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Recent Trends in Poultry Packaging: A Review

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INTRODUCTION

Packaging is a scientific method of containing food products against physical, chemical, or biological damage (Dallyn and Shorten, 1998) and also to display the product in the most attractive manner for consumer preference. Packaging of poultry meat and poultry based meat products has always been challenging because of their perishable nature due to high sensitivity to spoilage and pathogenic microorganisms (Yavas and Bilgin, 2010). Supermarkets and consumers ask for long shelf life as well as a good quality throughout the entire shelf life period (Balev *et al.*, 2011) and the predominant reason for meat shelf life is microbial spoilage activity (Koch *et al.*, 2009). Thus, packaging constitutes an important department of a food processing industry today and many meat-packaging systems are available with different attributes and applications. These systems range from overwrap packaging for short-term chilled storage and retail display to 100% carbon dioxide atmosphere packaging for long-term chilled storage (Payne *et al.*, 1998). Modern food packaging performs beyond the conventional protection properties and serves much more functions for the product contained (Han, 2005). In order to extend shelf life, preservation technologies like vacuum packaging or modified atmosphere packaging are being increasingly applied for distribution and retail sale of meat and meat products (Sang *et al.*, 2010). Furthermore, there have been remarkable developments in recent years in the polymeric and edible packaging films incorporated with antimicrobial agents for improving the preservation of packaged foods (Cha *et al.*, 2002; Janes *et al.*, 2002; Mecitoglu *et al.*, 2006). These films possess the potential for improving microbial stability of foods by acting on the food surface, upon contact (Hosseini *et al.*, 2008).

The need for packaging can be linked to the progress of civilization and need to preserve perishables for longer period of time. The purpose of meat packaging is to preserve the quality and safety of the meat or meat product it contains from the time of manufacture to the time it is used by the consumer. Besides protecting the product, it should also enhance the marketability of the product and be environment friendly (Hurme *et al.*, 2002). The ability to convince a potential buyer to use a given product has always been influenced by product packaging and has become an important marketing tool for communicating brand values. Packaging of poultry is done for both aesthetic and utilitarian purposes. Plastic films are materials of choice for the majority of meat products. The choice of films for packaging is largely determined by their moisture and gas permeability. Most of the films used are moisture barriers in order to avoid weight loss from the meat. Gas permeability is much more variable and is specific to individual polymers.

The functions of a food system can be divided into four areas: containment, information, convenience and protection (Barron, 1995). Containment includes the holding of a product without necessarily protecting it. Information is both a governmental regulation and marketing tool. Convenience is a function of the package. Single-serving sizes of sliced meat and microwaveable packages allow for cooking/reheating and consumption of the product in a part of the package. Protection is the most important function of package, protecting the product from microorganisms, rodents, dust, external contaminants, humidity, light and oxygen.

Packaging techniques: There are many packaging systems and the choice of which to use will depend on many factors including cost, the volume of product being handled and presentation. Modern meat packaging technologies include vacuum packaging, modified atmosphere packaging, controlled atmosphere packaging, active packaging, smart packaging, etc., which strive to enhance the food safety and quality in as natural way as possible. Some of the recent methods used in poultry industry are:

Vacuum packaging: Vacuum packaging refers to packaging in containers (rigid or flexible), from which substantially all air has been removed prior to final sealing of container. This method of packaging is actually a form of “modified atmosphere” since normal air is removed from the package.

Gas packaging: Gas packaging can be defined as the alteration of the proportional volumes of the gases which comprise a normal atmosphere. This type of packaging generally falls into two categories:

Modified atmosphere packaging: Refers to enclosing a product in some type of barrier and modifying the atmosphere either by drawing a vacuum or filling with a gas mix. During storage the level of these gases will change due to respiration of the product and permeability of the film. The application of modified atmosphere packaging to meat and meat products has grown greatly in recent years (Rajkumar *et al*., 2007; Sang *et al*., 2010; Yavas and Bilgin, 2010), but optimization of gas composition is critical to ensure both product quality and safety (Moller *et al*., 2000). Because of its antimicrobial activity, CO_2 is most important component in the normally applied gas mixtures (Farber, 1991) and N_2 is used as filler (Sorheim *et al*., 1999). The important advancement in packaging technique to satisfy the consumers need is application of modified atmosphere packaging (Rajkumar *et al*., 2007). Modified atmosphere packaged foods have become increasingly more available, as food manufacturers have attempted to meet consumer demands for fresh refrigerated foods with extended shelf life. The principle of modified atmosphere packaging is the replacement of air in the package with a different fixed gas mixture and once it is introduced, no further control of the gas composition is performed and the composition will inevitably change (Silvertsvik *et al*., 2002).

