Scope, Functions, and Novelty of Packaging Edibles

4

Nitya Sharma, Aastha Bhardwaj, Prashant Said, Sukirti Joshi, Amrita Poonia, and J. K. Sahu

Abstract

The idea of edible packaging has been around for a while, but now is the right time to ripe the idea to take hold in the food industry. Due to the prevailing adverse conditions of environmental pollution caused by plastic wastes that end up in soil and freshwater, it has become imperative to find a sustainable packaging solution to replace single-use, lightweight polyethylene polymer plastics for retail marketing. Edible films have been in focus for this purpose because of their biodegradability and additional advantages like partial permeability to moisture and oxygen, along with its role as a carrier of functional ingredients (antimicrobials and antioxidants). Natural biopolymers like starch-based biodegradable edible films are widely accepted because of its competence and abundance. In addition to this, they are easily extractable with high yields, do not affect sensory properties of the food, and can be consumed without any health concerns. They are also found to be significantly cost-effective because of its availability from a wide range of agricultural sources such as cereals or legumes and their by-products, tubers, unripe fruits, and other plant storage organs. The

N. Sharma (✉) · S. Joshi · J. K. Sahu
Centre for Rural Development and Technology, IIT Delhi, Hauz Khas, New Delhi, India

A. Bhardwaj
Department of Food Technology, School of Interdisciplinary Sciences and Technology, Jamia Hamdard (Deemed to be University), Hamdard Nagar, New Delhi, India

P. Said
College of Agricultural Engineering and Post Harvest Technology, CAU Imphal Gangtok, Sikkim, India

A. Poonia
Department of Dairy Science and Food Technology, Institute of Agricultural Sciences, Banaras Hindu University, Varanasi, Uttar Pradesh, India

A. Poonia, T. Dhewa (eds.), *Edible Food Packaging*,
https://doi.org/10.1007/978-981-16-2383-7_4

literature suggests that starch-based edible films are based on five main raw materials: corn, maize, wheat, potato, sweet potato, and cassava. And in the recent years, corn starch has been widely used as a raw material for biodegradable polymer production. This chapter discusses the present status of the various sources used to produce starch-based edible films, novelty in starch-based edible packaging, and their effect on the shelf life of certain category of foods.

Keywords

Edible packaging · Coatings and films · Starch · Environment friendly

4.1 Introduction

An incredible amount of energy and engineering is involved in the manufacturing of petroleum-based materials and they take forever to degrade in nature. Modern day consumers and modern science are paving a way forward in sustainable packaging in the form of edible packaging, which have been driven by factors like sustainability, environment and ecological consciousness, food quality and safety, convenience, and product cost (Janjarasskul and Krochta 2010). Nature is the best packaging material manufacturer, for example, it does create skin of fruits to protect from microbes and other environmental factors and shielding them from physical, chemical, and biological degradation (Patel 2020). Natural sources have been utilized to develop edible proxies for the substitution of these multilayered plastic materials. Edible packaging films and coatings are developed from various food-grade, film-forming biopolymers such as proteins, polysaccharides, lipids, and/or resins or a combination of these. This book chapter gives a brief account on this packaging innovation that can be eaten by the consumer as a part of the food product, types, trends, advantages and disadvantages, and challenges related to their production and commercialization.

4.2 Background

The term edible packaging has taken rebirth in last 50 years. The most common definition among the many available definitions of edible packaging is "Any type of material used for enrobing (i.e., coating or wrapping) various foods to extend shelf life of the product that may be eaten together with food with or without further removal is considered an edible film or coating" (Pavlath and Orts 2009). Films may either be fabricated distinctly and then are coated onto the food material or the coatings are fabricated and applied directly onto the respective food material. In either of the cases, these edible films and coatings act as an obstruction for the easy movement of moisture, oxygen, and solute of the food, across the packaging material and also functions as packaging material which can be consumed along with inside content. Edible coatings are thin films that act as laminates and have intact association with food surface until product is consumed. Application of wax on citrus fruits, that is, edible packaging, is one of the first records available from Southern China in early twelfth century where citrus fruits were preserved and transported to North for the British Emperor's table by coating them with wax and packing in boxes (Hardenburg 1967). This process, then known as larding in Europe, was used to prevent water loss, reduce respiration/gas exchange, and elongate the keeping quality of seasonal fruits. Another example is of soy milk skin (known as *yuba*) that has been traditionally used in Asian countries since the fifteenth century (Park et al. 2002) as a packaging material. Since then, edible packaging has improved significantly with use of different strategies and technologies to improve the functional properties of packaging materials. Edible films and coatings are purposeful materials, chiefly formed from edible biopolymers and food-grade additives (GRAS). For example, proteins, polysaccharides, and lipids have been used to formulate and fabricate edible films and coatings as packaging materials, with various functionalities. Starch- and gum-based (polysaccharide) films and gelatin, collagen, gluten-based (protein) films provide hydrophilicity, while fats and wax-based (lipids) films provide exceptional water vapor barrier properties.

