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Rekha Chawla
Ph. D, Assistant Professor, Department of Dairy Technology, College of Dairy Science and Technology, Guru Angad Dev Veterinary and Animal Sciences University, Ludhiana, Punjab, India

Sivakumar S
Ph. D, Assistant Scientist, Department of Dairy Technology, College of Dairy Science and Technology, Guru Angad Dev Veterinary and Animal Sciences University, Ludhiana, Punjab, India

Venus Bansal
M. Tech, Assistant Professor, Department of Dairy Technology, College of Dairy Science and Technology, Guru Angad Dev Veterinary and Animal Sciences University, Ludhiana, Punjab, India

Navdeep Singh
M. Tech. Scholar, Department of Dairy Technology, College of Dairy Science and Technology, Guru Angad Dev Veterinary and Animal Sciences University, Ludhiana, Punjab, India

Correspondence
Rekha Chawla
Ph. D, Assistant Professor, Department of Dairy Technology, College of Dairy Science and Technology, Guru Angad Dev Veterinary and Animal Sciences University, Ludhiana, Punjab, India

Edible packaging to valorize zero waste

Rekha Chawla, Sivakumar S, Venus Bansal and Navdeep Singh

Abstract
Plastic waste is growing as one of the major concern all across the world. In order to address existing problem, scientists are looking for an alternative novel packaging materials that not only preserve the quality of food products but at the same time are environmentally benign. Edible packaging material is emerging as a promising resolution in the zero waste movement. Packaging is intended to protect food from its surrounding and acts as a physical/mechanical, chemical and microbiological barrier to maintain the quality, safety and to increase or prolong the shelf life of food. There is large amount of research currently undergoing in industrial sector i.e. food and dairy industries, to improve the packaging and drift from synthetic packaging to edible packaging as much as possible. Although commercial use of the materials having edible films is still limited, this situation is likely to change in over a next decade. Over the last few years, many researches have been conducted on edible packaging and coatings in food industries. However, pertaining to applications in dairy sector is quite limited. The main objective of this article is to summarize the scientific researches concerning the edible films made from materials and biopolymers such as polysaccharides (Starch, cellulose, gums), lipids, proteins etc. Different materials such as antimicrobials (Nisin, pediocins), antioxidants (BHA, BHT), nutraceuticals can be added to edible films to further harness the applications of edible films to further improve the efficency.

Keywords: Edible packaging, valorize, zero waste

Introduction

Edible packaging is a thin layer made from edible materials or biopolymers which can be applied to the surface of product in order to protect the product from its spoilage and oxidative rancidity to prolong its shelf life. Edible packaging can be a film or coating. Edible coatings are applied directly on the surface of product, while edible films are formed separately as a thin sheet and then applied on the food. Its main functions is to acts like a selective barrier to retard the migration of moisture and gas. It also improves the mechanical properties and act as a carrier of antioxidants, antimicrobials, neutralceuticals and flavouring agents that results in the value addition with added nutritional benefit.

These films have been successfully tried over many products. However, dairy products are still remaining point of research to reach at some conclusive remark. Among dairy products, milk sweets and delicacies have been an integral part of social and cultural heritage of India. Several types of milk sweets are prepared and consumed in different parts of the country because of their rich aroma and pleasant taste. Most of the dairy based desserts are heat desiccated or use heat desiccated milk product *khoa*, as their base. The manufacture of most of the milk based products is largely in the hands of private milk confectioners (*halwais)* who use paper boxes or polythene bags for packaging of dairy products. Conventionally, paperboard is used for packaging of these sweetmeats. These packaging materials do provide protection for short duration and are versatile and inexpensive. During storage the product tends to pick up odours from surrounding atmosphere and lose its typical aroma. At the same time, the product is also prone to oxidative rancidity. Adding to the limitations, packaging materials are discarded with very little being recycled, which results in disposal problem for paper and cardboards whereas causes environmental pollution in case of plastic packages. Also, uncontrolled dumping of waste on outskirt of town and cities has created overflowing landfills which cause serious environmental implication in term of ground water pollution and contribution to global warming (Gupta *et al*., 1998) [7]. The most recently compiled waste generation statistics indicated that 245.7 million tons of MSW (Municipal Solid Waste) was generated in 2005, out of which approximately 168 million tons (68%) of MSW was discarded into the municipal waste stream of which 33.4 million tons (20%) was combusted prior to disposal (Marsh and Bugusu, 2007) [14] and 133.3 million tons was directly discarded in landfills.

