

Recent development in preparation of food packaging films using biopolymers

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Abstract

In the past decades, most materials used in the food packaging industry are non-biodegradable materials that pose increased environmental concerns and sustainability issues. Hence, polymer-based biodegradable materials and edible films have been developed to increase the shelf life of food products. Especially, biopolymer-based nanomaterials are engineered with multifunctional characteristics because of their size, surface area, shelf life, thermal stability, and mechanical and barrier strength. These materials display enriched properties of biodegradability, antimicrobial activity, and biocompatibility and may have the possibility to replace plastic materials in future. Thus, this review offers a brief overview of the classification of biopolymers, key parameters that are important in food packaging films (including the role of plasticizers, cross-linkers, pH, temperature, and relative humidity), and recent applications of novel biopolymer nanocomposite materials used in the food industries.

1. Introduction

Despite various initiatives from international and national governing bodies concerning the usage of plastic, it is impossible to avoid plastic in day-to-day activities because of high demands in rapid urbanization (Valdés *et al.*, 2014; Axelsson *et al.*, 2017; Geueke *et al.*, 2018). The superior properties of the plastic including water resistance; optical, mechanical, and barrier strength; transparency; chemical inertness; lightweight; and resistivity towards heat make them suitable for food packaging (Valdés *et al.*, 2014). Polyethylene (PE) is the first polymer used for food packaging to make cups, squeeze bottles, extrusion coating for paper boards (Geueke *et al.*, 2018). Later, various thermoplastic-based polymers were developed including polyvinyl chloride (PVC), polyethylene terephthalate (PET), polypropylene (PP), styrene butadiene (SB), and acrylonitrile butadiene styrene (ABS) materials for food packaging. Each individual polymer has unique characteristics in a certain way. PE is a heat-sealing polymer that can produce a tough and thick film with a better barrier to moisture (Coles *et al.*, 2003). PP is prepared using a Ziegler-Natta catalyst giving a harder and denser polymer with high transparency and flexibility (Marsh and Bugusu 2007). PP is widely used for lamination, printing, and coating. PET is a condensation polymer showing higher heat

resistance and mechanical strength than other non-degradable polymers (Kirwan *et al.*, 2011). PET is an alternate for PVC, and it is an emerging polymer used to prepare carbonated soft drinks bottles, packaged drinking water bottles, and edible oil containers (Geueke *et al.*, 2018).

Despite having these superior advantages, it lacks other important properties like degradability, having a low melting rate, and a low recycling rate. In addition, plastic materials have toxicity and high economic value to dispose of the waste, which make them unsuitable for various applications, particularly in food industries (Siracusa *et al.*, 2008). As an alternative, biopolymers have been successfully exploited by the food industries in recent years. These biopolymers or polymeric biomolecules are naturally produced or synthesized from renewable materials (starch, proteins, natural fat, oil, and sugar) (Nešić *et al.*, 2020). These prepared materials are biodegradable, biocompatible, non-toxic, chemically inert, and cost-effective, depending on the composition (Zhong *et al.*, 2019). In addition, a vast amount of money can be saved by converting natural-based polymer waste into usable biodegradable materials (Marsh and Bugusu 2007).

Bionanocomposites or biopolymer blends are

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prepared by using plasticizer, compatibilizer, or additives to the polymers (Vieira *et al.*, 2011). As an example, starch/MMT clay nanocomposites material were prepared to enhance the barrier and mechanical properties of the biodegradable film by melt extrusion method (Tang *et al.*, 2008). Various types of NPs were incorporated into the biopolymers (chitosan, alginate, agar, carrageenan and CMC-carboxy methylcellulose) to develop antimicrobial nanocomposite films for active packaging (Kanmani *et al.*, 2014). In addition, edible films are also prepared by making a thin layer that is used to wrap the food surface with biopolymeric materials. This is done by applying coating (by using methods like dipping and spraying) which forms a layer directly on the food surface (Zhong *et al.*, 2019). Edible films can be used to produce a soluble package for premixed food ingredients or additives that acts as a separate layer of individual food portions. Therefore, the preparation of novel Nano biopolymer-based materials for food industry applications and their functional properties are key to overcome the usage of non-biodegradable materials.

