Biobased Packaging - Application in Meat Industry

S. Wilfred Ruban

Department of Livestock Products Technology
Veterinary College, Hebbal, Bangalore-24

Abstract

Because of growing problems of waste disposal and because petroleum is a nonrenewable resource with diminishing quantities, renewed interest in packaging research is underway to develop and promote the use of “bio-plastics.” In general, compared to conventional plastics derived from petroleum, bio-based polymers have more diverse stereochemistry and architecture of side chains which enable research scientists a greater number of opportunities to customize the properties of the final packaging material. The primary challenge facing the food (Meat) industry in producing bio-plastic packaging, currently, is to match the durability of the packaging with product shelf-life. Notable advances in biopolymer production, consumer demand for more environmentally-friendly packaging, and technologies that allow packaging to do more than just encompass the food are driving new and novel research and developments in the area of packaging for muscle foods.

Keywords: Meat, Industry, Environmental, Product, Packaging, Shelf life, Bio-plastic.

Introduction

The purpose of food packaging is to preserve the quality and safety of the food it contains from the time of manufacture to the time it is used by the consumer. An equally important function of packaging is to protect the product from physical, chemical, or biological damage (Dallyn & Shorten, 1998). The most well-known packaging materials that meet these criteria are polyethylene- or co-polymer based materials, which have been in use by the food industry for over 50 years. These materials are not only safe, inexpensive, versatile, but also flexible (Tice, 2003). Within the plastic packaging market, food packaging is the largest growing sector (Comstock et al., 2004). However, one of the limitations with plastic food packaging materials is that it is meant to be discarded, with very little being recycled. The presence of these types of packaging materials in landfills can be problematic on many fronts. First, if plastic is not recycled, these items end up in land- fills, where they can last forever and never degrade. Secondly, many countries are faced with a decrease in landfill space, especially in densely populated areas. So, finding landfills for consumer and industrial waste may become more difficult in the future (Comstock et al., 2004).

Another factor to consider is the dependence on petroleum products in the production of plastic packaging materials. With rising petroleum costs, there is concern with finding cost-effective ways to manufacture packaging materials. In addition to the above environmental issues, food packaging has been impacted by notable changes in food distribution, including globalization of the food supply, consumer trends for more fresh and convenient foods, as well a desire for safer and better quality foods. Given these and previously mentioned issues, consumers are demanding that food packaging materials be more natural, disposable, potentially biodegradable, as well as recyclable (Lopez-Rubio et al., 2004).

To meet the growing demand of recyclable or natural packaging materials and consumer demands for safer and better quality foods, new and novel food-grade packaging materials or technologies have been and continue to be developed. Examples of these packaging materials include bio-based polymers, bioplastic or biopolymer packaging products made from raw materials originating from agricultural or marine sources (Cha & Chinnan, 2004). These types of packaging materials include, starch, cellulose, chitosan/chitin, protein (animal, plant-based), or lipids (animal, plant-derived, etc.). Within this context of packaging, edible films, gels or coatings may be considered biopolymers with some biodegradable properties. Another example of a biopolymer is polylactic acid (PLA). Other biopolymers have been made from marine prokaryotes, chemical synthesis, as well as from by-products of other microorganisms (ie., fungal exopolysaccharides). This review will address the implementation of biopolymers (i.e. edible gels, films, or coatings), bio-based plastic packaging materials to improve the quality and/or safety of fresh or further processed meat and poultry products.

Bio-based polymers or biopolymers

"Biobased food packaging materials or biopolymers are materials derived from renewable sources. These materials can be used for food applications". (Comstock et al., 2004; Weber et al., 2002). Biobased polymers may be divided into three main categories based on their origin and production: **Category 1:** Polymers directly extracted/removed from biomass. Examples are polysaccharides such as starch and cellulose, chitosan/chitin and proteins like casein and gluten. **Category 2:** Polymers produced by classical chemical synthesis using renewable biobased monomers. A good example is polylactic acid (Kandemir et al., 2005), a biopolyester polymerised from lactic acid monomers. **Category 3**: Polymers produced by microorganisms or genetically modified bacteria. To date, this group of biobased polymers consists mainly of the polyhydroxyalkonoates, but developments with bacterial cellulose are in progress. (Cutter & Sumner, 2002a).

Researchers also have further categorized biopolymers based on the ability to be compostable or biodegradable (Comstock et al., 2004). It is important to note that while some bio-based packaging materials may be biodegradable, not all biodegradable materials are bio-based (Weber et al., 2002). Recent technological advances also have allowed biopolymers to be processed similarly to petroleum-based plastics, whether in sheets, by extrusion, spinning, injection molding, or thermoforming (Comstock et al., 2004).

