Estrada et al., 2017). As soy protein is responsible to reduce the respiration of the fruit, the incorporation of antioxidant properties will help to reduce the enzymatic browning of fresh-cut fruits. Ferulic acid is added to soy protein and experimented on fresh-cut apples. It decreases the water transpiration rate and enzymatic browning of apples (Alves et al., 2017). There is a recent development in the area of nanocomposite edible films to enhance the properties of coating material. The use of silicon dioxide nanoparticles in soy protein isolate decreases the oxygen permeation even further. It is observed that it enhances the tensile strength of the coating material on apples (Liu et al., 2017).

Gelatin Films

It is a water-soluble protein derived from animal sources. The film prepared from gelatin does not impart a pungent smell. Initially, pig skin was used to produce the gelatin but now other vertebrate animals are in use to produce it. The basic process to extract the gelatin protein is the hydrolysis of insoluble protein present in skin bone and connective tissue (Usman et al., 2022). Gelatin has a triple helix structure and at a very low temperature, it can form a gel in comparison to other film-forming materials. As gelatin is a hydrophilic material, it is more susceptible to water vapor transpiration. But in combination with corn zein protein material, it performed a better result. Other than that transparency, mechanical strength of the coated material, and UV barrier properties were improved (Xia et al., 2019).

Corn Zein Protein

It is an insoluble protein. The hydrophobic property of corn zein protein is due to the amino acids present in it being non-polar in nature (Tadele et al., 2023). Due to its hydrophobic nature, it could be a better biodegradable film material in the near future. As it shows a non-polar nature it is soluble in ethanol solution and film formation is relatively easy. But plasticizers like glycerol are necessary to prevent cracking after film preparation.

Lipid-Based Coating Material

Lipid is generally used as a protective coating. Lipid is hydrophobic in nature so it is used to prevent moisture transportation from the fruit and vegetables to the environment (Milani & Nemati, 2022). The hydrophobic nature of lipids is due to the low polarity of it. So due to this lipid forms weak mechanical structure. Sometimes it is thicker and brittle in nature. Glycerides, waxes, and resins come under this category. So, it is used in the composite film. More commonly it is used with polysaccharide which provides better mechanical strength (Yousuf et al., 2022).

Waxes

These are more common in the coating sector. The various waxes are carnauba wax, paraffin wax, bee wax, and candelilla wax. Carnauba is plant-based wax. It is collected from palm tree leaves and has the highest melting point of all the naturally occurring waxes (Devi et al., 2022). Due to its high specific gravity, it is used with other waxes to increase the boing point. It gives more mechanical strength than other waxes. It is observed that the use of carnauba wax doesn't prevent the respiration rate but it significantly decreases the water vapor transportation (Chiumarelli & Hubinger, 2014). Carnauba wax is a GRAS (Generally recognized as safe) substance and is allowed to use as a coating material on fruit and vegetables. Paraffin wax is generally extracted from crude petroleum. Unlike carnauba wax, paraffin wax is not a GRAS substance. It is obvious because synthetic paraffin wax is not allowed in all countries. Any waxes whose melting point temperature is higher than the boiling point of water can cause severe problems during coating. If there is free water on the surface, it can form air pockets which can later decrease the shelf life of the product. Paraffin wax is preferable to root crops and sugarcane. Bee wax which is also called white wax is produced directly from bees. After the extraction of honey, a refining process is followed to get the bee wax. Bee wax comes under animal-based waxes and also comes under GRAS substances. It was also observed that starch incorporated with beeswax can increase the shelf life of products with low water vapor transport rate (Oliveira et al., 2018). Candeilla wax is a plant-based wax like carnauba wax. The hardness of the wax is lesser than the carnauba wax but more than beeswax. The setting time of the wax is more than other waxes. This wax also comes under GRAS substances.

Resins

These are however similar to waxes. It is secreted generally from a special duct called resin duct from a plant. It happens when the plant is affected by an injury or infection. Resin can also be prepared synthetically. Polyvinyl, polystyrene, polyethylene, polyesters, and epoxy resins, etc. are the synthetically prepared resin used in plastic industries (Ibrahim et al., 2021).

Shellac resin is derived from the secretions of the female lac bug, Laccifer lacca. It possesses the unique property of being soluble in alcohol, with ethanol commonly used for obtaining liquid shellac. Alternatively, shellac resin can be dissolved in alkaline solutions. It is important to note that shellac resin is classified as generally recognized as safe (GRAS) substance, which multifold its application in food and related industries, subject to regulatory considerations (Kumar et al., 2023). Another type of commonly used wax is Candelilla wax (CW), made from the leaves of Euphorbia cerifera and Euphorbia antisyphilitica, two tiny shrubs that are endemic to northern Mexico and the southwestern United States. CW is a widely used, FDA-approved food ingredient that is primarily employed as a glazing agent and binder for chewing gums (Aranda-Ledesma et al., 2022). Candelilla is effective against water vapor transmission thus possess potential functionality as a constituent of different food formulations. But when shellac resin is incorporated in candelilla wax, it gives a firm structure, gloss, and lesser moisture loss properties to the product (Alleyne & Hagenmaier, 2000).