2. Classification of biopolymers

Biopolymers are classified based on the applications or origin of resources or chemical or physical properties. Based on the origin of resources, biopolymers are classified as vegetable origin (lignin, starch, or cellulose), animal origin (chitin or collagen), from microbe sources (polyhydroxy butyrate or polylactic acid), and from bio-based monomers (poly-ε-caprolactone and polyglycolic acid) by Błedzki *et al.* (2012). Karthik *et al.* (2009) have classified the biopolymers into four types: agro-polymers

(polysaccharides and proteins), microorganism extracts (polyhydroxyalkanoates), bio conventionally synthesized monomers (polylactides), and petrochemical products (polycaprolactone, homopolyester, and aliphatic and aromatic copolyester which are synthetically synthesized monomers). Based on degradation, it was classified into two major categories: natural and synthetic biopolymers. Natural biopolymers are proteins, polysaccharides, and polynucleotides, whereas polylactic acids, polycaprolactone, polyhydroxy butyrate, are synthetic biopolymers, as shown in Figure 1 (Zia *et al.*, 2017). A detailed summary of polymer types and their sources, properties, and their applications with examples are shown in the Table 1.

3. Parameters that play role in food packaging applications

3.1 Effect of plasticizer

A plasticizer is an additive used to increase the elasticity of the film. Plasticizers are an important class of nonvolatile compounds with molecular weight ranging from 300 to 600 kDa (Sothornvit *et al.*, 2005; Vieira *et al.*, 2011; Muhammed *et al.*, 2015; Suderman *et al.*, 2018). The role of a plasticizer is to change the physical and/or chemical properties of materials when added. This leads to improving the mechanical properties (flexibility and tensile strength), barrier properties (water Vapour permeability and oxygen permeability), and optical properties (glossiness and opacity) (Vieira *et al.*, 2011). Currently, numerous plasticizers are being used in various applications. Water, glycerol, sorbitol, mannitol, sucrose, and polyethylene glycol are the most commonly used plasticizers in the food industry. These plasticizers help change the three-dimensional molecular structure of

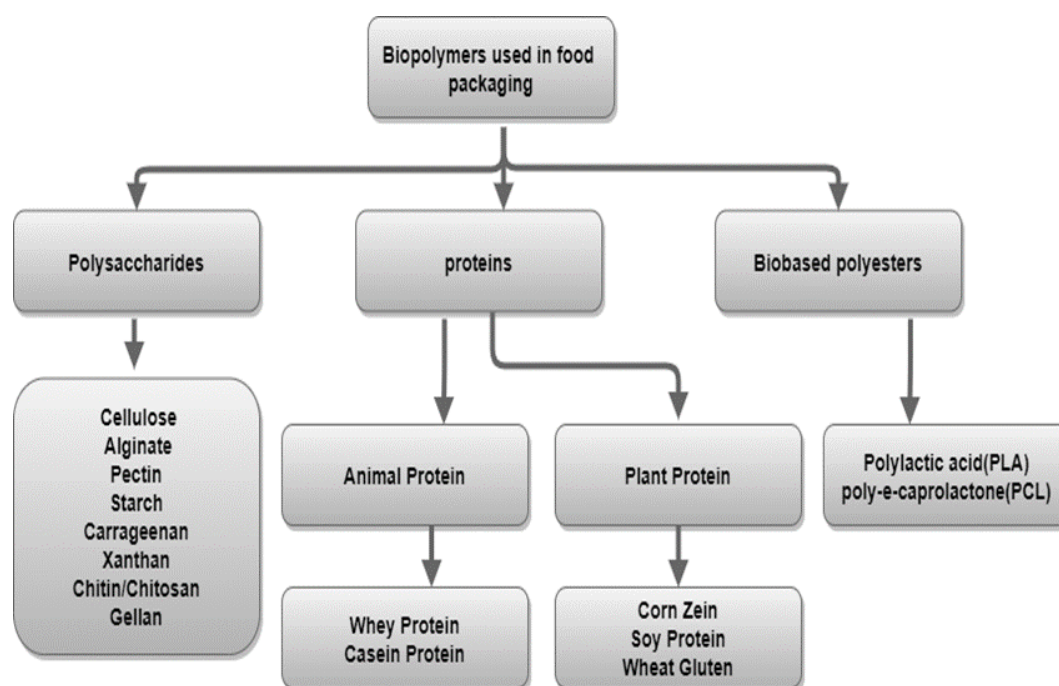


Figure 1. Schematic representation of the classification of the biopolymers.

