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 vinyl chloride, 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).

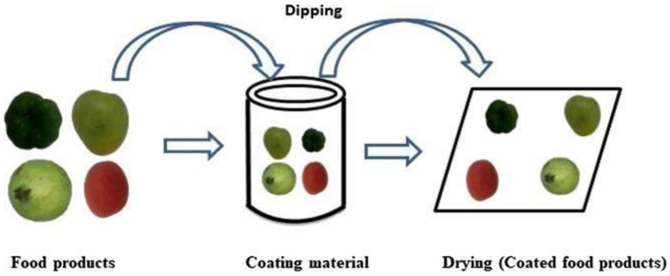

Fig. 2 dipping method of edible coating

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.

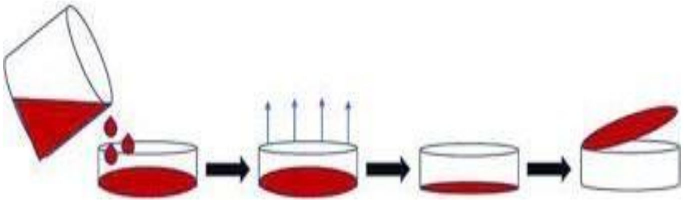

Fig. 3 Solvent Casting Method

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.

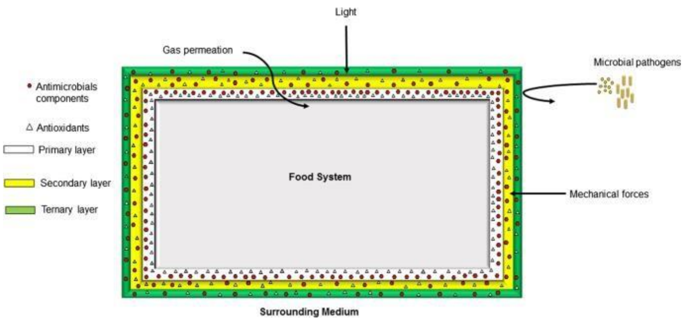

Fig. 3 Composite – Edible Packaging Method

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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