In recent years, India has a substantial growth in consumption of plastics and an increased production of plastic waste, where packaging is major plastic consuming sector with 42% of the total consumption (Mutha *et al*., 2006) [16].

The only solution to this problem is development of films which may be edible or non-edible but biodegradable for packaging of heat desiccated milk products. These films cannot totally replace synthetic packaging but can limit moisture, aroma and lipid migration from food and can also enhance the organoleptic properties of packaged food if sweetener, coloring agents are used in the film.

Essentials of edible films and its classification on the basis of components

There are different components used in preparation of edible films or coatings. These can be classified into different categories such as hydrocolloids (polysaccharides, proteins), lipids (fatty acid, acylglycerol, waxes) and composites. A brief overview of these have been given here.

1. Polysaccharides

Polysaccharides used for edible film or coatings include cellulose, starch derivatives, pectin derivatives, gums and chitosan (Krochta and Mulder-Johnson, 1997) [11]. Coatings by polysaccharides may not provide a good water vapour barrier but acts as a sacrificing agent in retarding moisture loss from food products. Few polysaccharides and polymers are listed as here under

a. Cellulose and derivatives

It is made up of repeating units of D-glucose linked through β-1,4 glycosidic bonds. The hydroxymethyl groups of anhydroglucose residues are present in above and below the polymer which result in tight packing of polymer chains and a highly crystalline structure. The conversion of cellulose to carboxymethyl cellulose (CMC), methyl cellulose (MC) and hydroxylpropyl cellulose (HPMC) can be attained by treating cellulose with alkali which swell the structure followed by reaction with chloroacetic acid, methyl chloride or propylene oxide. The film containing CMC, MC, HPMC possess good film forming characteristics and these films are generally odourless, tasteless, flexible, transparent, resistance to oil and fats, water soluble and moderate to moisture and oxygen transmission (Krochta and Mulder-Johnson,1997) [11]. MC is lower hydrophilic cellulose derivative and is most water resistant (Kester and Fenemma, 1986) [10]. MC and HPMC form thermally induced gelatinous coating which have been used to retard oil absorption in deep frying food products (Kester and Fenemma, 1986) [10]. MC could be applied as a coating on confectionery products as a barrier to lipid migration (Nelson and Fennema, 1991) [17].

b. Chitin and chitosan

It is made up of poly β-(1-4)-2-acetamide-D-glucose, structurally identical to cellulose except having secondary hydroxyl on the second carbon atom of the hexose repeat unit replaced by an acetamide group. Chitosan is derived from chitin by deacetylation in the presence of alkali. Chitosan is a copolymer consisting of β-(1-4)-2-acetamido-D-glucose and β-(1-4)-2-acetamido-D-glucose units with later usually exceeding 80%. Chitosan can form semi-permeable coatings which delays the ripening and decreases transpiration rates in fruits and vegetables. Butler *et al* (1996) [1] observed that film from chitosan were rather stable and their mechanical and barrier properties changes only slightly during storage. Chitosan coatings are usually used in fruits and vegetables such as strawberries, cucumbers, bell peppers as antimicrobial coating and on apples, pears, peaches and plums as gas barrier.

c. Starch

Starch is a polymeric carbohydrate composed of anhydro glucose units. Most starches contain two types of glucose polymers: a linear chain molecule termed as amylase and a branched polymer of glucose termed as amylopectin (Rodriguez *et al*., 2006) [3]. Starch has been evaluated in its film- forming ability for applications in the food packaging area; characteristics of the starch film matrices, the film formation methods, and physico-chemical properties of the starch films (Jiménez *et al*., 2012) [9]. Edible or biodegradable starch films can be obtained from the native starch or its components, amylose and amylopectin, by two main techniques: solution casting and subsequent drying (wet method) and thermoplastic processing (dry method) (Paes *et al*., 2008) [18]. Modified (López *et al*., 2008) [12] and soluble or pre-gelatinized starch have also been used (Pagella *et al*., 2002) [19] to obtain starch films. Many researchers have obtained films from different starch sources in combination with plasticizers. Films based on starch are transparent (Mali *et al*., 2004, Jiménez *et al*., 2012) [9], odorless, tasteless, and colorless.