Table 1. A detailed summary of polymer types and their sources, properties, and their applications with examples.

Biopolymers	Sources	Properties	Selected references
Cellulose	Most abundant biopolymer made of sugar monomer unit, extracted from plant fiber. It is a homo polysaccharide composed of (β -1,4)-linked glucopyranose units.	Light weight, durability, high melting point, low-permeability	Chen (2014); Padrão <i>et al.</i> (2016)
Alginate	Extracted from brown algae by treatment with aqueous alkali solutions. Calcium and sodium salts of alginic acid are known as alginates.	Anti-microbial, tensile strength, Thermal stability.	Lee and Mooney (2012); Adbollahi <i>et al.</i> (2013); Yang <i>et al.</i> (2019)
Pectin	Pectin is rich in apple, sugar-beet pulp and in citrus peels and different plant sources. It is a complex anionic polysaccharide having β -1, 4-linked D-galacturonic acid.	Biocompatibility in nature, ease of gelling, stabilizing ability, thickening and emulsifier.	Marquez <i>et al.</i> (2017); Ferrari <i>et al.</i> (2013)
Starch	Hydrocolloid polymer found in rice, corn, wheat, potatoes and cassava.	Hydrophilic nature, gel forming property, used as a thickener, colloidal, stabilizer, and water retention agent.	Ortega-Toro <i>et al.</i> (2017)
Carrageenan	Carrageenan is derived from red seaweed, forms highly viscous aqueous solutions. It is an anionic linear sulphated polysaccharide joined by glycosidic linkage.	Additive to preserve food, thickener and emulsifier.	Seol <i>et al.</i> (2009); Shojaee <i>et al.</i> (2013)
Xanthan	Xanthan gum produced by the bacterium <i>Xanthomonas campestris</i> , is soluble in cold and hot water. The polymer backbone is made up of (1 \rightarrow 4)-linked β -D-glucopyranosyl units (identical to cellulose).	Thickening, emulsifying, gelling and stabilizing agent.	García-Ochoa <i>et al.</i> (2000); Sharma and Rao (2015); Kim <i>et al.</i> (2012)
Chitin/ Chitosan	Chitin is the second most used polysaccharide after cellulose. Chitin is a white, hard nitrogenous polysaccharide found in the internal structure of invertebrates and cell walls of fungi.	Anti-microbial, anti-fungal and anti-oxidant properties.	Harish Prashanth <i>et al.</i> (2007); Cheba <i>et al.</i> (2015); Zhang <i>et al.</i> (2017)
Gellan	Anionic polysaccharides secreted and extracted from the bacterium <i>Sphingomonas paucimobilis</i> by aerobic fermentation.	Stabilizer, gelling, film-forming and encapsulation agent.	Xiao <i>et al.</i> (2011); Moreira <i>et al.</i> (2015); Wei <i>et al.</i> (2017).
Whey protein	Whey protein is obtained from milk. Cow milk contains 80% casein and 20% whey protein which is a byproduct in cheese production.	High binding ability, moderate permeability and plasticizing capacity	Javanmard (2008); Thawien (2012).
Casein Protein	Casein Protein is found in Mammalian milk and the production of cheese.	High tensile strength and good oxygen barrier property	Avena-Bustillos, <i>et al.</i> (1994); Picchio <i>et al.</i> (2018).
Zein	Zein is found in corn (Maize). It comes under the class of prolamine protein.	Odorless, water-insoluble and hydrophobic in nature, water-resistant capability and ability to remove moisture, it has been extensively used for making edible films.	Luecha <i>et al.</i> (2010); Ozcalik and Tihminlioglu (2013).
Soy protein	One of the most versatile proteins found in soybean and has all the essential amino acids. Soy protein exists in three forms which are soy flour (SF), soy protein concentrate (SPC) and soy protein isolates (SPI)	Hydrating capacity, solubility, colloidal stability, gelation, emulsification, foaming and adhesion/cohesion	Kinsella (1979); Singh <i>et al.</i> (2008); Chinma <i>et al.</i> (2012).
Wheat gluten	It belongs to the prolamine protein group. Wheat gluten is the by-product of the isolation of starch in wheat flour. Industrially gluten is produced from wheat flour by the drying process and wet	Gel forming ability, water-holding capacity, elastic nature and thermosetting properties.	Day (2011); Heralp (1993)
Poly Lactic acid (PLA)	It is obtained by ring-opening polymerization of lactides or from the condensation of lactic acid. PLA exist in two enantiomeric forms D-PLA and L-PLA.	High strength, oil and grease resistance, thermoplastic nature, hydrophobicity, flexibility, toughness and biocompatibility.	Ljungberg and Wessle (2005); Sébastien <i>et al.</i> (2006); Muller <i>et al.</i> (2017).

