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Shelf life enhancement of muscle foods with biodegradable film packaging

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Abstract

Bio-based products and innovative process technologies are receiving attention in food industry to reduce the dependence on fossil fuel and move to a sustainable materials basis. Biodegradable films are continuous matrices prepared from edible materials made up of proteins, polysaccharides and lipids. Edible coatings are either applied to or made directly on foods while films are independent structures. A significant progress has been made in the development of biodegradable plastics, largely from renewable natural resources, to produce biodegradable materials with similar functionality to that of oil-based polymers. These natural films are preferred over non biodegradable films due to less carbon emission, less energy consumption, less landfill area and recycling ability. Incorporation of nano composites, essential oils, plant extracts, antimicrobial substances etc. improve functionality of bio degradable polymers based films in terms of protection against external factors and increase the food's stability through antimicrobial properties and/or responding to environmental changes.

Introduction

Packaging has been defined as a socio-scientific discipline which operates in society to ensure delivery of goods to the ultimate consumer of those goods in the best condition intended for their use (Lockhart, 1997).

Food packaging requires protection, tampering resistance, and special physical, chemical, or biological needs. It also shows the product that is labeled to show any nutritional information on the food being consumed. The packaging and labels can be used by marketers to encourage potential buyers to purchase the product. Package design has been an important and constantly evolving phenomenon for several decades.

Marketing communications and graphic design are applied to the surface of the package and (in many cases) the point of sale display. Packaging can play an important role in reducing the security risks of shipment. Packages can be made with improved tamper resistance to deter tampering and also can have tamper-evident features to help indicate tampering. Packages can have features which add convenience in distribution, handling, stacking, display, sale, opening, reclosing, use, and reuse. The fundamental reasons for packaging fresh and processed meat products are preventing contamination, delaying spoilage, permitting some enzymatic activity to improve tenderness, reducing weight loss, and retaining colour and aroma (Mondry, 1996; Brody, 2007).

As traditional food packaging materials show shortcomings in terms of their environmental pollution impact and in their manufacturing requirements for non-renewable resources, the need for alternative packaging materials and packaging formats is now required more than ever.

Recently, a series of new packaging technologies and materials have been developed including active

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packaging, intelligent packaging, edible coatings/ films, biodegradable packaging, and nanomaterial packaging. These technologies and materials have the potential to improve the quality and safety, prolong the self-life, reduce the environment impact, and increase the attractiveness of the packaged product to the retailers and consumers, outcomes that are favourably welcomed by the food industry.

Current technologies for meat packaging

Packaging can lower the weight loss, cost of transportation and increase the shelf life of food products (Rozbeh *et al.*, 1993).

Packaging becomes active when it performs another desired role other than providing an inert barrier to external conditions and has developed as a series of responses to maintain quality and safety of food (Rooney, 2005).

Fresh packed meat has been one of the major meat products in the market since early in the 1900's (Cerisuelo *et al.*, 2013). Packaging delays meat quality deterioration such as microbial proliferation, discoloration, off-flavor, and nutrient loss (Zhou *et al.*, 2010).

Edward *et al.* (1987) reported that among vacuum packaging, aerobic packaging and modified atmosphere packaging, vacuum packaging was the most widely used for extruded products as this type of packaging could keep the product safe especially beef products for about 45 days at ambient temperature (32+2^{0}C).

Avilés *et al.* (2014) compared the color stability of beef steaks under vacuum packaging and re-packaging after leaks. They reported that repeated vacuum packaging should be avoided as it adversely affected color stability of product.

Zakrys *et al.* (2009) reported that modified atmospheric packaging (MAP) in beef was preferred by consumers because of their increased tenderness and juiciness compared with steaks packaged in traditional tray packaging. Cornforth and Hunt (2008) used anaerobic MAP with low levels (about 0.4%) of CO, 20-30% CO2 and the remainder N2 and observed that CO MAP maintained the red color stability of steaks not only during storage but also after opening the packages (Liu et al., 2014).

Zhou *et al.* (2012) designed an active packaging film for chilled meat by employing polyvinyl acetate (PVA) and polylactic acid (PLA) as film-forming materials and sustained-release microcapsules containing natural antimicrobial agent. They averred that antimicrobial agent was slowly released from the microcapsules, migrated in the film and finally reached the surface of the chilled meat to achieve antimicrobial and fresh-keeping effects. In the last few decades, there has been a marked increase in the use of natural polymer-based film materials and coatings in packaging for food industry, which protect food from external contamination, retarding its deterioration by extending its shelf-life and maintaining its quality and safety (Malhotra *et al.*, 2015).