2. Lipids

These compounds are utilized as protective coatings and consists of acetylated monoglycerides, natural wax and surfactants. Films prepared from lipids are thick and brittle in nature owing to their hydrophobic characteristics. Lipid based films are often supported on polymer structure matrix usually, polysaccharides to provide mechanical strength. Lipids that are most commonly used as edible film or coating is discussed hereunder:

a. Waxes and paraffin

Paraffin wax is derived from distillate fraction of crude petroleum and consists of a mixture of solid hydrocarbon resulting from ethylene catalytic polymerization. Paraffin wax is commonly used on raw fruits and vegetables and many varieties of cheeses. Carnuba wax is an exudate from palm tree leaves, whereas Bee wax is produced from honeybees. Waxes are used as barrier in films to gas and moisture and also to improve the surface appearance of various foods. If applied as a thick layer, these should be removed before consumption whereas in thin layers, these are often edible.

b. Acetoglyceride

Acetylated monoglycerides possess the unique characteristics of solidifying from molten state into flexible wax like solid. Apart from other lipids, it has very high elastic strength. Another property that allows to use acetoglyceride in edible film is low water vapour permeability.

3. Proteins

Proteins generally exist as either fibrous proteins or globular proteins. Fibrous proteins are mostly water soluble while globular proteins are soluble in water or aqueous solution of acids, bases and salts. Physical and chemical properties of these protein depends upon relative amounts of amino acids residues and their placement along protein polymer chain. There are some globular protein such as wheat gluten, corn zein, soy protein and whey protein that are commonly used for making edible films.

a. Gelatin

Gelatin is obtained from the hydrolysis of fibrous insoluble protein (collagen) which is found in skin, bones and connective tissue. It is made up of unique sequence of amino acids. High content of amino acids: glycine, proline and hydroxyl are the characteristic features of gelatin. Gelatin aqueous solution remains in liquid state up to 40 ºC and on cooling, it form physical thermo-reversal gels. Gelatin is used for encapsulation of low moisture or oil phase food ingredients and pharmaceuticals. Encapsulation provides protection against oxygen and light and also defines ingredient amount of drug dosage (Gennadios *et al*., 1994) [5]. Gelatin films can be prepared using 20-30% gelatin, 10-30% plasticizer and 40-70% water followed by drying (Guilbert *et al*., 1995) [6].

b. Corn zein

Corn zein is a prolamine protein which can be dissolved in 70-80% ethanol. It is hydrophobic in nature owing to its high content of non-polar amino acids. Corn zein is used in fabrication of biodegradable films and have excellent film forming properties. The film prepared from corn zein are brittle in nature and thus plasticizers are incorporated to increase the flexibility of films (Park, 1991) [21]. These films have good water vapour barrier properties as compared to other edible films. Apart from edible films, zein protein have been extensively used as coating material to preserve and maintain the quality of foods. Park *et al*. (1994) [20] utilizes corn zein as coating on fresh tomatoes and observed the reduction in moisture and firmness loss, delay in colour changes and reduce oxygen and carbon-dioxide transmission during storage.

c. Wheat gluten

Gluten is a water insoluble protein of wheat flour and is a mixture of polypeptide molecules. Wheat gluten contains prolamine (gliadine) and glutelin (glutenin) fractions. Gliadin is soluble in 70% ethanol while glutenin is insoluble. Gluten have cohesiveness and elasticity which give integrity to wheat dough that leads to film formation. Edible films can be formed by drying aqueous solution of wheat gluten. To further improve the film flexibility, plasticizer such as glycerin is commonly added in film prepared from gluten. The tensile strength of the film can be improved by incorporating a cross linking agent such as glutaraldehyde or heating / curing at 80 ºC.

d. Soy Protein

Soy protein is globular in nature. The protein content of soybean is 38-44% whereas protein content in cereal is 8-15%. Generally, soy protein is insoluble in water but can be solubilized in dilute neutral salt solution. On the basis of relative sedimentation rate, soy proteins can be categorized into 2S, 7S, 11S and 15S fraction. The dominance of fraction effects the functional properties of the soy protein for the application in food and dairy industry. Edible films based on soy protein can be made by two technological approaches i.e. wet process or dry process. The films prepared from soy proteins have good oxygen barrier properties and are impermeable to lipids (Cho *et al*., 2010) [4].

Composite film

Composite film as its name suggest is made by blending two or more ingredients and may be homogeneous or heterogeneous in nature depending upon the type of materials used for its manufacture. The films are made by combining polymer such as protein and carbohydrates, protein and lipids, carbohydrates and lipids or synthetic polymer or natural polymer. The main objective of producing composite films is to improve the functional properties of the film that lacks in the film prepared from individual ingredient. Researchers have used different ingredients to improve the properties of edible films. Jagannath *et al*. (2003) [8] studied the mechanical and barrier properties of composite film prepared from starch and protein. Casein-based film demonstrated a lower water vapor transmission rate, water gain at different relative humidity conditions, and higher tensile strength compared to the films containing gelatin and albumin. Similarly, Zhong *et al*. (2008) [25] developed the edible and preservative films from chitosan/cassava starch/gelatin blend plasticized with glycerol and analyzed the physico-chemical properties of films. The properties of the resulting chitosan-based blends for films were greatly influenced by the incorporation of cassava starch, gelatin and glycerol.