Table 1 (Cont.). A detailed summary of polymer types and their sources, properties, and their applications with examples.

Biopolymers	Sources	Properties	Selected references
PolyCapro Lactone (PCL)	Obtained by ring-opening polymerization of caprolactone extracted from sugar cane.	Used as an additive or a plasticizer to food coating due to the non-toxic nature, flexibility, resistivity toward water and oil.	Yun <i>et al.</i> (1966); Joseph <i>et al.</i> (2011); Sogut and Seydim (2018).

polymers resulting in a change in the mobility of the polymer chain and also increasing extensibility to the chain (Sanyang *et al.*, 2015). For instance, increasing the glycerol content in cassava starch film solution gives more flexibility, less stiffness, and rigid nature to the film because of the interaction between the adjacent biopolymer chains in the film matrix (Souza *et al.*, 2012). Gelatin film was made by using different plasticizers involving glycerol, sorbitol, and polyethylene glycol; however, gelatin-glycerol plasticization showed good mechanical strength compared with other compositions. The main reason is that the penetration of a small amount of glycerol into the polymer chain loosens the hydrogen bonding and creates free volume between the film matrix, thus increasing the flexibility and extensibility of the film (Suderman *et al.*, 2018). It can be crystalline solid or amorphous (glassy or rubbery) in nature. Glass transition (T_g) theory can be utilized to explain plasticizer effects on mechanical and permeability properties. Glass transition occurs when polymer structures changes from brittle glass to highly viscous or rubbery solid state. An increase in plasticizer content leads to a decrease in glass transition temperature. If T_g is decreased, the brittleness of the film increases because of the polymer-plasticizer interactions (Bhandari *et al.*, 2016). In the sugar palm starch (SPS) film, different plasticizers were used to increase the mechanical and barrier properties of the film due to plasticizers diminishing the strong intramolecular attraction between the starch chains and promoting the formation of hydrogen (Sanyang *et al.*, 2015).

Barrier properties are essential in the food packaging system for commercial manufacturing to extend the shelf life and quality of food products by controlling the permeability of gases (like water Vapour, CO_2 , and O_2) and aroma transport. In general, gas permeability for a film highly depends on the nature of gas, the structure of a material, relative humidity, and processing temperature. These gases are involved in degradation processes (rancidity, enzymatic browning) that change the internal space of the packaging film and its environment. This leads to economic and commercial disadvantages of food packaging applications; hence, controlling the permeability of the gases in packaging materials is particularly important (Siracusa *et al.*, 2012). Film prepared with corn zein, wheat gluten, and cellulose (methyl and hexamethyl cellulose) showed lower oxygen

and CO_2 permeability than commercial plastic film. Adding Myvacet 7-OOT, as a plasticizer, decreased the permeability of hexamethyl cellulose (HPC) to approximately 43.2% (Park *et al.*, 1995). To increase the physicochemical properties of fish gelatin film, a composite was made by using fish gelatin and chitosan at different concentrations, resulting in a reduction in water vapour permeability (WVP) and solubility. Chitosan limits the amount of water Vapour passing through the film membrane, thus lowering the WVP (Fakhreddin *et al.*, 2013).