4.3 Functions and Scope

Edible coatings have been applied to food applications, intended for improvement in appearance by imparting gloss to the product, enhancing overall sensory attributes, retention of food texture, and preservation of food product against chemical and microbial spoilages (Lee et al. 2002; Janjarasskul and Krochta 2010). Edible films can also act as a carrier for various bioactive food components. List of functions and specific properties of such packaging edibles is given below.

4.3.1 Edible and Biodegradable Nature

The edibility and inherent biodegradability are two most beneficial characteristics of edible packaging (films and coatings). To maintain GRAS status and edibility of films and coatings, all packaging materials like biopolymers, plasticizers, and other additives should be food-grade along with acceptable food-processing facilities and equipment.

4.3.2 Containment and Protection

An ideal packaging is one which has better mechanical properties and serves function to shield food/content from mechanical injure, from harvesting to processing, during transit and storage, until consumption. The mechanical properties of edible films and coatings are dependent on nature and composition of film-forming materials, and their structural cohesion (Janjarasskul and Krochta 2010).

Simulated standard mechanical examinations are carried out to examine sustainability or strength of edible packaging material to physical impact, pressure, vibrations, or similar mechanical forces. The mass transfer between environment and food or vice versa depends on permeability properties which decide suitability of packaging material. The biopolymers are significantly influenced by the moisture content of food, humidity, and temperature. The physical strength of these biopolymers dramatically varies with temperature and humidity levels which is one of the limitations of edible packaging material being an ideal packaging material. Moisture or oil migration; oxygen, carbon dioxide, and other gases permeation; flavor and odor migration in and out of food; or leaching of packaging material components into food may retard the quality of food (Krochta 2002). Edible films have wide range of barrier properties, although these properties differ with the source of manufacturing like edible packaging have excellent oxygen barrier properties (except lipid-based materials).

4.3.3 Convenience and Preservation

Coating of fruits and vegetables can prevent brushing, cutting, and similar mechanical injuries during handling which results in improved handling convenience. Moreover, the protection from physical damage and prevention from chemical changes causes enhancement of quality of stored/coated foods, ultimately resulting in increased shelf life. The edible coating creates a barrier film between foreign contaminants and the food, thereby contamination and cross contamination are minimized.

4.3.4 Appearance and Printability

Esthetic appearance of a food package is a prime contributor to consumer purchase intention and acceptance. Edible films and coatings facilitate glossy appearance and a smoother texture for printing and labeling.

Edible packaging offers great hope to take control over use of plastic waste which is growing concern. Although having vast scope for edible packaging, consumers have psychological limit to eat wrappers along with wrappers or coatings resulting in hygienic concern. Besides all, the global market shows considerable interest to replace petroleum-based packaging films with edible and renewable biopolymers. Data Bridge Market Research predicted that edible packaging market will attain record hike of about 703.5 million by 2027, growing with the CAGR of 5.00% during 2020–2027. Furthermore, the global bioplastic market is estimated to grow at a CAGR of 25.8%, accounting to approximately US$ 215 billion, during 2020–2027. In Europe, edible packaging materials are included in the Regulations EC 1331/2008 and EU 234/2011 for food additives, enzymes, and flavorings. The raw materials must be part of this list and used according to legislations/permissions. To obtain GRAS status, manufacturer has to apply to FDA. There are three types of

Table 4.1 Commercially available edible packaging materials

Trade name of edible packaging material	Manufacturer
Semperfresh	AgriCoat NatureSeal Ltd.
Pürbloom	FruitSymbiose Inc.
FreshSeal	BASF
Bio-Fresh	De Leye Agro
BioCheeseCoat	Improveat
FibreCoat	Caragum International
Durkex 500	Loders Croklaan
Crystalac	Mantrose-Haeuser
WikiPearl	WikiFoods

Source: Cerqueira et al. (2016)

