

# A REVIEW ON SUSTAINABLE SOLUTIONS: THE RISE OF EDIBLE PACKAGING AND BIOPOLYMERS MOVEMENT FOR FOOD AND DAIRY INDUSTRY

## Abstract

Food packaging exhibits a significant role in chain supply and also is considered one amongst the essential steps in the final process. Edible coatings or films have received considerable attention in recent years. Edible films and coatings have long been used for food protection and shelf-life improvement. Materials used in edible packaging (polysaccharide, lipid and protein-based and their composites) have apparent advantages over synthetic films. It could contribute to the reduction of environmental pollution. The main advantage of edible films over synthetics is that these may be safely eaten as a part of the food products and are environment-friendly at the same time as they increase the shelf life of fresh products. Edible packaging materials include edible coatings, films, pouches and sheets. Depending on the type of final edible packaging material, these can be used either alone or in combination as per the requirement of the food product to be stored in it. Potential applications of edible films as smart packaging needs research, which is still in its infancy and extension on its industrial use will be a breakthrough in the packaging industry.

**Keywords:** Edible film, sustainable packaging, shelf-life enhancement , food products.

## Authors

### Vraj Patel

B.Tech. Scholar  
SMC College of Dairy Science  
Kamdhenu University  
Anand, Gujarat  
patel.vraj6705@gmail.com

### Dhyey Vaghasiya

B.Tech. Scholar  
SMC College of Dairy Science  
Kamdhenu University  
Anand, Gujarat  
svaghasiya016@gmail.com

### Dr. Komal Patel

Assistant Professor  
Department of Dairy Technology  
SMC College of Dairy Science  
Kamdhenu University  
Anand, Gujarat  
komal.patel@kamdhenuuni.edu.in

### Krupa Ramani

Assistant Professor  
Department of Dairy Technology  
SMC College of Dairy Science  
Kamdhenu University  
Anand, Gujarat, India  
kruparamani@gmail.com

## **I. INTRODUCTION**

In the current era, the global push for sustainable practices has intensified, leading to advancements in various technologies. One of them is the 'Edible Packaging'. [49] The term edible packaging means, a type of sustainable food packaging designed to be eaten or biodegraded as efficiently as the food it protects. [22] Commonly it is made from natural, plant-based materials such as seaweed or casein. Any type of film, sheet, layer or coating qualifies as edible packaging so long as it can be eaten alongside the food product. It is also important for ensuring the safety and integrity of food, preserving its quality and freshness, and providing essential information to consumers. It also plays a vital role in branding, marketing, and convenience. The edible packaging has dual functionality. Not only does it provide a protective barrier for products, extending their shelf life, but it also eliminates the need for separate disposal, thus minimizing waste accumulation. With the unprecedented increase in plastic waste and environmental concerns, the development of edible packaging might be a great option to reduce our ecological carbon footprint otherwise it is projected to double the plastic pollution globally by 2050. [12,19] With the environmental benefits, further innovations can be done involving the consumer's experience. In this generation of keen environmental consciousness, a flare of hope has been provided by edible food packaging.

## **II. HISTORY**

In ancient times, edible packaging was used in the production of sausages, preserving meat by stuffing it in animal intestines, a process developed by Sumerians in Mesopotamia around 3000 B.C., and by Chinese settlers in China around 580 B.C. [30] A particular type of edible thin film made from the skin of boiled soy milk was used in Japan during the 4th century to cover different foods. In China and Europe, during the 16th century animal grease (lard) and wax were used to coat fruits and other food products for their conservation and later consumption. [35] And later, back in the 19th century, a coating made from gelatin was patented by the USA and used in meat products. As recently as 1967, edible films had very little commercial use and were limited mostly to wax layers on fruits. During intervening years, a significant business grew out of this concept (i.e., in 1986, there were little more than ten companies offering such products, while by 1996, numbers grew to 600 companies). [3] Today, edible film use has expanded rapidly for retaining the quality of a wide variety of foods, with total annual revenue exceeding \$100 million. [10]