3.2 Effect of cross-linkers

Cross-linkers are used to improve the water resistance, rigidity, barrier and mechanical strength, and thermostability. The most commonly used cross-linkers are glutaraldehyde, citric acid, glyceraldehyde, transglutaminase, formaldehyde, and lactic acid. Cross-linkers are particularly suitable for proteins when compared with other biopolymers. Cross-linkers increase the intermolecular hydrogen bonding by generating the strong covalent bond leading to three-dimensional networks (Liang *et al.*, 2019). Introducing cross-linking agent to the biopolymer is completely dependent on the structural arrangement of biopolymer, molecular weight, and compatibility of cross-linker (Garavand *et al.*, 2017). Cross-linking effect of citric acid on pea starch biocomposite film has modified the storage modulus, tensile strength, and glass transition temperature (Ma *et al.*, 2009).

3.3 Effect of pH, temperature, time, and relative humidity

3.3.1 pH

Depending on the pH, gel formation for a film differs in its functional properties because of the presence of hydrogen bonding, hydrophobic interaction, electrostatic interaction, and disulphide linkage of protein. The effect of pH on surimi-gelatin composite film shows that there was a change in the mechanical properties when pH was adjusted to an acidic or alkaline condition. High and low Elongation at Break (EAB) was observed at pH 3 and pH 10 respectively and vice versa for Tensile Strength (TS); however, both EAB and TS were lowest at pH 7. This is mainly due to the protein unfolding and interactions when the pH of the solutions are changed (Tao *et al.*, 2015). In preparation of biodegradable food packaging film using fish (white

mouth croaker) protein, pH can vary from 2 to 10. At pH 2, the film has greater elasticity during gelation and maintains the mechanical strength in comparison to pH 10 due to the conformational changes of the protein structures (Romani *et al.*, 2018). In gelatin film incorporated with corn oil, tensile strength (TS) value decreased when pH increased; under neutral pH, TS increased. The highest value of TS was obtained at pH 9.5 because of the high crystallinity and gel-forming ability of gelatin (Bourtoom *et al.*, 2006).

3.3.2 Temperature and time

Temperature and time are major important factors to improve the quality and shelf life of food packaging film. The solubility of whey protein isolate (WPI) was affected by heating time and temperature. Heating at a higher temperature can unfold the protein, resulting in protein-protein cross-linking interaction by exposing -SH groups that enable the formation of covalent intermolecular disulfide bonds, which are accountable for film water insolubility (Perez-Gago and Krochta 2001). In cassava starch and soy protein concentrate (SPC)-based edible films, tensile strength, elastic modulus, and water Vapour permeability of edible films increased with increasing the temperature because of the free movement of the polymer segment, film-forming formulation and drying process (Chinma *et al.*, 2015). In the preparation of Potato starch film; there was an increase in Tensile strength and microstructure properties due to the effect of mixing temperature (80°C, 85°C). The obtained SEM images were confirmed that the development of microstructures during gelation resulting in the formation of smooth and homogenous film structure (Zakaria *et al.*, 2018).

3.3.3 Relative humidity

In the food packaging industry, maintaining the relative humidity (RH) for a film is an essential factor for its mechanical and barrier properties. Compared with plastic, biopolymers can modify their mechanical and barrier properties in high moisture conditions, especially in fresh-cut fruits and vegetables. Generally, films having high RH have higher water content than films containing lower RH. For example, Composite film made by using chitosan, fish gelatin, glycerol, and transglutaminase were highly homogenous and flexible because of the effect of relative humidity on tensile strength and elongation. Tensile strength and elongation were increased when RH is increased. This is due to the hydrophilic nature of gelatin and cross-linking ability of glycerol (Alvarado *et al.*, 2015). Protein (corn zein and wheat gluten) and cellulose-based films (methylcellulose (MC) and hydroxypropyl cellulose) were studied to test the Tensile strength of the film as a function of RH and

T. An increase in the RH and T resulting in a decrease in the TS due to the amount of water absorbed by the hydrophilic films (Gennadios *et al.*, 1993).

4. Biopolymers applications in selected food industries

Food packaging technology is one of the vast developing fields because of the increasing demands for packaged food products. Particularly, edible food packaging may increase the economic and nutritional value of food products. Packaging is an essential bridge between the manufacture and consumer to increase the availability of quality food products, hygiene, and safety. Therefore, biopolymers can provide the best solution to enhance the quality and prolonged shelf life of food products. The applications of the biopolymers are discussed for five major food industries that are responsible for producing and selling millions of products in day-to-day life.