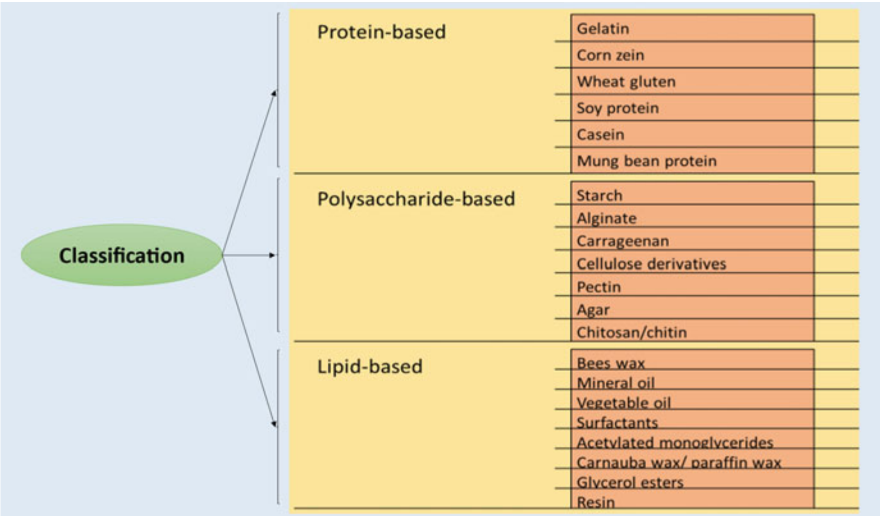

Fig. 4.1 Classification of edible packaging (Saklani et al. 2019)

GRAS status, that is, self-affirmed, FDA approved, and no comment response from FDA. However, GRAS does not guarantee complete food safety to allergenic or sensitive consumers. Cerqueira et al. (2016) has reported some commercially available packaging edibles along with their manufacturers (Table 4.1).

4.4 Types/Classification

Figure 4.1 summarizes the classification of edible films based on their source of origin. Hydrocolloids (e.g., proteins, polysaccharides, and alginate), lipids (e.g., fatty acids, acylglycerol, waxes), and miscellaneous composites are the major sources for formulation and fabrication of edible coatings and films. Additionally,

Table 4.2 Commonly used additives and their examples

Additive	Examples
Plasticizers	Mono-, di-, or oligosaccharides (e.g., glucose, fructose-glucose syrups, mannose, sucrose), polyols (e.g., glycerol, sorbitol, mannitol, xylitol, glyceryl derivatives, ethylene glycol, diethylene glycol, triethylene glycol, tetraethylene glycol, and polyethylene glycol), and lipids and derivatives (e.g., phospholipids, fatty acids, vegetable oils, etc.)
Emulsifiers	Acetylated monoglyceride, lecithin, glycerol monopalmitate, glycerol monostearate, polysorbate (60, 65, 80), sodium lauryl sulfate, sodium stearoyl lactylate, sorbitan monooleate, and sorbitan monostearate
Antimicrobial agents	Organic acids and their salts, chitosan, plant-based essential oil extracts, enzymes, and bacteriocins
Antioxidants	Phenolic antioxidants (butylated hydroxyanisole, butylated hydroxytoluene, propyl gallate, and tertiary butylhydroquinone), tocopherols, citric acid, phosphoric acid

plasticizers are often added to increase their elasticity and augment their physical and functional properties. An interesting research trend has also been exploring food industry by-products and waste as potential edible packaging materials: whey protein from cheese production, chitosan from crustacean shells, corn zein from ethanol production, fish proteins from surimi wash water, etc. (Bourtoom et al. 2006), potato starch from potato chips waste, mung bean protein from mung bean starch (Bourtoom 2008), and fruit pomace from beverage production (Park and Zhao 2006).

Furthermore, film additives are materials other than film formers incorporated to enhance structural and mechanical properties or to provide active functions to the films (Janjarasskul and Krochta 2010). Table 4.2 summarizes a few that have been used for the same.

4.5 Edible Packaging Materials and Their Composition

Edible films are mostly soluble formulations that can be applied to food surfaces to prevent microbial and mechanical spoilage/damage and maintain food quality. They are generally produced by either wet casting or dry extrusion processes; advanced methods such as spraying, fluidized bed coating, and panning are also employed for deposition of edible coatings on the surface of the food material (Suhag et al. 2020). Most preferred method for small-scale fabrication is solvent casting and dipping, while spraying and extrusion are commonly used methods for industrial scale. Henceforth, the various hydrocolloid-based films and coatings and their respective food applications are discussed as follows.