Methods for Edible Film and Coating Processing

Edible films can be obtained by two technological methods i.e. thermoplastic processing (dry method) and solution casting and drying (wet method). A dry process is used for the materials which have thermoplastic properties such that they become soft (melted or rubbery) at a temperature lower than decomposition temperature and they can change their shape according to the mould under a thermal/mechanical process. These methods are described as follows:-

a. Wet Method Processing

The wet process consists of forming a film by means of dispersion or as an emulsion. This method include use of solvents such as water or ethanol or combination thereof. The method involves the dispersion of polymers onto the flat surface and drying under controlled conditions for removal of solvent which results in the formation of film. This is the basic principle behind the wet processing. The complete process could be divided into several steps: gelatinization or dispersion, homogenization of the mixture (in the case of emulsions or mixes), casting, and drying.

Apart from film formation, coating of fruits and vegetables is also presented by wet method. In this method film forming solution is sprayed though a nozzle to the surface of product and dried to evaporate the solvent which results in the coating of the product.

b. Dry Method Processing

This is another method used for making films at large scale i.e. at industrial level. The dry method of edible film manufacturing process involves unit operations of extrusion, injection, blow molding and heat processing. The dry method of film preparation does not involve the use of solvent.

Application of Edible Films and Coatings in Dairy Sector

Edible packaging has been extensively employed to increase the shelf life of different food products but the applications of edible films on dairy products is still quite limited till date. Cheese is the only product which have been extensively used by researchers to improve the quality of cheese utilizing edible films and coatings. Edible films and coatings have been also used to diminish the risk of *Listeria monocytogens* in different food products.

Yildirim *et al*. (2006) [24] studied the effect of casein coating containing natamycin to retard mold growth on Kashar cheese. The author observed that coating of kashar cheese with casein containing natamycin suppressed the mould growth for one month without effecting the quality of cheese. Similarly, Cerquira *et al*. (2009) [2] studied the effect of chitosan coating on the quality of semi hard cheese. The treated sample showed decreased respiration rate and mold growth compared to uncontrolled sample of semi hard cheese. In an another study, Cerqueira *et al*. (2010) [2] coated commercial semi-hard cheese with a galactomannan coating and observed that the cheese shelf life was improved, as the coating decreased the O_2 consumption and the CO_2 production rates, enhancing its weight and appearance. The authors finally remarked that coating can be used to incorporate natural preservatives to reduce post contamination**.**

Martins *et al*. (2010) [15] evaluated the growth of *Listeria monocytogenes* in ricotta cheese kept at 4 ºC coated with edible coating made up of galactomannan with added effective nisin. The decrease in oxygen permeability from 1.84 to 1.35 × 10^{-12} cm^3/pa.s.n and increase in elongation at break from 50.93 to 68.16% was observed. Results showed that galactomannan based coating with nisin gave best result to reduce *Listeria monocytogens* contamination on the cheese during storage. Similarly, Ramos *et al*. (2012) [22] applied antimicrobial emulsified coating to full fat cheese with different antimicrobial compounds. The edible coating of cheese reduces water loss, hardness and colour change and microbial growth during 60 days of storage as compared to uncoated counterpart.

Conclusion

A variety of polysaccharides such as starch, cellulose, gums, chitosan, proteins and lipids derived from plants can be utilized either alone or in combination to develop edible film. The applications of edible films and coatings have been extensively studied and reported in the literature. However, the industrial use of edible films is still in infancy stage and requires an academic-industrial partnership to develop product specific films to retard the physiological, chemical and microbiological changes in food products.