4.1 Fruits and vegetable industries

Fresh cut fruits and vegetables are generally perishable materials when in contact with open air, resulting in loss of sensory properties, loss of tissue texture, and degradation of the cell membrane. When fruits or vegetables are peeled or cut, certain enzymes are exposed to air and oxidized, leading to the browning of the surface of fruits or vegetables. In addition, the growth of microorganisms such as bacteria (e.g., *Lactobacillus* spp. and *Escherichia coli*), yeasts (e.g., *Saccharomyces*), and moulds (e.g., *Rhizopus*) spoils the agricultural products; hence, storage and food packaging are the essential tools to increase the shelf life (Barth *et al.*, 2009). Therefore, bio-derived polymers such as alginate, chitosan, and carrageenan were used as edible packaging materials (Abdul Khalil *et al.*, 2018). A combination of 1.29% (w/v) chitosan with 0.42% glycerol and 1.49% (w/v) carrageenan with 0.03% glycerol were coated to preserve the postharvest longan fruits, and it showed minimal quality changes and quantity losses proved by the response surface methodology (RSM) test (Lin *et al.*, 2018). The electrostatic spraying (ES) technique was applied to strawberries using natural antimicrobial agents (alginate, carvacrol, and methyl cinnamate) that reduced the microbial contamination and mould count for approximately 11 days. After 13 days of storage, ES-coated strawberries showed colour retention, weight loss reduction, and firmness in the film (Peretto *et al.*, 2017). Edible coating using aloe vera gel (2%) with corn starch (1%) enhanced the shelf life of ber (*Zizyphus mauritiana Lamk*) fruit for up to 15 days. Aloe vera gel-coated fruits showed a minimum loss in weight, maximum colour retention, and lesser loss in acid content when compared

with uncoated fruit. In addition, aloe vera coating reduced the ascorbic acid loss and decay percentage (Mani *et al.*, 2017).

4.2 Meat industries

The meat industry involves a chain of segments that can be classified as production, processing, preserving, and packaging. Microbial contamination and protein oxidation in meat leads to food-borne illness and reduces the shelf life. Therefore, meat quality and food safety are completely dependent on the packaging materials and techniques that are used. An active packaging using edible films protects the meat from moisture loss during storage in frozen conditions, reduces the rate of rancidity, and maintains the juice content of meat. Recently, a series of new packaging technologies have been developed, including edible packaging, nanomaterial packaging, and biodegradable packaging. Such packaging mainly ensures quality, prolonged shelf life, and increases the economic value of meat products (Fang *et al.*, 2017). The incorporation of green tea extract (GTE) into potato starch films significantly improved the film mechanical properties and decreased the oxidation of packaged fresh beef and inhibited the formation of metmyoglobin (Lee *et al.*, 2015). Chitosan and tea polyphenol solution as natural antioxidants were used to develop a film to protect cooked pork sausages against oxidation (Domínguez *et al.*, 2018). Polysaccharides such as agar, gelatin, corn-starch, and citrus pectin were used as components of a film-forming coating to prolong the shelf life of natural semi-finished pork meat at a storage temperature of -1 to $+1^{\circ}\text{C}$ for 2 days (Soletska *et al.*, 2018).

4.3 Dairy industries

Milk, fermented milk, yogurt, cheese, butter, and their functional foods are the major dairy products. Dairy products play an important role in diet to maintain the nutritional functions of the human body and act as excellent sources of vitamin A, proteins, lipids, and minerals like calcium, magnesium, and phosphorous. To prevent milk products from contamination and rancidity (aroma changes) and to maintain the aesthetic appearance, various biopolymers are used by the food industries. Chitosan/whey protein composite (CWC) is an active coating used to extend the shelf life of ricotta cheese. The coating delayed the development of acidity and did not change the sensory appearance of texture and no change in pH over 30 days of storage period. In CWC, lactic acid bacteria and mesophilic and psychrotrophic microorganisms were lower when compared with films that were using chitosan alone (Di Pierro *et al.*, 2011). The effect of antimicrobial activity in mozzarella cheese was evaluated by using lemon