4.6 Protein-Based Films

Globular proteins, such as wheat gluten, soy protein, corn zein, whey protein, and mung bean protein, have been assessed for their film properties (Wittaya 2012). Proteins can be denatured with heat and organic solvents to bring about a change in their physical nature and subsequently formed into a film through solution casting method. The denatured polypeptide chains reassociate through new intermolecular interactions, ensuing modified film properties. Generally, protein-based films have good mechanical and optical properties and are optimal barriers of oxygen, carbon dioxide, and aroma. However, these films are susceptible to moisture, owing to their natural hydrophilic nature (Janjarasskul and Krochta 2010). Thus, incorporation of hydrophobic components by copolymerizing with a hydrophobic polymer or sandwiching between hydrophobic polymer layers to limit the ability of water absorption, seek to improve the hydrophilicity of the protein edible films and coatings. Additional methods include lamination, composite formation, nanoparticle addition, aging, annealing/heat curing, irradiation, cross-linking, ultrasound, microfluidization, etc., that have been attempted and have successfully demonstrated enhanced physicochemical functionality of protein films (Beikzadeh et al. 2020; Vachon et al. 2000).

4.6.1 Wheat Gluten Films and Coatings

They show versatile elastic and cohesive nature, thus providing a sturdy, heat sealable, and optimally transparent biodegradable material. Cross-linking (via enzymatic and chemical treatments) and incorporation of the nonpolar hydrophobic substance (such as mineral oil) have been sought after as potential ways to enhance the barrier properties of the films (Chen et al. 2019). These enhanced functionalities of wheat gluten-based films could be useful for active packaging, drug delivery systems, or modified atmosphere packaging (Guilbert et al. 2002). For instance, gluten-based edible film developed through thermoplastic processing with incorporation of thyme essential oil imparted the film in vitro antioxidant and antimicrobial properties (Ansorena et al. 2016).

4.6.2 Soy Protein Isolate (SPI)-Based Films

These are generally developed through solution casting, spinning, and extrusion methods, and structured via intermolecular disulfide and hydrophobic interactions. These have shown multiple functional attributes, such as adhesiveness, cohesiveness, water and fat absorption capability, fiber formation, and texturizing capacity (Chen et al. 2019). Additionally, they have documented various applications in edible packaging such as coatings on precooked meat and beef products to retard lipid oxidation and prevent meat surface shrinkage (Guerrero and O'Sullivan 2015), coatings on fresh horticultural produce to delay moisture evaporation (Shon and

Choi 2011), and coating on cheese (Al-Sahlany 2017). Composites of gluten protein and SPI have also been applied to peanuts in the form of a coating to prevent lipid oxidation. Addition of additives such as sodium dodecyl sulfate (SDS) and carboxymethyl cellulose (CMC) have also demonstrated improved extensibility and moisture barrier properties of SPI-based films. SPI films and coatings are also potential carriers of antimicrobials (such as essential oils) and flavoring agents for active packaging. A recent trend involves reinforcement of starch nanocrystals in SPI films with exceptional physical and mechanical properties that may also be employed in active food packaging applications (González and Igarzabal 2015).

4.6.3 Casein Protein-Based Coatings and Films

These films have the ability to form a continuous 3D network to form a cohesive film with flexibility, optimal mechanical properties, steady control of mass transfer, and appreciable sensory attributes. However, their hydrophilic nature limits their use in moisture barrier applications. Many techniques such as irradiation and cross-linking have aided in effectively improving their moisture barrier properties (Khwaldia et al. 2004) and have been applied as water-soluble food pouches for fresh produce, dried fruits, and frozen food products (Shendurse et al. 2018). These also have capacity to hold nutrients and bioactive ingredients that could be used to enhance organoleptic and shelf-life characteristics of foods. Due to their sorption ability, they facilitate controlled release of flavor and aroma components, thus enhancing the flavor profile of the food. For instance, irradiated calcium caseinate-based films have been used for microencapsulating flavors in coating of fruits, vegetables, and cheese (Shendurse et al. 2018).