Controlled atmosphere packaging: Refers to a controlled system where by gases are added or removed to maintain a desired balance. In this case the bulk bin or the storage vessel is virtually impermeable.

Vacuum packaging and Modified-Atmosphere Packaging (MAP) has been used to extend the shelf life of packaged poultry fresh meat for several decades. Several MAP packaging systems for fresh poultry meat exist, including flexible trays with vacuum or gas flush and master/bulk packaging overwrap for vacuuming or gas-flush multiple packages (Lawlis and Fuller, 1990). The shelf life extension realized with vacuum packaging is largely due to the buildup of carbon dioxide in the small amount of air space remaining in a vacuum package. The term vacuum package is misleading in that there is no vacuum created inside the package but rather a partial vacuum is used by the packaging machine to highly restrict the air space in the package. The result is a minimum package headspace with most of the residual air in the package being dissolved in the meat aqueous phase. The aqueous phase of the fresh poultry is the majority of the meat (65-75%). When vacuum packaged fresh meat is held for several days, the CO_2 concentration in the residual air space reaches 20-70%, with oxygen concentration becoming less then 1%, which results in a shelf life extension of 3 to 5 times that of aerobically packaged refrigerated meat.

The three most common gases used in MAP are CO_2, oxygen and nitrogen. The general function of each gas is maintenance of fresh colour (oxygen), inhibition of bacterial growth (CO_2) and reduction of purge (nitrogen). CO_2 content is critical in MAP to control the growth of aerobic spoilage bacteria and will slow bacterial growth rate at concentrations above those found in air (<1%). The inhibitory effect of CO_2 on bacteria is theorized to be due to two main effects i.e. modification of cell membranes and inhibition of bacterial enzymes. Haines (1933) was the first to show an inhibitory effect of CO_2 on aerobic spoilage bacteria. Barnes *et al.* (1979) found that vacuum packaged, chill stored poultry lead to the growth of mainly lactic acid bacteria and, in some cases, cold-tolerant coliforms. The use of CO_2-enriched atmospheres for chilled poultry is based on early work of Ogilvy and Ayres (1951). They found that the ratio of poultry meat shelf life in CO_2 to the shelf life in air could be expressed as a linear function with CO_2 concentration. A minimum concentration of 20% in the package headspace is required to see a significant effect on shelf life (Shaw, 1995; Greengrass, 1993). The growth of pathogens on fresh chicken was inhibited by increasing the concentration of CO_2 with storage at 1.1°C; however, the lactic acid bacteria present were not inhibited due to their facultative anaerobic abilities (Sanders and Soo, 1978). Thomson (1970) also reported that a high CO_2 atmosphere inhibited the growth the growth of bacteria on poultry compared to chicken packed with ambient air. Fresh ground or skinless poultry meat is packaged in a high-oxygen atmosphere (70 to 80%), with the balance of atmosphere being CO_2 to maintain colour yet limit the growth of spoilage bacteria. A refrigerated shelf life of 14 days is attainable using this system (Lawlis and Fuller, 1990) and slightly longer if accompanied by deep chilling.

Rajkumar *et al.* (2007) studied the effect of modified atmosphere (80% oxygen + 20% carbon dioxide) packaging, vacuum packaging and aerobic packaging on the quality characteristics of fresh and stored turkey meat at 4±1°C. The microbial counts were lowest under modified atmosphere packaging and meat kept well up to twenty-one days of storage under modified atmosphere and vacuum packaged conditions but based on the odour score meat packed under vacuum revealed to be better. It was concluded that turkey meat packed under modified atmosphere kept safely up to 14 days at 4±1°C whereas meat packed under vacuum could be safely kept up to 21 days of storage. Yavas and Bilgin (2010) studied the effect of some preservatives on the quality characteristics of

Table 1: Typical MAP combinations showing bulk storage life

Bulk MAP product	Packaging	Gas Mix	Temp. (°C)	Life (Max. days)
Whole chicken	5L PA/PE	100% CO_2	-2 to 0	20-25
Whole turkey	5L PA/PE	100% CO_2	0 to 2	14-20
Poultry portions	5LPA/PE	100% CO_2	-2 to 0	10-14

Table 2: Reported gas compositions of processed meat products

Gas percentage	O_2	CO_2	N_2
Chicken, cooked	<0.2	30	70
Chicken, thighs, breaded, baked	-	30	70
Chicken breaded flash fried	-	-	100
Poultry products	-	25	75
Turkey, cooked	<0.2	30	70

chicken nuggets under modified atmosphere packaging and reported enhanced shelf life and quality parameters. Table 1 shows some MAP combinations showing bulk storage life (Down, 1996) and Table 2 shows some gas compositions of processed meat products (Church, 1993).