## **III. PROPERTIES OF EDIBLE FILMS**

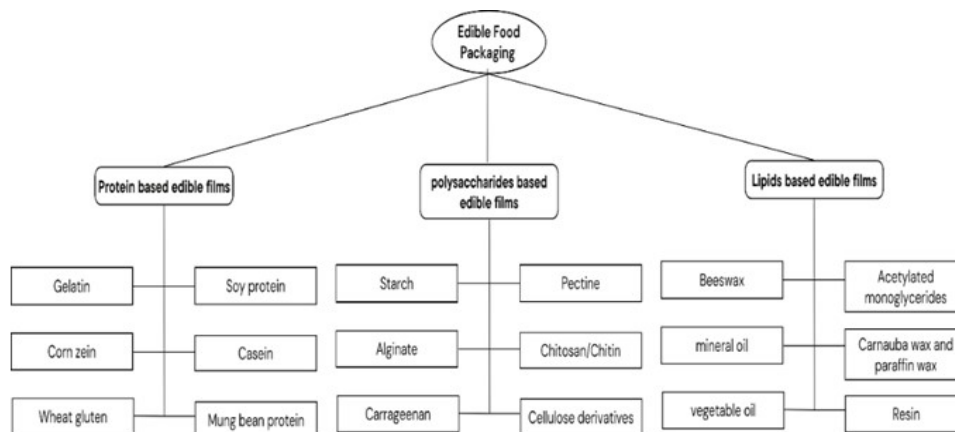
The packaging of food can retard product deterioration enhance shelf-life, retain the beneficial effects of processing and maintain the quality and safety of food. In doing so, it protects three significant classes of external influences: chemical, physical and biological. Chemical protection reduces compositional changes triggered by environmental impacts such as exposure to gases, moisture or light. Biological protection provides a barrier to microorganisms (spoilage and pathogenic agents), insects, rodents and other animals, thereby preventing disease and deterioration. Also, biological barriers maintain conditions to control senescence (ripening and ageing).

Mechanical properties should be optimized regarding elastic modulus, tensile strength, elongation-at-break, compression strength, stiffness, puncture strength, tearing strength, burst strength, folding endurance, abrasion resistance, adhesion force, etc.[20,45]

- 1. Environmental Barrier:** The coatings and edible films serve as environmental barriers and are responsible for controlling the mass transfer between the ambient atmosphere and the food. Permeability is considered to be an important factor when selecting edible material for packaging.
- 2. Convenience and Quality Preservation:** Edible film and coating can retard surface dehydration, moisture absorption, oxidation of ingredients, frying oil absorption, aroma loss, ripening/aging, and microbial spoilage of food products. They also contribute to visual quality, flavor carriage, surface smoothness, edible colour printing, and other marketing-related quality factors.
- 3. Shelf-life Extension and Safety Enhancement:** An increased protective function of food a product enhances shelf life and reduces the possibility of contamination by foreign matter.
- 4. Active Packaging:** Besides working as partial barriers to vapor and gases, edible films and coatings can serve as carriers of ingredients to help preserve quality and improve nutritional value of fruits and vegetables. When coating is used for more than providing a barrier to external conditions, it is called active coating.[39]

#### IV. CLASSIFICATION OF EDIBLE FOOD PACKAGING MATERIAL

The demand for environment-friendly, renewable alternatives for polymeric based material has been increasing day by day. To fulfill this demand, films and packaging materials have been made from the renewable resources, like casein, whey, soy, corn zein, collagen, whey gluten, keratin and egg albumen. These are creating new outlets for agricultural products and waste stream; all of this can greatly impact the economics of food products. Classification of this edible food packaging is given below.



**Figure 1:** Classification of edible packaging based on raw material

## V. FIGURE 1 CLASSIFICATION OF EDIBLE FOOD PACKAGING

1. **Protein-based Edible Films:** Films and coatings can be made up of proteins and can be of plant origin also. Due to casein's ability to form water-resistant films, it was used for hundreds of years in paints and coatings.[16]

Proteins-based films and coatings are made from solutions mainly having three components: protein, plasticizer and solvent. The properties of such a film are affected by the intrinsic factors viz. amino acid composition, crystallinity (of the protein and/or plasticizer), hydrophobicity/hydrophilicity, surface charge, pI, molecular size, and three-dimensional shape, whereas extrinsic factors include processing temperature, drying conditions, pH, ionic strength, salt-type, relative humidity during processing and storage, shear and pressure.[9]