References

1. Butler BL, Vergano PJ, Testin RF, Bunn JM, Wiles JL. Mechanical and barrier properties of edible chitosan films as affected by composition and storage. Journal of Food Science 1996; 61(5):953-6.
2. Cerqueira MA, Lima AM, Souza BW, Teixeira JA, Moreira RA, Vicente AA. Functional polysaccharides as edible coatings for cheese. Journal of Agricultural and Food Chemistry 2009; 57(4):1456-62.
3. Cerqueira MA, Sousa-Gallagher MJ, Macedo I, Rodriguez-Aguilera R, Souza BW, Teixeira JA, Vicente AA. Use of galactomannan edible coating application and storage temperature for prolonging shelf-life of “Regional” cheese. Journal of Food Engineering 2010; 97(1):87-94.
4. Cho SY, Lee SY, Rhee C. Edible oxygen barrier bilayer film pouches from corn zein and soy protein isolate for olive oil packaging. LWT-Food Science and Technology 2010; 43(8):1234-9.
5. Gennadios A, McHugh TH, Weller CL, Krochta JM, Krochta JM, Baldwin EA, Nisperos-Carriedo MO. Edible coatings and films to improve food quality. Technomic, New York, 1994, 201-303.
6. Guilbert S, Gontard N, Cuq B. Technology and applications of edible protective films. Packaging Technology and Science. 1995; 8(6):339-46.
7. Gupta S, Mohan K, Prasad R, Gupta S, Kansal A. Solid waste management in India: options and opportunities. Resources, conservation and recycling. 1998; 24(2):137-54.
8. Jagannath JH, Nanjappa C, Das Gupta DK, Bawa AS. Mechanical and barrier properties of edible starch–protein-based films. Journal of applied polymer science. 2003; 88(1):64-71.
9. Jiménez A, Fabra MJ, Talens P, Chiralt A. Edible and biodegradable starch films: A review. Food and Bioprocess Technology 2012; 5(6):2058-76.
10. Kester JJ, Fennema OR. Edible films and coatings: a review. Food technology (USA). Food Technology. 1986; 40(12):47-59.
11. Krochta JM, Mulder-Johnston, CD. Edible and biodegradable polymer films: challenges and opportunities. Food Technology. 1997; 51(2):61-74.
12. López OV, García MA, Zaritzky NE. Film forming capacity of chemically modified corn starches. Carbohydrate polymers. 2008; 73(4):573-81.
13. Mali S, Karam LB, Ramos LP, Grossmann MV. Relationships among the composition and physicochemical properties of starches with the characteristics of their films. Journal of agricultural and food chemistry. 2004; 52(25):7720-5.
14. Marsh K, Bugusu B. Food packaging—roles, materials, and environmental issues. Journal of food science. 2007; 72(3):R39-55.
15. Martins JT, Cerqueira MA, Souza BW, Carmo Avides MD, Vicente AA. Shelf life extension of ricotta cheese using coatings of galactomannans from nonconventional sources incorporating nisin against Listeria monocytogenes. Journal of Agricultural and Food Chemistry. 2010; 58(3):1884-91.
16. Mutha NH, Patel M, Premnath V. Plastics materials flow analysis for India. Resources, conservation and recycling. 2006; 47(3):222-44.
17. Nelson KL, Fennema OR. Methylcellulose films to prevent lipid migration in confectionery products. Journal of Food Science. 1991; 56(2):504-9.
18. Paes SS, Yakimets I, Mitchell JR. Influence of gelatinization process on functional properties of cassava starch films. Food Hydrocolloids. 2008; 22(5):788-97.
19. Pagella C, Spigno G, De Faveri DM. Characterization of starch based edible coatings. Food and Bioproducts Processing. 2002; 80(3):193-8.
20. Park HJ, Chinnan MS, Shewfelt RL. Edible corn-zein film coatings to extend storage life of tomatoes. Journal of food processing and preservation. 1994; 18(4):317-31.
21. Park HJ. Edible coatings for fruit and vegetables: Determination of gas diffusivities, prediction of internal gas composition and effects of coating on shelf life. Georgia, USA: University of Georgia, 1991.
22. Ramos ÓL, Pereira JO, Silva SI, Fernandes JC, Franco MI, Lopes-da-Silva JA, *et al*. Evaluation of antimicrobial edible coatings from a whey protein isolate base to improve the shelf life of cheese. Journal of dairy science. 2012; 95(11):6282-92.

23. Rodríguez M, Oses J, Ziani K, Mate JI. Combined effect of plasticizers and surfactants on the physical properties of starch based edible films. Food Research International. 2006; 39(8):840-6.
24. Yildirim M, Güleç F, Bayram M, Yildirim Z. Properties of kashar cheese coated with casein as a carrier of natamycin. Italian Journal of Food Science. 2006; 18(2):127-138.
25. Zhong QP, Xia WS. Physicochemical properties of edible and preservative films from chitosan/cassava starch/gelatin blend plasticized with glycerol. Food Technology and Biotechnology. 2008; 46(3):262-9.