4.6.4 Polysaccharide-Based Films

The monomeric units of polysaccharides are attached together by glycosidic bonds and the disruption of these bonds during the coacervation process to structure new intermolecular hydrogen bonds upon evaporation of the solvent results in fabrication of polysaccharide-based films and coatings. These have good film-forming properties and the presence of large number of hydrophilic moieties renders them permeable to water, while they evidence excellent mechanical as well as gas barrier properties. Thus, polysaccharides can easily be modified to improve their physiochemical properties by addition of salt and solvent, pH change, gelatinization, chemical modification of hydroxyl groups, cross-linking, hydrolysis, and employing nanotechnology (De Moura et al. 2009). They have an ability to form thermally induced gelatinous coatings. Methyl cellulose (MC) and hydroxypropylmethyl cellulose (HPMC) have been used as batter ingredients to minimize oil uptake and moisture loss during deep fat frying (Garcıa et al. 2002).

4.7 Starch-Based Coatings

Being water receptive demonstrates low water vapor barrier ability and has been applied as coatings of fruits and vegetables to augment their shelf life (Sapper and Chiralt 2018). Coatings reduce moisture migration, gaseous exchange, respiration and oxidative reaction rates, suppress physiological disorders, and retard textural changes (Versino et al. 2016). Emulsifiers and plasticizers are added to the film solution to improve the flexibility and extensibility of the final film structure. Owing to their biodegradability, edibility, and low cost, native and modified starch-based films have also received tremendous attention and applause for food packaging applications (Dai et al. 2019). Starch films have been demonstrated as a potential polymer matrix for controlled release of bioactive agents such as antioxidants and antimicrobial agents for active food packaging applications.

4.8 Chitosan-Based Films

These films have good mechanical properties and are selectively permeable to carbon dioxide and oxygen, however, are poor barriers to moisture and water vapor. Numerous strategies, such as cross-linking, irradiation, ultrasonication, and addition of neutral lipids and fatty acids waxes (Cieśla et al. 2006; Morillon et al. 2002), have been used to improve the functionality of such biopolymer-based films. Chitosan-based coatings are also associated with antifungal and antimicrobial activities that can be applied to antimicrobial food packaging applications. Direct addition of essential oils to chitosan films also show supplementary enhanced effects and applications in food packaging. For example, chitosan coating incorporated with essential oils to retard enzymatic browning in fresh produce (Yuan et al. 2016) and to extend the shelf life of meat products (Soares et al. 2015) have been reported.

4.9 Pectin-Based Edible Films and Coatings

Apple pomace, citrus albedo, sugar beet pulp, etc., are anticipated as potential by-products from food and beverage industries to extract pectin for film/coating formation. Pectin coatings are characterized by their good oxygen and carbon dioxide barrier, ability to retard lipid migration, and prevent moisture loss while retaining the sensory properties of the food product. The most recent trends in the field of pectin coating applications include the shelf-life extension of fresh cut, highly perishable, horticultural produce; the application of pectin coatings as prefrying treatment to reduce the oil consumption in deep fat fried products; and the use as predried treatments to improve the retention of nutrients and quality characteristics of dehydrated and lyophilized food (Valdés et al. 2015).

4.10 Alginate-Based Edible Coatings and Films

These films seek much curiosity and attention for packaging applications such as for improving product quality and extending the shelf life of fresh produce, meat, poultry, and seafoods, as well as cheese by reducing dehydration (as sacrificial moisture agent), regulating respiration, improving product appearance, and enhancing mechanical properties (Senturk Parreidt et al. 2018). A great variety of antimicrobial agents (e.g., essential oils) and antioxidants have been incorporated into alginate-based edible films and coatings that find application in food packaging to protect food against surface discoloration and scalding, mechanical degradation, and oxidative rancidity.

4.11 Lipid-Based Edible Coatings and Films

Lipid-based films are intended to prevent moisture migration. Unlike other films, lipid-based coatings exhibit water vapor barrier properties, owing to their hydrophobicity. Application of natural waxes on fresh horticultural produce prevents their desiccation during processing and handling, in addition to providing gloss to the product. Lipid compounds commonly used for the preparation of lipid-based edible films and coatings include neutral lipids, fatty acids (most fatty.

acids derived from vegetable oils), waxes (carnauba wax, candelilla wax, rice bran wax, beeswax, etc.), and resins (shellac, wood rosin, and coumarone indene). These are not cohesive and self-supporting structures, thus necessitating the addition of additives to film formulations such as plasticizers, emulsifiers, lubricants, binders, and defoaming agents. Acetylated glycerol monostearate-derived coatings have optimal oxygen barrier capability than other counterparts. A more common form of lipid-based film is a composite involving both lipid and hydrocolloid components; lipid imparts water vapor barrier property, while the hydrocolloid component provides selective barrier to oxygen and carbon dioxide, respectively. Lipids have been used as edible films and coatings for meat, poultry, seafood, fruits, vegetables, grains, candies, and fresh, cured, frozen, and processed foods (Singh et al. 2016; Galus and Kadzinska 2015). Composite edible coating systems based on herbs (such as plant exudates, gums, resins, essential oils) act as potential antimicrobial and antioxidant agents for meat- and chicken-based products (Matiacevich et al. 2015). Such films impart a waxy flavor and texture, slippery and greasy surface, and are associated with potential rancidity as a major disadvantage.