- **Whey Protein:** Whey protein is the commonly used protein which comprises of several individual proteins, like beta-lactoglobulin, alpha-lactalbumin, bovine serum albumin, and immunoglobins being the main proteins.[11]Whey Protein edible film is principally a dry, highly interacting polymer network with a three-dimensional gel-type structure. Regardless of film-formation techniques, the final films can result in a spatially reorganized gel arrangement that includes all the additional film-forming agents. Whey Protein coatings have been proven as efficient gas barriers capable of acting as vehicles for several compounds that include antioxidants, antimicrobials, or different nutrients, although their mechanical properties need to be improved.
- **Soy Protein:** Soy protein is comprised of a mixture of globular proteins. The two main globular proteins are beta-conglycinin and glycinin, which make up 37% and 31% of the soy proteins, respectively. Glycinin is known to gelling agent, emulsifier and foaming agent.[44]Soy proteins can be denatured by heat and alkaline condition, affecting film formation. pH and ionic strength can affect the soy protein association and stability.

Soy protein increases the shelf life of eggs and fresh-cut fruits. The best application is in protective coatings for foods. When applied to the surfaces of foods as a coating, protein-based edible films can protect food from chemical or microbial damage, thus lengthening product shelf life and maintaining high product quality. The combination of gelatin and soy protein to the papaya films had improved the mechanical, barrier, optical properties along with structural properties.

2. **Polysaccharide-based Edible Films:** Polysaccharide gums are hydrocolloids of considerable molecular weight, and are water-soluble. polysaccharides have the ability to thicken and/or gel aqueous solutions as a result of both hydrogen bonding between polymer chains and intermolecular friction when subjected to shear.

Polysaccharide coatings 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. Hydrogenbonded 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.[37]

- **Cellulose:** Cellulose is the most generous biopolymer in the world. It is found in the cell walls of all plants, but also in some fungi and algae and also in some marine organisms of tunicates family, invertebrates and some Gram -negative bacteria.[47]

The most commercially utilized sources of cellulose are wood pulp and cotton fibres. The recent researches have shown that various plant-based waste material like peel, husk, shell and sugar cane bagasse present suitable sources of cellulose, which is important from both the point of view: Economic and ecologic.[8,27,48] Cellulose has a good gelation and film-forming properties as well as processing suitability. It also acts as a good barrier to oxygen, lipids and mechanical abrasion. It also has a good adsorptive property relatively: Renewable, biodegradable, biocompatible, food additive.[21,24,46] Film prepared at higher drying temperature and solute concentration improve the tensile strength and also the swelling power of chitosan film.

- **Pectin:** Pectin is composed of complex polysaccharides that are present in the primary cell walls of a plant, and are abundant in the green parts of terrestrial plants.[17]

Dried citrus peels or apple pomace are the main materials for pectin production. Pomace from sugar beets is also used to a small extent. Pectin and its derivatives extracted from the peel of certain fruits (e.g., fig, lemon, apple, and thornapple) have antioxidant and antimicrobial activities. Furthermore, pectin has a weak antibacterial effect, but its degradation products (especially pectin enzymatic hydrolysis products) have an obvious inhibitory effect on common foodborne pathogens such as *Staphylococcus aureus*, *Escherichia coli*, and *Vibrio parahaemolyticus*. [2,5,7,29,36]

Pectin-based active packaging can be developed in either wet or dry processes. Wet process contains casting method leading to compact surface morphology and spraying method requiring specialized equipment, while dry process mainly refers to extrusion method with higher efficiency and meets the needs at commercial production. Physical properties of packaging including mechanical, hydrophobic and thermal characteristics are enhanced by modification of pectin conformation or incorporation with bio-polymers, overcoming the weaknesses of pure pectin packaging, such as thermal instability and strong hydrophilicity. After being functionalized with active compounds, pectin-based packaging with great antimicrobial, antioxidant and barrier properties is quite suitable for food preservation. Pectin-based packaging has great advantages to extend shelf-life of food by retarding lipid oxidation, inhibiting microbial growth, controlling water movement, etc. As a result, pectin-based active packaging with great physical and functional properties, has promising prospects in food preservation.