Biodegradable film packaging

Edible coatings or films are defined as continuous matrices prepared from edible materials made up of proteins, polysaccharides and lipids. They can be used to incorporate functional food substances, such as antimicrobials, antioxidants, flavouring agents and nutrients, to improve safety, stability, sensory, and nutritional properties of foods (Lin and Zhao, 2007; Silva-Weiss *et al.*, 2013).

There is a growing demand by consumers for foods perceived as natural, fresh-tasting, nutritious, healthy and safe, including meat and meat products (Grunert and Valli, 2001).

Bio degradable films have received considerable attention in recent years because of their advantages including use as edible packaging materials over synthetic films.

The primary factors driving development of the biodegradable packaging market include the increase in crude oil prices, which has narrowed the price differential, other key factors include consumer demand, the proliferation of convenience packaging, the development of new applications for bioplastics and the increased economic viability as production ramps up and unit costs decrease (Pawar and Purwar, 2013).

Bio degradable films can be produced either by wet processing or dry processing. For wet processing films can be produced from materials with film forming ability. During manufacturing, film materials must be dispersed and dissolved in a solvent such as water, alcohol or mixture of water and alcohol or a mixture of other solvents. Plasticizers, antimicrobial agents, colors or flavors can be added in this process. Adjusting the pH and/or heating the solutions may be done for the specific polymer to facilitate dispersion. Film solution is then casted and dried at a desired temperature and relative humidity to obtain free standing films. Film solutions can be applied to food by several methods such as dipping, spraying, brushing and panning followed by drying. The dry process does not involve solvent dispersion as it relies on inherent thermoplastic characteristics of some biopolymers and is produced by compression, molding or extrusion (Liu *et al.,* 2014).

Biopolymers such as polysaccharides, proteins and lipids can be used alone or in combination to form coatings and films, the physical and chemical properties of the base materials, greatly influencing the functionality of the films and coatings produced. The choice of materials is generally based on their water solubility, hydrophilic and hydrophobic nature, easy formation into coatings and films, sensory properties, and targeted applications.

Polysaccharide-based biodegradable films

Polysaccharides, such as cellulose and its derivatives, starch, chitosan, and pectin have been commonly used to make edible coatings and films. Polysaccharide based coatings and films provide a good barrier to O_2 and CO_2, but a poor barrier to water vapor due to their hydrophilic nature (Vargas *et al.,* 2008).

Polysaccharide coatings are colorless, have an oily-free appearance and a minor caloric content and can be applied to pro-long the shelf life of fruits, vegetables, shellfish or meat products by significantly reducing dehydration, darkening of the surface and oxidative rancidity (Hassan *et al.,* 2018).

Cellulose and derivatives - Cellulose is the most abundant natural biopolymer on earth. It is composed of D-glucose units through β-1,4 glycosidic bonds, and is insoluble in water in its native form. The water solubility of cellulose can be improved by alkali treatment to swell the structure, followed by reaction with chloroacetic acid, methyl chloride, or propylene oxide to yield carboxy methyl cellulose (CMC), methyl cellulose (MC), hydroxyl propyl methyl cellulose (HPMC), or hydroxypropyl cellulose (HPC) (Lin and Zhao, 2007).

Chitosan and derivatives - Chitosan, one of a few natural cationic polysaccharides, is the N-deacetylated derivative of chitin. Chitin exists in three morphologically distinct forms as α, β, and γ. α-Chitin is mainly sourced from shrimp, crab, and krill shells, β-chitin is sourced from squid pens, and γ-chitin is usually derived from fungi and yeast. Chitosan-based coatings and films have selective permeability to O_2 and CO_2, and good mechanical properties, but high water vapour permeability (Elsabee and Abdou, 2013).

Pectin - Pectin, a complex group of structural polysaccharides found in plants, is mainly composed of Dgalacturonic acid polymers with varying degrees of methyl esterification (Deng and Zhao, 2011).