extract as an active agent and in combination with brine and sodium alginate solution. Shelf-life tests were performed at 15°C to monitor the cell load of spoilage and functional microorganisms during storage. The film inhibited the growth of microorganisms such as coliforms and *Pseudomonas* spp. and the shelf life of mozzarella cheese was increased without affecting the sensory properties (Conte *et al.*, 2007). Minas Padrao cheeses were coated with zein-oleic acid (Z-OA) and Z-OA-xanthan gum (XG) and studied storage up to 56 days. The coated cheese samples exhibited preservation of physicochemical characteristics such as chlorides, ash, protein, and acidity compared with unpackaged and plastic-packaged cheese samples. The biodegradable coating prevented the early microbiological contamination and decreased the cheese moisture loss in comparison to unpackaged samples (Youssef *et al.*, 2017).

4.4 Confectionery industries

The confectionery industry is segmented into five categories, which include chocolate, sugar, gum, cereals, and flour. The major products of the confectionery industries are candy, cake, cookies, ice creams, frozen desserts, pastries, jams, and jellies. Biopolymer-based edible packaging on the confectionery products makes more desirable outer covering and extend the product's shelf life. Edible films made with Mexican lime pectic extract and lime's essential oil possessed antibacterial potential (Aldana *et al.*, 2015). The edible film made from sago starch, various concentrations of nutmeg pectin, and glycerol showed an increase in the water vapour permeability (WVP) value of the film. Edible sago starch films can be used as a dodol packaging material due to oxidation and act as a better barrier from oxygen permeation when compared with synthetic films (Layuk *et al.*, 2019). An edible film consisting of potato starch and invert sugars improved the quality and safety. Incorporation of sorbate potassium and citric acid additive in the film further inhibits the yeast and mould growth up to 48 days in mini panettones (Saraiva *et al.*, 2016). Starch, gelatin, and urea combined as a plasticizer were used as an alternative edible coating for "Korivka" candies instead of traditional paper coating. The cost of the proposed edible coating was lower by \$ 8.77 per 1 ton of candies compared with traditional paper material (Shylga *et al.*, 2018).

4.5 Seafood industries

Seafood is consumed all over the world because of its nutritional benefits. However, it is perishable in nature when compared with chicken and other meat products. Therefore, smart edible packaging is needed to avoid the loss of texture and reduce microbial growth.

For example, hake fish is one of the largest consumed fish in Spain. To prevent fish from microbes, the composite polymer of whey protein isolate (WPI) with essential oil is used as coating with modified atmosphere packaging (MAP) resulting in enhanced quality of the fish product during storage in the refrigerator (Carrión *et al.*, 2018). The edible coating based on ultrasound (35 kHz)-treated whey protein reduced the lipid oxidation in Atlantic salmon. In addition, thaw yield, drip loss in thawing, drip loss after chilled storage, and cooking loss have not influenced the fish properties when compared with fishes with untreated whey protein coatings (Rodriguez *et al.*, 2012). Using vacuum packaging and wrapping with chitosan-based edible film, the shelf life of fresh sea bass (*Dicentrarchus labrax*) fillets was improved under cold storage at 4°C until 20 days. Growths of microorganisms (total mesophilic and total psychrophilic aerobic bacterial counts) were significantly reduced in vacuum-packaged chitosan film wrapping (Günlü and Koyun 2013).

5. Conclusion

The utilization of biopolymer-based packaging is an alternative for synthetic plastics to limit the environmental damages. Although synthetic plastics are economically cheaper than degradable polymer materials, an alternative strategy is required to increase the availability of biodegradable materials. Thanks to advancements in nanotechnology, several changes have been made to extend the shelf life of food products. Specifically, Nano composite-based biomaterials exhibit numerous enhanced characteristics, including barrier properties. In addition, underutilized waste by-products from food processing industries should be converted into eco-friendly, cheaper, and degradable packaging materials, which may gain more attention and acceptance to solve environmental pollution by creating wealth from waste. Toxicity, risk assessment of nanocomposites, and migration assays are needed to ensure that these enhanced packaging materials can be utilized at their maximum by food packaging industries

Conflict of interest

The authors declare that there is no conflict of interest regarding the publication of this article.

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