4.12 Technology Transfer/Patent

The number of edible packaging technologies developed in the last decade shows a growing interest of the scientists in this area of research. A list of patents that shows the production of edible films and coatings containing bioactives using different biopolymers and active compounds for different purposes is shown in Table 4.3.

Table 4.3 Technologies or patents in the area of packaging edibles

Patent publication number	Publication date	Inventor	Title
CN106317477B	November 5, 2019	Cui Haiying, Wu Juan, Lin Lin	Preparing method and usage of edible sodium alginate antibacterial coating
WO2017091095A1	June 1, 2017	Rui Miguel Nabeiro	Coffee-derived edible component, edible product system comprising said edible component, and use of said system
WO2017091094A1	June 1, 2017	Rui Miguel Nabeiro	Edible coating, edible product system provided with said edible coating, and use of said system
CN105199401B	December 26, 2017	Zhang Le, Wang Lihui, Yin Haisong, Pan Zhiheng, Tang Weihua, Chen Shan, Huang Yanling, Lv Chunhui, Dragon Tail, Liu Xin, Long Cheng Xiuwei, Chen Xi, Qi Fei, Yang Jingyuan, Peng Gao Lubao	Edible antibacterial calcium supplementing packaging film and preparation method thereof
CN104211975B	February 1, 2017	Yin Shouwei Shi, Weijian Tang Chuanhe, Yang Xiaoquan	Preparation method of water-blocking oxygen-blocking edible film
WO2016130376A1	August 18, 2016	Hector Gregorio Lara	Edible emulsion coating for extended shelf life
WO2016111659A1	July 14, 2016	Aykut Onder Barazi	Edible antimicrobial film made of pistachio resin
CN105461973A	April 6, 2016	Chen Yizhong	Preparation method of anti-oxidative edible orange peel fresh-keeping film
CN105061819A	November 18, 2015	Meng Lingwei Zhang, Dongjie Wang Xia, Gaofei Sun Tingting	Edible packaging film, preparation method and applications thereof
CN105086000A	November 25, 2015	Zou Xiaobo, Zhai Xiaodong, Shi Jiyong, Wang Sheng, Zhou Xucheng, Huang Xiaowei, Zhu Yaodi, Li Zhihua	Preparation method for edible packaging film
WO2015031663A1	March 5, 2015	Beverly A. Schad	Edible coating compositions, edible coatings, and methods for making and using the same
CN103589170A	February 19, 2014	Song Linxia	Edible chocolate film

(continued)

Table 4.3 (continued)

Patent publication number	Publication date	Inventor	Title
CN103159970A	June 19, 2013	Wang Xinwei, Zhao Renyong, Tian Shuangqi	Preparation method of edible film with antibacterial and antioxidant functions
WO2013089397A1	June 20, 2013	Gang Mo Sung, Won Jin Kim, Seok Hoon Chang, Jeong Jun Yu	Method and apparatus for manufacturing edible film product
WO2009045022A3	July 22, 2010	Seok Hoon Chang, Kyoung Tae Jung	Edible film
EP1692064B1	March 25, 2009	Jean-Pierre Giraud	Moisture-tight edible film dispenser and method thereof
US20070231441A1	October 4, 2007	Andrew Verrall, Stephen Goodrich, Solomon Brown	Edible film having improved sealing properties
WO2006103698A1	October 5, 2006	Gurudutt Prapulla Siddalingaiya, Mysore Nagarajaro Ramesh	Edible films and coatings based on fructooligosaccharides with probiotic properties
US6165521A	December 26, 2000	Walter G. Mayfield	Food products utilizing edible films and method of making and packaging same
US005620757A	April 15, 1997	Hirofumi Ninomiya, Shoji Suzuki, Kazuhiro Ishii	Edible film and method of making same
US5089307A	February 18, 1992	Hirofumi Ninomiya, Shoji Suzuki, Kazuhiro Ishii	Edible film and method of making same