A. Polysaccharide Films:

Polysaccharide films are made from starch, alginate, cellulose ethers, chitosan, carageenan, or pectins and impart hardness, crispness, compactness, thickening quality, viscosity, adhesiveness, and gel-forming ability to a variety of films. These films because of the make up of the polymer chains exhibit excellent gas permeability properties, resulting in desirable modified atmospheres that enhance the shelf life of the product without creating anaerobic conditions (Baldwin et al., 1995). Additionally, polysaccharide films and coatings can be used to extend the shelf-life of muscle foods by preventing dehydration, oxidative rancidity, and surface browning, but their hydrophilic nature makes them poor barriers for water vapor (Nisperos-Carriedo, 1994).

a) Starch: Starch, composed of amylose and amylopectin, is primarily derived from cereal grains, potatoes, or tapioca. Starch-based films exhibit physical characteristics similar to plastic films in that they can be odorless, tasteless, colorless, non-toxic, biologically absorbable, semi-permeable to carbon dioxide, and resistant to passage of oxygen. High amylose starch films have been made that are flexible, oxygen impermeable, oil resistant, heat-sealable, and water soluble. Since the water activity (aw) is critical for microbial, chemical, and enzymatic activities, edible starch based films can retard microbial growth by lowering the a_w within the package, thereby reducing drip loss of meat products and binding water that otherwise would be available for microbial growth (Wong et al., 1994).

b) Alginate: Alginates are derived from seaweed, and possess good film-forming properties that make them particularly useful in food applications (Nisperos-Carriedo, 1994). Divalent cations (calcium, magnesium, manganese, aluminum, or iron) are used as gelling agents in alginate film formation. Desirable properties attributed to alginate films, include moisture retention, reduction in shrink, improved product texture, juiciness, color, and odor of treated muscle foods.

c) Carrageenan: Carrageenan is a complex mixture of several polysaccharides. To date, there are only a limited number of studies addressing the use of carrageenan with muscle foods. Carrageenan-based coatings have been used to prolong the shelf life of a variety of muscle foods including poultry and fish. Additional studies have demonstrated that antioxidants, such as gallic or ascorbic acids or lecithin, salt or antibiotics, can be added to the coatings to improve the quality and microbiological stability of muscle foods.

d) Cellulose ethers: Cellulose is a non-digestible component of plant cell walls. In the manufacture of edible films, cellulose-based films tend to be water soluble, resistant to fats and oils, tough, and flexible. Cellulose based films applied to muscle foods can reduce oil uptake during frying, minimize run-off during cooking, and reduce moisture loss when applied as glazes for poultry and seafood (Cutter & Sumner, 2002). Cellulose based films have been commonly used to provide mechanical, oxygen barrier, and oil barrier properties for foods such as pizza and ice cream cones, where as very little information exists for application to fresh or further processed muscle foods (Gennadios et al., 1997). Cellulose casings also are widely used by the meat industry in the manufacture of ready-to-eat meat and poultry products, including frankfurters, sausages, bologna, and other small diameter meat products subject to thermal processing.

e) Pectin: Pectins are a group of plant-derived polysaccharides that appear to work well with low-moisture foods, but are poor moisture barriers (Baldwin et al., 1997). Currently, very little information exists to the application of pectin-based edible films on muscle foods.

f) Agar: Another seaweed-derived polysaccharide is agar. Used extensively in microbiological media to provide firmness, agar exhibits characteristics that make it useful for coating meats. It forms strong gels characterized by melting points far above the initial gelation temperature (Whistler & Daniel, 1985 and Natrajan & Sheldon, 2000a).

g) Chitin/Chitosan: Chitosan is an edible and biodegradable polymer derived from chitin, the major organic skeletal substance in the exoskeleton of arthropods, including insects, crustaceans, and some fungi. Next to cellulose, Chitosan is the most abundant natural polymer available. Some desirable properties of chitosan are that it forms films without the addition of additives, exhibits good oxygen and carbon dioxide permeability, as well as excellent mechanical properties and antimicrobial activity against bacteria yeasts, and molds (Vartiainen et al., 2004). However, one disadvantage with chitosan is its high sensitivity to moisture.

B. Lipid Films

Larding, or enrobing muscle foods with fats, has been performed primarily to reduce shrinkage of the food product, as well as to provide oxygen or moisture barriers. Waxes and other types of fat-based oils also have been added to protein- or polysaccharide-based films to impart flexibility, to improve coating characteristics, or to prevent sticking during cooking. Edible lipid or resin coatings can be prepared from waxes (e.g., carnauba, beeswax, and paraffin), oils (vegetable, animal, and mineral), and surfactants. There are a number of advantages for coating foods with lipids. Lipids not only impart hydrophobicity, cohesiveness, and flexibility, but they also make excellent moisture barriers due to the tightly packed crystalline structure of lipids that naturally restricts the passage of water vapor molecules. Despite these advantages, lipid-based films at higher storage temperatures may exhibit lower permeability to gases such as oxygen, carbon dioxide, and ethylene, leading to potentially anaerobic conditions which may present food safety issues, as well as lack structural integrity, and poor adherence to hydrophilic surfaces. Lipid-based films are vulnerable to oxidation, racking, flaking, retention of off-flavors, as well as bitter aftertastes (Ben & Kurth, 1995).