The technology of edible coating and films is creating a new path for tackling plastic-based packaging material. It can be used in new-generation packaging material as it can impart a wide range of properties. Three major category products are used to prepare coating material e.g., Hydrocolloid, lipid, and composite of both. Hydrocolloid is a good barrier to oxygen, and carbon dioxide but not to water vapor. As lipid is hydrophobic in nature in combination with hydrocolloid, it could be a better solution to water vapor transmission. Hydrocolloid imparts good mechanical strength to coated material. Other than that, all these materials can be used as a food fortification medium with water-soluble vitamins, minerals, and antioxidants. More research is needed in the edible coating and film sector to improve the film preparation techniques and their properties.

Application of Edible Films in Food

The applicability of edible films is growing at a rapid rate, to overcome environmental and food packaging issues. Researchers are continuously exploiting new means of development and different formulations to develop the best compatible packaging material. Edible films provide a protective barrier and enhance the shelf life of various food products. Film-based packaging material helps to maintain the quality and freshness of food products by providing a protective barrier against moisture, oxygen, and other environmental factors that can cause spoilage (Aga et al., 2021). Film-based packaging provides an innovative and sustainable packaging solution to differentiate products and promote environmental sustainability. One of the notable applicability of the films is their usage in the packaging of fresh produce. The quality and shelf-life of fruits and are vegetables extended by providing a protective covering around the commodity. Various researchers have suggested the use of films in maintaining the quality of meat and poultry, thus reducing the problems of contamination. Also, the studies reveal the antimicrobial properties of certain functional films that inhibit microbial growth in various products (Dharini et al., 2022). The organoleptic characteristics of certain products are enhanced by wrapping them in functional film. The film induces the desirable characteristics for the marketability and consumption of the product. Some moisture-desirable products are protected by wrapping in a water barrier film around the product.

The other noteworthy application of film-based packaging is its use as sustainable food packaging material. The use of various renewable and biopolymers to develop the film-based packaging films drastically reduce the usage of petrochemical polymers, thus reducing waste production and environmental problems. Agricultural waste and seaweed are generally exploited for the making of such films. The film-based materials for packaging applications are going through many processing procedures and ingredient incorporation. The main aim of such packaging is to address the challenges of sustainability, protection, containment, transportation, and shelf life. Therefore, the packaging film development is still in its primary phases. More of studies and research work needs to be carried out to improve and diversify its applicability in the packaging sector. In addition to sustainability, films can be utilized as a carrier for antimicrobial chemicals, control oxygen and carbon dioxide exchange rates, and prevent microbiological deterioration. The properties such as flexibility, transparency, and ability to protect products from external factors such as moisture and air make films suitable for packaging of bakery products. Bakery products such as bread, cakes, cookies, and pastries are often packaged using film packaging, which can be made from a variety of materials including plastic, biodegradable materials, and paper. Film-based packaging provides a protective barrier that can help to prevent moisture loss and keep products fresh for longer periods of time. This is particularly important for bakery products that are prone to staling or drying out quickly, such as bread and pastries. The protection from external factors is facilitated by the use of film packaging material. This will help to preserve the aroma and flavors of bakery products, making them more appealing to consumers. Also, the film-based packaging material provides a convenient and hygienic option for consumers. Film packaging is also a continent for opening and closing of the package, allowing consumers to access the product without compromising its freshness or quality. Additionally, film packaging can help to prevent contamination by providing a protective barrier between the product and the external environment.

Visual appearance of bakery products is also enhanced by film wrapping, clear film packaging can showcase the product inside, allowing consumers to see the product before purchasing it (Simmonds & Spence, 2017). Biodegradable films, such as those made from plant-based materials like corn starch, are also gaining popularity due to their eco-friendliness and ability to break down naturally in the environment. Paper-based films, such as parchment paper and wax paper, can also be used to package bakery products, providing a natural and sustainable option. Film packaging is a versatile and effective option for packaging bakery products.

Film-based packaging finds its scope in the dairy industry as well for packaging of products such as milk, cheese, yogurt, and butter. The use of film-based packaging provides several benefits, including product protection, extended shelf life, and ease of use, a barrier against oxygen, moisture, and light. This protection helps to preserve the quality, texture, and flavor of dairy products, ensuring that they arrive at the consumer in optimal condition (Thakur & Raposo, 2023). Film-based packaging prevents the growth of bacteria and other microorganisms, thus extending the shelf life of dairy products. This is particularly important for perishable dairy products such as milk and cheese, which can spoil quickly if not stored properly. Biodegradable films, made from materials such as corn starch or polylactic acid, are gaining popularity due to their eco-friendliness and ability to break down naturally in the environment. Paper-based films, such as wax paper and parchment paper, can also be used to package dairy products, providing a more natural and sustainable option. In addition to traditional film-based packaging, there are also innovative packaging solutions such as, active packaging, this type of packaging can include oxygen scavengers, antimicrobial agents, and moisture absorbers, all of which can help to maintain the quality and freshness of dairy products. Film-based packaging also helps to prevent the contamination of meat products. The films provide a barrier against external contaminants, such as dust, insects, and other pollutants, that can contaminate the meat and compromise its safety. In the meat industry, it can be used for packaging various meat products, including beef, pork, poultry, and seafood. There are many advantages to using film-based packaging for meat products, such as extending shelf life, preserving freshness, and preventing contamination. It also imparts the freshness of the product by reducing desiccation and discoloration. It also helps in the retention of the original flavor of meat products and does not confer the sensory qualities. Active films are nowadays an interesting field in achieving desirable characteristics of meat products.