4.13 Limitations and Challenges

The limiting factors like poor inferior physical characteristics and mechanical strength create hurdle in the growth of edible film market but provides a scope to scientific community for overcoming these limitations. As previously discussed, a number of techniques have been employed to modify/alter the native properties of films. Another major limitation is the compatibility of edible packaging materials with the consumers suffering from respective food allergies. Gluten allergy is a common prevalence among population and packaging coatings derived from wheat gluten will have an adverse effect on the health of the consumer; likewise for milk and lactose intolerant people who would face issues with coatings/films containing dairy ingredients in any form. Another limitation of usage of such films deals with consumer acceptance of edible packaging, who are accustomed to see plastic packages over the shelves, particularly for products that cannot be sold without a package.

4.14 Conclusion

Edible and biodegradable coatings and films are the most upcoming intervention in food packaging field that envisions creating sustainable approach for reducing packaging wastes, and additionally, improving stability, quality, safety, and variety for consumers. Ample researches have pointed out their importance and addressed respective issues related to the functional properties, particularly, the effect of miscellaneous factors (such as types of ingredients used, concentration of plasticizers, temperature, and pH values) on their properties and how these can be applied to food packaging applications. Regarding consumer acceptance, as more consumers are becoming mindful of their carbon footprint and waste contribution, there could be a shift to using edible food packaging as an alternative to harmful plastics. Intelligent technology and innovative marketing strategy, together, are quintessential for the success of edible food packaging.

References

Al-Sahlany ST (2017) Production of biodegradable film from soy protein and essential oil of lemon peel and use it as cheese preservative. Basrah JAgric Sci 30(2):27–35

Ansorena MR, Zubeldía F, Marcovich NE (2016) Active wheat gluten films obtained by thermoplastic processing. LWT-Food Sci Technol 69:47–54

Beikzadeh S, Ghorbani M, Shahbazi N, Izadi F, Pilevar Z, Mortazavian AM (2020) The effects of novel thermal and nonthermal technologies on the properties of edible food packaging. Food Eng Rev 12:333–345

Bourtoom T (2008) Factors affecting the properties of edible film prepared from mung bean proteins. Int Food Res J 15(2):167–180

Bourtoom T, Chinnan MS, Jantawat P, Sanguandeekul R (2006) Effect of select parameters on the properties of edible film from water-soluble fish proteins in surimi wash-water. Lebensm Wiss Technol 39(4):406–419

Cerqueira MÁPR, Teixeira J, Vicente A (2016) Edible packaging today, vol 36. CRC Press, Boca Raton, FL, p 1

Chen H, Wang J, Cheng Y, Wang C, Liu H, Bian H, Pan Y, Sun J, Han W (2019) Application of protein-based films and coatings for food packaging: a review. Polymers 11(12):2039

Cieśla K, Salmieri S, Lacroix M (2006) Modification of the properties of milk protein films by gamma radiation and polysaccharide addition. J Sci Food Agric 86(6):908–914

Dai L, Zhang J, Cheng F (2019) Effects of starches from different botanical sources and modification methods on physicochemical properties of starch-based edible films. Int J Biol Macromol 132:897–905

De Moura MR, Aouada FA, Avena-Bustillos RJ, McHugh TH, Krochta JM, Mattoso LHC (2009) Improved barrier and mechanical properties of novel hydroxypropyl methylcellulose edible films with chitosan/tripolyphosphate nanoparticles. J Food Eng 92(4):448–453

Galus S, Kadzinska J (2015) Food applications of emulsion-based edible films and coatings. Trends Food Sci Technol 45(2):273–283

Garcıa MA, Ferrero C, Bertola N, Martino M, Zaritzky N (2002) Edible coatings from cellulose derivatives to reduce oil uptake in fried products. Innov Food Sci Emerg Technol 3(4):391–397

González A, Igarzabal CIA (2015) Nanocrystal-reinforced soy protein films and their application as active packaging. Food Hydrocoll 43:777–784

Guerrero P, O'Sullivan MG, Kerry JP, de la Caba K (2015) Application of soy protein coatings and their effect on the quality and shelf-life stability of beef patties. RSC Adv 5(11):8182–8189

Guilbert S, Gontard N, Morel MH, Chalier P, Micard V, Redl A (2002) Formation and properties of wheat gluten films and coatings. Protein-Based Films Coat 3:69–122