Protein based biodegradable films

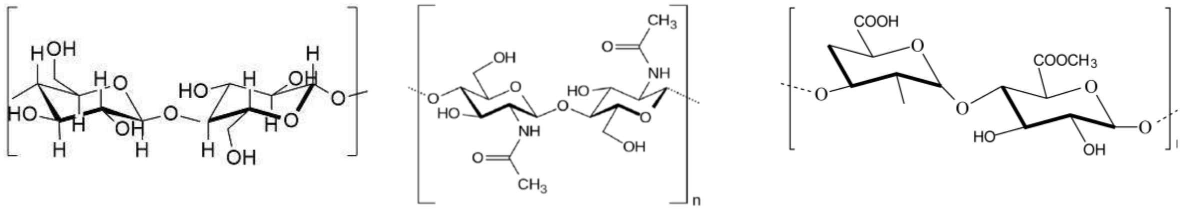
Protein-based edible films are generally formed from solutions or dispersions of the protein as the solvent/carrier evaporates. The solvent/carrier is generally limited to water, ethanol or ethanol-water mixtures.

Generally, proteins must be denatured by heat, acid, bases, and/or solvents in order to form the more extended structures that are required for film formation.

Proteins of both plant and animal origin can form coatings and films with good mechanical properties and O_2 and CO_2 barrier functionality, particularly at low relative humidity. Corn zein coatings and films possess a good oxygen barrier and relatively good water barrier properties.

However, plasticizers are required to improve the extensibility of the films. Soy protein as soy protein concentrate (SPC, 70% protein) or soy protein isolate (SPI, 90% protein) have been made into coatings and films with potent oxygen barrier but poor moisture barrier properties due to the inherent hydrophilicity of the proteins.

Wheat gluten protein is soluble in aqueous alcohol, but alkaline or acidic conditions are required for the formation of homogeneous coatings or films. These coatings and films have high water permeability due to their hydrophilic nature but are good barriers to O_2 and CO_2 (Baldwin, 2007).



Cellulose Chitosan Pectin

Fig. 1: Chemical structure of carbohydrate based biodegradable films

Collagen is used to make the most commercially successful edible protein films. It is biocompatible and non-toxic to most tissues and has well-documented structural, physical, chemical and immunological properties.

Collagen can be processed into a variety of forms; and it is readily isolated and purified in large quantities. Gelatin is unique among hydrocolloids in forming a thermo-reversible substance with a melting point close to body temperature, which is particularly significant in edible and pharmaceutical applications. It can form flexible, clear, strong and oxygen permeable films by formation of ionic crosslinks between amino and carboxyl groups of amino acid side chains, when dissolved in aqueous solutions, (Nur Hanani *et al.,* 2014).

Caseinates films are made from aqueous solutions without heat treatment due to their random coil nature. Interactions in the film matrix are likely to include hydrophobic, ionic, and hydrogen bonding (Avena-Bustillos and Krochta, 1993).

Lipid-based Biodegradable Films

Lipid based coatings and films are very effective moisture barriers due to their hydrophobic character, and are used primarily to inhibit moisture loss from foods and to improve consumer appeal by adding a glossy finish to the treated products.

Most fatty acids, such as capric, lauric, myristic, oleic, palmitic, and stearic acids, that are derived from vegetable oils are considered GRAS, and are commonly used with glycerides as emulsifiers in the preparation of edible coatings and films (Baldwin, 2007).

Resin (e.g. shellac and terpene resin) based coatings generally have lower permeability to O_2, CO_2 and ethylene gas, and moderate permeability to water vapour. Coatings incorporated with lipids are generally a good solution owing to their stability.

However, they can also negatively affect the sensory parameters leading a waxy sensation (Galus and Kadzinœka, 2015).

Lipid-based coatings and films provide a good moisture barrier, but poor mechanical properties, poor adherence, a greasy surface, waxy taste and lipid rancidity may occur. Lipids are usually applied in combination with polysaccharides or proteins to form composite coatings and films for taking advantage of the special functional characteristics of each component (Furkan *et al.,* 2017).

Advancement in Biodegradable Films

The combination between polymers to form films could be from proteins and carbohydrates, proteins and lipids, carbohydrates and lipids or synthetic polymers and natural polymers.

The main objective of producing composite films is to improve the permeability or mechanical properties as dictated by the need of a specific application (Bourtoom, 2008).

Various materials can be incorporated into protein films to influence the mechanical, protective, sensory, or nutritional properties. Plasticizers are additives that are an important class of low molecular weight non-volatile compounds that are widely used in polymer industries. The primary role of such substances is to improve the flexibility and capacity for processing of polymers by lowering the second order transition temperature, the glass transition temperature (Tg) (Wittaya, 2013).