Active and intelligent packaging: Active packaging is a modern development consisting of a group of techniques in which the package is self motivated and is actively involved with food products or act together with internal atmosphere to extend the shelf life while maintaining quality and safety (Rathore *et al*., 2010). Active packaging is sometimes referred to as interactive or smart packaging which is planned to sense internal or external environmental changes and to take action by changing its own properties or attributes. Potential techniques used in active packaging are use of oxygen scavenging/carbon dioxide, ethylene and moisture absorbing systems by placing sachets, incorporation of antimicrobial agents into polymer surface coatings or in plastic films, sheets or on materials and into the pads for fresh produce (John, 2008).

An active or intelligent packaging thus, has an additional, desired role that improves the quality of the food product as a supplement to pure packaging properties. These properties can either be integrated in the packaging material or separated from it. Intelligent packaging contains an external or internal indicator for the active product history and quality. It has an inherent ability to gather information on its operating environment or history, to process that information in order to draw intelligent inferences from it and to act on those inferences by changing its characteristics in an advantageous manner. Active packaging has an extra function in addition to that of providing a protective barrier against external influence. It can control and even react to, phenomena taking place inside the package. It actively and constantly changes either package permeation properties or the concentration of various volatiles and gases in the package headspace during storage, or actively adds microbial, antioxidative or other quality improving agents, e.g., flavour enhancing substances, via packaging material into food in small amounts during storage. Examples of active packaging are those that exhibit preferential permeability; temperature compensating attributes; oxygen, carbon dioxide, alcohol, or ethylene scavenging systems; moisture absorbers; antimicrobials incorporated directly into the packaging matrix; controlled release of colourants, flavors, spices, minerals, antimicrobials, ethanol, or antioxidants; or the ability to absorb odors (Labuza and Breene, 1989; Rooney, 1995). Based on their way of functioning, active packaging are categorized into four groups viz scavengers, emitters, indicators and others. The first three types can be evaluated as groups, because of the similarities in the intended function of the product but for other types (e.g., Susceptor materials) of active packaging, an individual evaluation will have to be done from case to case.

Active packaging scavengers: Active packaging scavengers consists of ingredients, which are intended to absorb, remove and then eliminate substances, such as oxygen, ethylene, moisture, or taint from the interior of a food package. The constituents of active packaging material and articles have an effect on the shelf life or the organoleptic properties of the food. The examples are the oxygen scavengers and ethylene scavengers, which are used for eliminating oxygen and ethylene respectively from the package resulting in an extended shelf life of the food. Commercial oxygen scavengers are in most cases based on iron powder, which, in the presence of oxygen, forms iron oxide. Non-metallic and organo-metallic compounds have also been developed.

The use of oxygen scavengers may have merit in selective poultry products and the addition of a scavenger within the package along with a physical barrier package can maintain nearly a 0% oxygen level inside the package. Chemical oxidizing systems such as metaxylene adiamide, plus a cobalt salt catalyst or enzyme-reacting system using glucose oxidase and catalase, can actually remove oxygen from the package environment (Yoshii, 1992). A system exist using mixed iron powder and calcium hydroxide that scavenges both oxygen and carbondioxide (Labuza and Breene, 1989).

Because purge can increase bacterial growth, a moisture absorber placed in the package will slow the growth of bacteria. Absorbent pads placed beneath fresh poultry reduce the buildup of purge in the package. Films with entrapped propylene glycol will absorb moisture from the surface of meat when contacting its surface (Labuza and Breene, 1989) and may increase the shelf life of fresh poultry.

Active packaging indicators: Various indicators viz. indicators for temperature, microbial spoilage, package integrity, physical shock and product authenticity etc can give information on the quality of the food product directly, besides the package and its headspace gases, as well as on the storage conditions of the package. Some indicators do not need to interact with the product or the headspace, while others do. These indicators are often called intelligent packaging and certain concepts are already commercially available and their uses seem to be increasing. New concepts of leak indicators and freshness indicators are patented and it can be expected that new commercially available products will be available in the near future.

Antimicrobial agents: By incorporating antimicrobial agents directly into packaging films, the packaging material can serve as a source of releasing preservatives or antimicrobial agents, or even prevent the growth of microorganisms. Floros *et al*. (1997) reviewed the products and patents in the area of active packaging and identified antimicrobial packaging as one of the most promising versions of an active packaging system. Of the active packaging applications, the incorporation and/or slow release of antimicrobials is receiving considerable attention as a means of extending the bacterial lag phase, slowing the growth rate of microorganisms, prolonging shelf life and maintaining food safety. The general premise of antimicrobial packaging is a controlled migration of the compound to the food through diffusion or partitioning (Han, 2000, 2002), which not only allows for initial inhibition of undesirable microorganisms, but also retains residual activity over time.