For the high-quality food product with extended shelf life, some functional ingredients are loaded inside a film matrix. These functional ingredients provide necessary protection from any sort of biological, chemical, and physical hazards. Organic or inorganic functional ingredients such as extracts, essential oils, nanoparticles, and metal oxides provide essential functional properties (Vieira et al., 2022). These can act as potential antimicrobials and antioxidants in films, wrapped in food products.

Safety Concerns of Edible Films

The application of edible films in food offers a promising solution for enhancing the quality, safety, and sustainability of food products. From packaging fresh produce to creating functional coatings and barriers, edible films can provide a range of benefits for food manufacturers, retailers, and consumers. The safety aspect is also another challenge to work on. The films need to be validated and certified by the national and international agencies for their safety as food grade. The materials used in edible films may contain chemical additives, such as plasticizers, colorants, and preservatives. These additives can potentially migrate into the food product and cause chemical contamination. The ingredients of the film should not confer the chemical, or biological nature of food. There should be an in-depth study of ingredients that are to be used in food packaging. Moreover, the composition of the particular ingredient should not cross the maximum permissible limits. The main safety concerns associated with edible films need to be addressed to make them fit for food packaging. Edible films can be made from a variety of materials, including proteins derived from animal or plant sources. This can lead to potential allergy concerns for individuals who are allergic to specific proteins or ingredients. Manufacturers need to be transparent about the ingredients used in their edible films and provide clear labelling for consumers. Edible films can provide a suitable environment for the growth of microorganisms, particularly if they are not stored and handled properly. This can lead to the potential for microbial contamination of the food product, which can cause foodborne illness. The edible films should be produced and stored in a hygienic environment and should have adequate barriers against microbial contamination. Safe and approved additives should be used in film development that should not cause chemical contamination of the food product. In some cases, edible films may not dissolve or break down completely in the mouth, leading to the potential for choking hazards. Edible films should dissolve or break down easily in the mouth to ensure their safety for consumption. Some edible films may contain ingredients that interfere with nutrient absorption in the body. For example, some edible films made from chitosan have been shown to bind with dietary fats, potentially reducing the absorption of important nutrients such as vitamins and minerals. Therefore, edible films do not interfere with nutrient absorption, and they are safe for consumption.

Future Scope

Consumers and businesses alike are increasingly aware of the environmental impact of traditional packaging materials and are seeking more sustainable alternatives. Film-based biodegradable packaging solution has emerged as a promising alternative to petroleum-derived polymers. Although the barrier properties of biodegradable films are far less than the petrochemical polymers, still the biopolymers offer a suitable substitution. There are many emerging solutions for biodegradable packaging, including plant-based materials, bioplastics, edible packaging, algae-based materials, and paper-based materials. As research and development in sustainable packaging continue, more innovative and eco-friendly biodegradable packaging solutions will be available. Researchers are working on developing advanced materials that are more durable, flexible, and cost-effective than current biodegradable materials. These materials may include bio-based polymers, nanocellulose, and other advanced materials that can be used to create packaging with improved performance and environmental benefits. Recent advances in packaging are active and intelligent packaging films. Some novel strategies for the fabrication of such polymers that are often used these days are composite, multilayer, and emulsified films. Also, some advanced methods are also employed for the development of nanocomposite films. 3D printing technology is being explored as a potential way to manufacture biodegradable packaging. This technology can create complex and customizable shapes, which can be tailored to specific products and reduce waste. 3D printed biodegradable packaging could also be made from a variety of sustainable materials, including plant-based materials and bioplastics. Active packaging is also an emerging technique in film development. It helps in the shelf-life extension of food products, reducing food waste and the need for additional packaging. These additives can include oxygen scavengers, antimicrobial agents, and moisture absorbers, all of which can help to maintain the quality and freshness of food products. Advanced materials, 3D printing, active packaging, blockchain technology, and the circular economy are all areas where biodegradable packaging can make a significant impact in reducing waste and improving sustainability.

Conclusion

From extending the shelf life of products to enhancing their visual appeal, film packaging offers a range of benefits for manufacturers and consumers. Also, the food sector is emphasizing biopolymers usage as packaging materials because they are safe and well adapted to include active agents (such as emitters and scavengers) that preserve food quality and extend shelf life. The barrier and mechanical properties need to be improved to compete with synthetic polymers. As research and development in sustainable packaging continue, we can expect to see even more innovative and eco-friendly film packaging solutions for the industry.

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