- **Alginate:** Alginate is a naturally occurring, edible polysaccharide found in brown algae. As it is hydrophilic in nature, it forms viscous gum when hydrated. With metals such as sodium and calcium, its salts are known as **alginates**. Its color ranges from white to yellowish-brown. It is sold in filamentous, granular or powdered forms. Alginate exhibit polyanion behavior in an aqueous solution and have a certain amount adhesion.[32,41] Alginates in the form of films and coatings exhibit good film-forming properties, low permeability to O<sub>2</sub> and vapors, flexibility, good tensile strength, flexibility, tear resistance, rigidity, water solubility and gloss while being tasteless and odorless. When combined with additives such as essential oils, plant extracts, bacteriocins, enzymes, chitosan, organic acids, metallic nanoparticles and chelating agents, they contribute to the retention of moisture, reduction in shrinkage, retardation of oxidation, color and texture degradation, reduction in microbial counts, improvement of mechanical and barrier properties, enhancement of sensory acceptability and minimization of cooking losses.

3. **Lipid Based Edible Films:** The beneficial properties of some lipids, such as their reasonably good compatibility with other film-forming agents and their good barrier properties against water vapor and other gases, make them desirable candidates for increased use as edible films and coatings in foods.

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 covalent bonds to form coherent, stand-alone films. Thus, they are fragile and do not generally build cohesive, self-supporting film structures.[18] Pure lipids can be combined with hydrocolloids, such as proteins, starches or celluloses, and their derivatives, either by incorporating lipids into the hydrocolloid film-forming solution (emulsion technique) or by depositing lipid layers onto the surface of the pre-formed hydrocolloid film to obtain a bilayer.[25]

## VI. ADDITIVES

Materials used in edible films enhance structural, mechanical and handling properties or provide active functions to the coating.[37]

1. **Plasticizers:** Plasticizers are typically small-molecular-weight hydrophilic agents added to film-forming preparations to improve film mechanical properties by situating themselves in their polymeric network and competing for chain-to-chain H-bonding along the polymer chains. The most commonly used plasticizers in edible packaging films are mono-, di-, or oligosaccharides, polyols, and lipids and derivatives. Generally, the selected plasticizers require considering plasticizer compatibility, efficiency, permanence, and economics.[43]

Plasticizers such as glycerol, sorbitol, acetylated monoglyceride, polyethylene glycol, sucrose and edible oil are used to modify mechanical properties of films and coatings. Incorporation of small molecules into the polymer network also alters film barrier properties.

barrier properties of polymeric networks are affected by plasticizer concentration and molecular weight, water content of the film and strength and type of polymer-polymer and polymer-plasticizer interactions.

2. **Emulsifiers:** Emulsifiers are surface active compounds, with both polar and nonpolar character, capable of modifying interfacial energy at the interface of immiscible systems, such as a water-lipid interface or a water-air surface. Emulsifiers are essential for the formation and stabilization of well-dispersed lipid particles in composite emulsion films or to achieve sufficient surface wettability to ensure proper surface coverage and adhesion to the coated surface.[13]Some common emulsifiers are acetylated monoglyceride, glycerol monopalmitate, glycerol monostearate, polysorbate 60, polysorbate 80, sodium lauryl sulphate, sodium stearylactylate, sorbitanmonooleate and sorbitanmonostearate. Many proteins have emulsifying properties owing to their amphiphilic nature.
3. **Antimicrobials:** The main cause of spoilage for many food products is surface microbial growth. Reduction of water activity (aW) and protection with moisture-proof packaging are common methods used to prevent spoilage in food products incorporation of both natural and synthetic antimicrobial agents into various edible packaging has been developed as an effective alternative for controlling the growth of microorganisms.[23] (Table 1) Use of antimicrobials such as benzoic acid, sodium benzoate, sorbic acid, potassium sorbate, and/or propionic acid represents an additional means of food preservation.