Edible coatings and films can provide multiple functions for meat and meat product packaging. There is increased interest in the development and usage of antimicrobial edible coatings and films to preserve meat quality for longer shelf life and improved food safety.

Antimicrobial agents commonly incorporated into edible coatings and films for meat and meat products include organic acids (lactate and acetate, malic acid, propionate, and p-aminobenzoic acid), essential oils and plant extracts (lemongrass, oregano, pimento, thyme, or cinnamon), bacteriocins (nisin, pediocin), enzymes (lysozyme), chitosan and lauric arginate (Sung *et al.,* 2013).

Baranenko *et al.* (2013) developed chitosan coatings with gelatin, distarch glycerol, wheat fibre, sodium alginate, or guar gum in various ratios and applied them to the surfaces of retail cuts of veal and rabbit meat, boiled sausages, smoked sausages and smoked-boiled pork brisket stored at 4±1°C. All coatings reduced the total viable counts of microorganisms compared to uncoated samples. Coatings based on 2% chitosan and 2% gelatin solution in a ratio of 1:1 showed the strongest bacteriostatic effect against *B. subtilis, S. aureus* and *E. coli*. Combined application of vacuum and protective coatings provided the strongest suppression effect in all samples.

Nano composites (NCPs) are novel polymers formed by extruding blends of polysaccharides, proteins and/or lipids or by laminating two or more edible films or by emulsion formation, which have essentially been incorporated with nanoparticles. The microstructure of composites consists of a continuous phase and a discontinuous phase or filler (Matthews and Rawlings, 1994).

The continuous phase or matrix is formed by the polymer while the discontinuous phase or filler may be the active components like antioxidants or antimicrobials or metals or ions. In nano-composites the filler material/nano-components or materials have at least one dimension smaller than 100 nm (Neethirajan and Jayas, 2011).

Nanotechnology has been used to generate new products with desirable characteristics such as enhanced shelf-life, delayed spoilage and protection from food-borne pathogens (Ozcalik and Tihminlioglu, 2013).

Challenges and Opportunities

Biodegradable packaging is not the answer to all plastic packaging solutions. Cellulose derivative films are poor water vapor barriers because of the inherent hydrophilic nature of polysaccharides and they possess poor mechanical properties. One method of enhancing the moisture barrier would be by incorporation of hydrophobic compounds such as fatty acids into the cellulose ether matrix to develop a composite film like hydroxypropyl methylcellulose (HPMC) (Dhanapal *et al.,* 2012).

However, again there are difficulties in preparing a homogenous composite film with both hydrophobic and hydrophilic compounds. Chitosan was the second most abundant natural and nontoxic polymer in nature after cellulose and form translucent films to enhance the quality and extend the storage life of food products (Ribeiro *et al.,* 2007).

However, chitosan products are highly viscous, cohesive and compact and the film surface has a smooth contour without pores or cracks. The poor electrical conductivity of hydrogen results in a poor response time and a high operating voltage limits its applicability in chitosan based sensor devices. Hence, composites have been attempted by incorporating a rigid conducting polymer (such as PANI) into a flexible matrix (such as chitosan) to combine the good possibility of the matrix and the electrical conductivity of the conductive polymer (Xu et al., 2006).

The amount of energy used to actually process these materials has also been questioned in regards to how environmentally-friendly the technology is. While nanotechnology could improve the material's performance characteristics, the jury is still out as to whether it is actually biodegradable. Compostable materials refer to those that can degrade in a natural environment and is the most environmentally-friendly package to date.

However, the materials are yet to be produced at processing speeds sufficient for large quantities. Biodegradable products have been available for quite some time but usually at a much higher cost or reduced performance characteristics when measuring moisture or oxygen barrier properties, or even temperature resistance.

Conclusion

Natural polymers are an alternative source for packaging development due to their precise taste and biodegradability. Biodegradable edible polymers have appeared as a substitute for synthetic plastic for food applications and have received significant attention in recent years because of their advantages over synthetic polymer.

Nowadays, nanotechnologies are being used to enhance the nutritional features of muscle foods by means of nanoscale additives and nutrients and nanosized delivery systems for bioactive polymeric compounds. Micro- and nanoencapsulation of active compounds with edible polymer coatings may help to control their release under specific conditions, thus protecting them from moisture, heat, or other extreme conditions and enhancing their stability and viability.

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