Hardenburg RE (1967) Wax related coatings for horticultural products. A bibliography. Agricultural Research Service Bulletin 51–15, United States Department of Agriculture, Washington, DC

Janjarasskul T, Krochta JM (2010) Edible packaging materials. Ann Rev Food Sci Technol 1:415–448

Khwaldia K, Perez C, Banon S, Desobry S, Hardy J (2004) Milk proteins for edible films and coatings. Crit Rev Food Sci Nutr 44(4):239–251

Krochta JM (2002) Proteins as raw materials for films and coatings: definitions, current status, and opportunities. In: Gennadios A (ed) Protein-based films and coatings. CRC Press, Boca Raton, FL, pp 1–41

Lee SY, Dangaran KL, Krochta JM (2002) Gloss stability of whey-protein/plasticizer coating formulations on chocolate surface. J Food Sci 67(3):1121–1125

Matiacevich S, Acevedo N, Lopez D (2015) Characterization of edible active coating based on alginate-thyme oil-propionic acid for the preservation of fresh chicken breast fillets. J Food Process Preserv 39(6):2792–2801

Morillon V, Debeaufort F, Blond G, Capelle M, Voilley A (2002) Factors affecting the moisture permeability of lipid-based edible films: a review. Crit Rev Food Sci Nut 42(1):67–89

Park S, Zhao Y (2006) Development and characterization of edible films from cranberry pomace extracts. J Food Sci 71(2):E95–E101

Park SK, Hettiarachchy NS, Ju ZY, Gennadios A (2002) Formation and properties of soy protein films and coatings. In: Protein-based films and coatings. CRC, Boca Raton, FL, pp 123–137

Patel P (2020) Edible packaging. ACS Cent Sci. https://doi.org/10.1021/acscentsci.9b01251

Pavlath AE, Orts W (2009) Edible films and coatings: why, what, and how. In: Embuscado ME, Huber KC (eds) Edible films and coatings for food applications. Springer, London, New York. https://doi.org/10.1007/978-0-387-92824-1

Saklani P, Siddhnath Das SK, Singh SM (2019) A review of edible packaging for foods. Int J Curr Microbiol Appl Sci 8(7):2885–2895. https://doi.org/10.20546/ijcmas.2019.807.359

Sapper M, Chiralt A (2018) Starch-based coatings for preservation of fruits and vegetables. Coatings 8(5):152

Senturk Parreidt T, Müller K, Schmid M (2018) Alginate-based edible films and coatings for food packaging applications. Foods 7(10):170

Shendurse AM, Gopikrishna G, Patel AC, Pandya AJ (2018) Milk protein based edible films and coatings–preparation, properties and food applications. J Nut Health and Food Eng 8(2): 219–226

Shon JH, Choi YH (2011) Effect of edible coatings containing soy protein isolate (SPI) on the browning and moisture content of cut fruit and vegetables. J Appl Biol Chem 54(3):190–196

Singh S, Khemariya P, Rai A, Rai AC, Koley TK, Singh B (2016) Carnauba wax-based edible coating enhances shelf-life and retains quality of eggplant (*Solanum melongena*) fruits. LWT-Food Sci Technol 74:420–426

Soares NMF, Oliveira MS, Vicente AA (2015) Effects of glazing and chitosan-based coating application on frozen salmon preservation during six-month storage in industrial freezing chambers. LWT-Food Sci Technol 61(2):524–531

Suhag R, Kumar N, Petkoska AT, Upadhyay A (2020) Film formation and deposition methods of edible coating on food products: a review. Food Res Int 136:109582

Vachon C, Yu HL, Yefsah R, Alain R, St-Gelais D, Lacroix M (2000) Mechanical and structural properties of milk protein edible films cross-linked by heating and γ-irradiation. J Agric Food Chem 48(8):3202–3209

Valdés A, Burgos N, Jiménez A, Garrigós MC (2015) Natural pectin polysaccharides as edible coatings. Coatings 5(4):865–886
Versino F, Lopez OV, Garcia MA, Zaritzky NE (2016) Starch based films and food coatings: an overview. Starch-Stärke 68(11–12):1026–1037
Wittaya T (2012) Protein-based edible films: characteristics and improvement of properties. Struct Funct Food Eng:43–70
Yuan G, Chen X, Li D (2016) Chitosan films and coatings containing essential oils: the antioxidant and antimicrobial activity, and application in food systems. Food Res Int 89:117–128