**Table1.effect of antimicrobials on different edible packaging material**

Foods	Edible packaging materials	Antimicrobial agents	Target microorganisms	References
Culture media	Chitosan	Chitosan	Listeria monocytogenes	Coma <i>et al.</i> 2002[40]
		Organic acids		
Cooked ham, bologna, pastrami	Chitosan	Acetic, propionic acid	Migration test, Lactobacillus sakei, Serratia liquefaciens	Ouattara <i>et al.</i> 2000[33]
Culture media	Whey protein isolate	p-Aminobenzoic, sorbic acids	L. monocytogenes Escherichia coli, Salmonella typhimurium	Cagri <i>et al.</i> 2001[4]
Water-glycerol	Whey protein isolate	Potassium sorbate	Migration test	Ozdermir&Floros 2001[34]
Water-glycerol	Whey protein isolate	Potassium sorbate	Migration test	Franssen 2002[15]
Buffer solution	Carrageenan	Potassium sorbate	Migration test	Choi <i>et al.</i> 2005[6]

- 4. Antioxidant:** Antioxidants increase stability of food components, especially lipids, and maintain nutritional value and color by preventing oxidative rancidity, degradation and discoloration. Acid or phenolic compounds act as antioxidants. Acid compounds, such as citric and ascorbic acid, are metal chelating agents. Phenolic compounds, such as butylated hydroxy anisole (BHA), butylated hydroxytoluene (BHT), tertiary butylated hydroxyquinone (TBHQ), propyl gallate and tocopherols inhibit lipid oxidation. These antioxidants can be incorporated into edible coatings.

## VII. APPLICATIONS IN DAIRY PRODUCTS

- 1. Paneer:** The cinnamon essential oil-added edible film is having excellent antioxidant, antimicrobial activity against spoilage and pathogenic microorganisms. The quality of paneer during storage can be increased by packing it in alginate-calcium edible film. It helps to increase its shelf life from 5–6 days to 13 days.[38]

Composite edible coating prepared by using whey protein concentrate and applied on the cubes of paneer. Edible coating acted as moisture and gas barrier, control microbial growth, preserve the color, texture and moisture of the product and effectively extend the shelf life of the product. Then edible coated paneer cubes were packed into polypropylene, LDPE, and laminates and stored at temperatures  $5 \pm 1^\circ\text{C}$ ,  $30 \pm 1^\circ\text{C}$  and ambient conditions.

Acid casein prepared from skimmed milk was used to make sodium Caseinate. Edible coating solution was prepared using sodium caseinate, glycerol, pectin and essential oil. The coating solution was prepared by adding glycerol and pectin to sodium caseinate solution. The solution was blended thoroughly using a magnetic stirrer for 30 minutes. After complete dissolution, essential oil was added in different levels. The addition of essential oil was followed by 1 hour of magnetic stirring to make the solutions homogenous. Paneer cubes were dipped in the coating solutions for one hour followed by drying at room temperature for 1 to 2 hours.

- 2. Cheese:** The literature study suggests that packaging of cheese is one of the potential application areas for edible packaging given that antimicrobial film in cheese has been found to have a significant impact on its shelf life.[14]

By employing the chitosan-based film as a natamycin carrier, saloio cheese's stability was increased; and the product was stable for 7 days in ambient storage settings. Saloio cheese is a small, firm-textured, unsalted sheep's milk cheese known as *Saloio Regional* is traditionally served in authentic cylindrical molds (*cinchos*) in which the cheese was prepared originated from the Portuguese county of Ponte do Rol, north of Lisbon.

Application in cheese



**Table 2. Applications of edible films in different varieties of cheese**

Material used	Types of cheese	Coating/film composition	Application method
Sodium alginate	Mozzarella	Water and calcium chloride Water and glycerol	Dipping/immersion spraying
Chitosan	Saloio regional	Water, lactic acid, tween 80, glycerol, sorbitol and corn oil	Brushing
	Ricotta	Water and HCl	Dipping/immersion
	Cheddar	Water, acetic acid, glycerol and nisin-silica liposomes or nisin liposomes	N/A
	Emmental	Aqueous acid solution	Dipping/immersion
Sodium caseinate	Kashar	Water and glycerol	Immersion wrapping
Whey protein	Ricotta	Water, HCl, chitosan	Dipping/Immersion

Source: Maria J.,Luís C.(2018)Use of edible films and coatings in cheese preservation: Opportunities andChallenges, Food Research International

One of the important aspects of the use of coatings is the application method, once the choice will depend on the type and size of the cheese where the coating is going to be applied. This choice will affect the cost and the efficiency of the coating and should be adapted to the production process (at the end of production, before or after the maturation step). The application of an edible packaging (coatings or films) can be performed by dipping, spraying, electrostatic spraying and brushing in the case of coatings and individual wrapping in the case of films.