C. Protein Films

Casein, whey protein, gelatin/collagen, fibrinogen, soy protein, wheat gluten, corn zein, and egg albumen have been processed into edible films (Ben & Kurth, 1995). Protein-based films adhere well to hydrophilic surfaces, provide barriers for oxygen and carbon dioxide, but do not resist water diffusion. Casein and whey are the two common milk proteins that have been used in the manufacture of edible films. These proteins are desirable as components of these films because of their nutritional value, excellent mechanical and barrier properties, solubility in water, ability to act as emulsifiers, and because of their industrial surplus. While a considerable amount of research has been conducted with films made from milk proteins on fruits and vegetables and other dairy foods, there are limited studies addressing the application of these films on muscle foods. Despite the advantages to using proteins in film formation, research has indicated that enzymes associated with muscle foods can degrade protein films. Additionally, the application of protein films to muscle foods may present health problems, especially for individuals with food allergies associated with milk, egg, peanut, soybean, or rice proteins (Cutter & Sumner, 2002).

Gelatin/collagen: Edible films also may serve as gas and solute barriers, thereby improving the quality and shelf life of muscle foods. Gelatin films have been used as a delivery system for applying antioxidants to poultry or applied directly to poultry meat surfaces or processed meats to prevent microbial growth, salt rust, grease bleeding, handling abuse, water transfer, moisture loss, and oil adsorption during frying. Despite these successes, gelatin lacks strength and requires a drying step to form more durable films. Currently, the meat industry currently uses collagen films during the processing of meat products. When heated, intact collagen films can form a "skin" or edible film that becomes an integral part of the meat product (Cutter & Miller, 2004). These commercially available collagen films have been purported to reduce shrink loss, increase permeability of smoke to the meat product, increase juiciness, allow for easy removal of nets after cooking or smoking, and absorb fluid exudates.

D. Composite Films

When it comes to improvements in edible film technologies, most research has addressed film formulations using various combinations of edible materials. Two or more materials can be combined to improve gas exchange, adherence to coated products, or moisture vapor permeability properties. Composite films consisting of lipids and a mixture of proteins or polysaccharides take advantage of the individual component properties. In doing so, these individual or combined films can be applied as emulsions or bilayer films. Additionally, plasticizers can be used to modify film mechanical properties, thereby imparting resulting film. Example- a combination of vegetable oils, glycerin, citric acid, and antioxidants prevented rancidity by acting as a moisture barrier, restricting oxygen transport, and serving as a carrier for antioxidants to various foods (Baldwin et al., 1997). If these types of films are to be considered as alternatives to plastic packaging, future research should determine the edible resulting film. Example- a combination of vegetable oils, glycerin, citric acid, and antioxidants prevented rancidity by acting as a moisture barrier, restricting oxygen transport, and serving as a carrier for antioxidants to various foods (Baldwin et al., 1997). If these types of films are to be considered as alternatives to plastic packaging, future research should determine the edible nature of these composite films and overall consumer acceptability.

E. Poly lactic Acid Films

Polylactic acid (PLA) is a biodegradable polymer derived from fermentation of starch and condensation of lactic acid. It is a highly versatile material and is made from 100% renewable resources like corn, sugar beets, wheat and other starch-rich products (Krishnamurthy et al., 2004). In addition to its strength, biodegradability, and compostability, PLA polymers also are resistant to oil-based products, are sealable at lower temperatures, and can act as flavor or odor barriers for foodstuffs. Currently, very little research exists to address the application of PLA to improve the quality of muscle foods. It is a material that is creating a lot of interest in the packaging industry for its outstanding properties and earth-friendly biodegradability.

Conclusion

Consumer demands are driving research and development for alternatives to petroleum-based packaging materials including those with recyclable or edible properties, as well as those materials made from renewable/sustainable agricultural products. Biopolymers when applied to muscle foods with other food grade compounds (i.e. chelators, antimicrobials, anti-oxidants), bio-based, edible, or biopolymer packaging cannot only enhance the quality or safety of the food, but slow deterioration, extend the shelf life, and in some cases, impart desirable characteristics (color, flavor, etc.) to the food. However, as with all new or novel packaging developments destined for consumers, cost, organoleptic, consumer preference, toxicological, safety, and regulatory considerations must be addressed if these types of technologies are to be adopted and implemented by the muscle foods industry (Cutter, 2002b).

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