Most of the reported work with antimicrobial films and coatings has utilized acids carried in a variety of materials (Torres and Karel, 1985; Vojdani and Torres, 1990; Sirugusa and Dickson, 1992). Sorbic acid has been incorporated into corn zein (Torres and Karel, 1985) and methyl cellulose and hydroxymethyl cellulose as coating to inhibit the bacterial growth on food surfaces (Vojdani and Torres, 1990).

Active packaging emitters: This group of active packaging contains, or produces, substances, which are meant to migrate into the food packaging headspace or into the food in order to obtain a technological effect in the atmosphere in the packaging or in the food itself as e.g., food additives, flavourings or biocides. In these cases, the consumer together with the food ingests the components.

Edible films: To reduce the amount of synthetic polymer waste, considerable research has been conducted to develop and apply bio-based polymers mainly from a variety of agricultural commodities and/or waste of food products. An edible film is a special active part of the food, which is regarded as a foodstuff from a legal point of view, along with the food packed in the film. Such films will have to fulfill same requirements as for food in general. Biodegradability, edibility, biocompatibility, aesthetic appearance and barrier properties are a variety of advantages offered by edible coatings and films (Han, 2000). Recent information suggests that edible gels, films and coatings made from lipid (fats, waxes, or oils), polysaccharide (starch, alginate, cellulose ethers, chitosan, carageenan, or pectin), or protein (casein, whey protein, gelatin/collagen, fibrinogen, soy protein, wheat gluten, corn zein, or egg albumen) components not only enhance the quality of fabricated muscle foods, but also improve the safety of fresh and processed muscle foods by reducing moisture loss, minimizing lipid oxidation, preventing discolouration, reducing drip and controlling levels of spoilage or pathogenic microorganisms (Gennadios *et al.*, 1997). The benefits of using edible films as packaging materials are threefold. Since the water activity (a_w) is critical for microbial, chemical and enzymatic activities, edible films may resist the migration of outer moisture into the food during storage. They may serve as gas and solute barriers and compliment other types of packaging by improving the quality and shelf life of foods (Wong *et al.*, 1994).

Chitosan prepared from chitin, one of the most abundant natural polymers in living organisms (Coma *et al.*, 2002), is a biodegradable and biocompatible polymer having antimicrobial properties (Coma *et al.*, 2002; Molloy *et al.*, 2004; Sebastien *et al.*, 2006). Hosseini *et al.* (2008) suggested the use of clove and thyme essential oils in combination with EDTA and chitosan to make antimicrobial edible films and coatings for various food applications.

Biopolymers: Bio-based polymer films derived from natural sources such as plant and animal materials help effectively to reduce the amount of synthetic polymer waste. The use of plant material to form films is an active research topic (Jane and Wang, 1996). The advantages of using biopolymers for food packaging include: reduced dependence on petroleum-based packaging, use of a renewable agricultural resource, the biopolymers can act as carriers to deliver shelf-life extenders such as antimicrobials or antioxidants and biodegradability. Since the forming of a film requires cross-linking of molecular units to impart strength and flexibility, proteins and carbohydrates are often the best candidates for biopolymer films. Proteins investigated include wheat gluten, corn zein, whey, pea protein, meat proteins, egg proteins and soy. Starches studied in the literature include alginate, polysaccharides, cellulose, carrageenans and microbial polysaccharides. Pearce and Lavers (1949) reported using carrageenan to protect frozen poultry and Klose *et al.* (1952) incorporated an antioxidant into a gelatin coating to slow the development of oxidative rancidity in cut poultry meat prior to freezing. Edible film packaging of meat act as a moisture barrier, oxygen barrier, texture modifier, breading adhesion aid, mold suppressor, bacterial inhibitor, physical protectant, oil barrier, antimicrobial carrier and antioxidant carrier.

CONCLUSIONS

Packaging plays an important role in preserving the quality and safety of the product it contains and also protects the product from damage due to physical, chemical, or biological hazards (Dallyn and Shorten, 1998). The need to package poultry meat and meat products in a versatile manner for transportation and storage, along with the increasing consumer demand for fresh, convenient and safe products presages a bright future for effective packaging methods. It is likely that future research into a combination of naturally-derived antimicrobial agents, biopreservatives and biodegradable packaging materials will highlight a range of the merits of active packaging in terms of food safety, shelf-life and environmental friendliness (Dallyn and Shorten, 1998; Floros *et al.*, 1997; Nicholson, 1998; Rodrigues and Han, 2000). The challenge continues to finding new and innovative ways to get its message across to buyers, in a world where product price reduction and pressures to lower packaging manufacturing costs are a brutal reality due to the globalization.

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