- 3. Ice-Cream Cone:** Ice-cream cone is mainly made up of flour and sugar, and mainly contains acetylated monoglycerides and good moisture barrier property, which holds the ice-cream for longer as well as crunchy and edible too. The chocolate coating of cone plays role as a barrier which maintained the crispiness of that cone.[26]

## VIII. APPLICATIONS IN FOOD

- 1. Mango Kernel Starch:** Mango kernel starch (MKS) was useto pack red chili as a sample as well as in commercially packaging. By comparing this for 6 months at 40°C, MKS packed chili powder gave better results in pungency and color. MKS film was having

glycerol and sorbitol in a 1:1 ratio. This MKS film also helped to increase the shelf life of red chili powder.[31]

2. **Fresh Fruits and Vegetables:** The fruit purees are used to form the film with biopolymer and active compound of film material, which helps to increase shelf life of perishable foods.[1]

Papaya puree added to the edible coating increases the shelf life of minimally processed pumpkin, carrots, papaya, etc. For enhancing the shelf life of cut mango, composite coating was made from mango puree, gaur gum, sesame protein and calcium chloride. This composite coating aids to decrease the degradation of ascorbic acid, carotenoids and phenolic content lever of fruit.[42]

3. **Fried foods:** Mashed potato balls coated with corn zein (CZ), hydroxyl propyl methyl cellulose (HPMC) or methyl cellulose (MC) film-forming solution, gave a reduced of moisture 14.9%, 21.9% and 31.1% in CZ, HPMC and MC coated ball, respectively, as compared to uncoated balls. Also, reduction in fat uptake by the balls was observed viz., 59.0%, 61.4% and 83.6% in CZ, HPMC and MC respectively. Methyl Cellulose gave the most effective barrier properties when used an edible coating material in fried foods.[28]

## IX. CHALLENGES

Despite the benefits there are some challenges. The main concern with many types of edible packaging is that they are water-soluble, meaning that they break down in water and have a shorter shelf life than other packaging options. Allergies are another major factor to consider with edible food packaging. Since natural materials are used to make the packaging, people with food allergies to those materials may be restricted from consuming them. So, depending on the product, its packaging, and method of storage and shipping, these edible packages may not be the right fit for every company.

There are some other challenges. The edible packaging material is water soluble is both an advantage and disadvantage. If the packaging is too water soluble it will not hold up in humid climates. It would also break down faster if kept cold and then exposed to condensation effects once removed from the refrigerator. Another downside is that some edible packaging wouldn't be as sanitary when it is exposed to different environments and during shipping. Some edible packaging will still require outer packaging to protect it from contaminants and keep it safe for consumption. The outer packaging would not be biodegradable and still made from original packaging substances making it not as eco-friendly.

## X. CONCLUSION

Looking to today's scenario, people have become more and more conscious regarding the food they consume, its safety, and its packaging. Along with the consumers, the manufacturers are also concerned about the harmful effects of packaging waste disposal into the environment. Hence, many researchers have come up with the innovative ideas of the edible forms of packaging materials that would help to create low and biodegradable wastage. Though tremendous research is been carried out, commercialization is still in a very slow

pace. Hence still more and more new forms of edible films in bulk have to be made available, for its mechanization. Soon within few years we expect these edible films to occupy its major place in place of plastics in the packaging of food products.

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A REVIEW ON SUSTAINABLE SOLUTIONS: THE RISE OF EDIBLE PACKAGING AND BIOPOLYMERS  
MOVEMENT FOR FOOD AND DAIRY INDUSTRY

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