Available online at www.sciencedirect.com
SCIENCE DIRECT®
Meat Science 74 (2006) 131–142
MEAT SCIENCE
www.elsevier.com/locate/meatsci

Opportunities for bio-based packaging technologies to improve the quality and safety of fresh and further processed muscle foods

Catherine Nettles Cutter *

Department of Food Science, 111 Borland Laboratory, Pennsylvania State University; University Park, PA 16802, United States

Received 28 March 2006; received in revised form 27 April 2006; accepted 28 April 2006

Abstract

It has been well documented that vacuum or modified atmosphere packaging materials, made from polyethylene- or other plastic-based materials, have been found to improve the stability and safety of raw or further processed muscle foods. However, recent research developments have demonstrated the feasibility, utilization, and commercial application of a variety of bio-based polymers or bio-polymers made from a variety of materials, including renewable/sustainable agricultural commodities, and applied to muscle foods. A variety of these bio-based materials have been shown to prevent moisture loss, drip, reduce lipid oxidation and improve flavor attributes, as well as enhancing the handling properties, color retention, and microbial stability of foods. With consumers demanding more environmentally friendly packaging and a desire for more natural products, bio-based films or bio-polymers will continue to play an important role in the food industry by improving the quality of many products, including fresh or further processed muscle foods.

Keywords: Packaging; Edible; Bio-based polymers; Biopolymers; Muscle foods

1. 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 (Dallyn & Shorten, 1998). 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). Global production of packaging materials are estimated at more than 180 million tons per year, with growth and demand increasing annually (Tice, 2003). Within the plastic packaging market, food packaging is the largest growing sector (Comstock, Farrell, Godwin, & Xi, 2004). It is estimated that of the $100 billion packaging market in the United States, 70% is attributed to beverage and food production (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 (Comstock et al., 2004). In fact, during the 1990s less than 10% of all plastic packaging materials (not including bottles) was recycled by consumers (Comstock et al., 2004). 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 landfills, where they can last forever and never degrade. Secondly, many countries are faced with a decrease in landfill space, especially in densely populated areas (Comstock et al., 2004). Thirdly, existing landfills may be unable to meet new regulatory guidelines set forth by the US Environmental Protection Agency, and may end up closing (Environmental Protection Agency, 2006). So, finding landfills for consumer and industrial waste may become more difficult in the future (Comstock et al., 2004).

* Tel.: +1 814 865 8862; fax: +1 814 863 6132.
E-mail address: cnc3@psu.edu.

0309-1740/$ - see front matter © 2006 Elsevier Ltd. All rights reserved.
doi:10.1016/j.meatsci.2006.04.023

Another factor to consider is the reliance 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. Weber, Haugaard, Festersen, and Bertelsen (2002) state that "polymers and materials used for food-packaging today consist of a variety of petroleum-derived plastic materials, metals, glass, paper and board, or combinations hereof. With the exception of paper and board, all of these packaging materials are actually based on non-renewable materials, implying that at some point, more alternative packaging materials based on renewable resources have to be found". The authors also point out that "naturally-derived resources" are becoming more essential in the production of these industrial products, and that bio-based packaging materials are beginning to replace petroleum-based packaging materials in the food industry (Weber et al., 2002).

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, but are not limited to 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) (Cha & Chinnan, 2004).

In addition to the development of packaging materials from these polymers, researchers are employing various types of packaging materials to be active, intelligent, or interactive. Such food packaging systems have been developed for a variety of chemical (chelators, antioxidants, flavors, essential oils, etc.) or antimicrobial compounds (bacteriocins, organic acids, lysozyme, etc.); gas (i.e. ethylene, carbon dioxide, oxygen, nitrogen, etc.) scavengers or emitters; humidity absorbers or controllers; aroma absorbers or emitters; or active enzyme systems (Lopez-Rubio et al., 2004). When applied, research has demonstrated that packaging can enhance the quality or safety of the food, slow deterioration, and impart desirable characteristics to the food.

Given the wealth of information in the field of food packaging as well as notable and recent developments in the area of active, interactive, and intelligent packaging systems, this review will address the implementation of biopolymers (i.e. edible gels, films, or coatings), bio-based plastic packaging materials, as well as the incorporation of antimicrobials into these packaging materials to improve the quality and/or safety of fresh or further processed meat and poultry products.

2. Bio-based polymers or biopolymers

Typically, bio-based polymers or biopolymers are developed from renewable resources (Comstock et al., 2004; Weber et al., 2002; Fig. 1). Examples of renewable resources used in the manufacture of these types of polymers include polysaccharides (i.e. starch, alginates, pectin, carrageenans, chitosan/chitin), proteins (casein, whey, collagen, gelatin, corn, soy, wheat, etc.), and lipids (fats, waxes, or oils, etc.; Comstock et al., 2004; Cutter & Sumner, 2002). Polymers, such as polylactate (PLA) or polyesters, also may be synthesized from biologically-derived monomers, while microorganisms also can produce polymers such as cellulose, xanthan, curlan, or pullulan (Comstock et al., 2004; Kandemir et al., 2005). 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). 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.

3. Edible gels, films and coatings

In the last 50 years, considerable research has been conducted to develop and apply bio-based polymers made from a variety of agricultural commodities and/or wastes to food products. Edible coatings and films made from a number of these commodities have been developed that offer a variety of advantages to fresh and further processed meats and poultry such as edibility, biocompatibility, aesthetic appearance, and barrier properties (Han, 2000, 2002). Because edible films are considered a packaging as well as a food component, they should fulfill a number of requirements, such as: good sensory qualities; high barrier and mechanical efficiencies; biochemical, physico-chemical, and microbial stability, non-toxic, simple, non-polluting,