Shelf-life Extension of Fresh and Processed Meat Products By Various Packaging Applications

Keun Taik Lee
Department of Food Science and Distribution, Gangneung-Wonju National University, Gangneung 25457, Rep. of Korea.
Corresponding email: leekt@gwnu.ac.kr

ABSTRACT

This article delves into the current status of various packaging technologies, which are currently being applied or are under development for the shelf-life extension and quality improvement of fresh and processed meat products. Traditional packaging methods include vacuum packaging, modified atmosphere packaging, and air-permeable packaging. Recently, innovative packaging methods have been introduced that utilize technologies such as barrier-films, active packaging, nanotechnology, microperforated films, far-infrared radiations, and plasma treatment. All of these packaging methods have their own merits and drawbacks in terms of shelf-life and quality maintenance. A right choice of packaging system for fresh and processed meat products must be made in accordance with the conditions of the raw material, storage, and distribution in the market and household, and while considering the environmental sustainability and consumer's expectations.

Keywords: Packaging, Shelf-life, Fresh and Processed Meat Products, Quality of meat

INTRODUCTION

It is estimated that about one-third of food is lost or wasted from the time of its agricultural production down to the stage of human consumption. In developed countries, the losses and wastes of fresh and processed meat products are most dominant at the end of the food supply chain (FSC), while in developing countries, they occur evenly throughout the FSC, accompanied by high losses at the livestock rearing stage because of diseases (e.g. pneumonia, digestive diseases, and parasite infections) (FAO, 2011). Significant losses can occur at the stages of processing and consumption in the FSC, which can be reduced or avoided by the application of appropriate packaging technologies (Lipinski et al., 2013).

Fresh and processed meat products are susceptible to spoilage and poisoning. Shelf-life extension can be achieved by suppressing the growth of microorganisms and enzyme activity during storage after meat preparation. To achieve this goal, various intrinsic, extrinsic, and implicit preservation countermeasures should be adopted, such as chilling, heating, drying, salting, fermenting, addition of chemical preservatives, and packaging.

Apart from traditional packaging technologies, including air-permeable packaging (APP), modified atmosphere packaging (MAP), and vacuum packaging (VP), various innovative packaging technologies have been tested and partly applied in the field to extend the shelf-life and preserve the quality of fresh and processed meat products. It would be valuable to review the status of traditional packaging technologies, while considering their advantages and drawbacks, where the latter would be highlighted in order to be solved by innovative technologies in the future. The future packaging systems of fresh and processed meat products should be developed to meet the need for high convenience and quality of packaged products and to achieve better functional efficacy of these systems without damaging the environment and health safety.

The Significance of Packaging in the Global Value Chain

Agriculture is an important sector in the economy of the world's developing countries, contributing nearly 15~40% of national GDP in 2017 (Kim, 2017). In the case of the meat industry in developing countries, the marketing and processing sector has its challenges; as most producers are small and have mediocre mechanization, their products are often distributed without proper processing. Consequently, improved management and processing/packaging of raw meat materials after slaughtering would considerably reduce financial losses, and thus contribute to enhancement of the quality of products.

Linkage effects refer to the degree to which certain factors can induce the demand of manufactured goods and influence the economic prospects of other related industries. Forward linkage promotes more advanced industries to flourish and function as a base on which other industries can be established. Contrarily, backward linkage has a somewhat beneficial feedback effect on agriculture itself, where linking factors, such as market expansion, act as stimuli to increase agricultural production (Granis et al., 2001).

For animal rearing, backward linkage industries include feeds, equipment, breeding stocks, veterinary services, and construction. On the other hand, packaging industries, together with slaughter, processing, storage, and distribution industries, constitute forward linkage industries. In order to convert livestock to fresh and processed meat products and bring them into distribution chains and supermarkets, they require to be packaged and labeled after undergoing processing procedures, such as slaughtering, deboning, dressing, grinding, cutting, heating, or smoking etc. Besides, the manufacturing date of product states, when the product was packaged. Therefore, packaging is a prerequisite for processed meat products to be converted into commercial commodities in the modern global value chain system.

Requirements of Packaging

Eilert (2005) reviewed the current status and major influences on the evolution of meat packaging and elucidated the three major demands in this sector in the 21st century: 1) the growing demand for convenient products, 2) the demand for bio-based packaging materials, 3) the demand for pre-packaged meat with longer shelf-life. However, the traditional role of meat packaging has been restricted to preservation and protection of meat quality from chemical, physical, and biological deterioration till consumption. According to this concept, spoilage retardation, shelf-life extension, and quality preservation of packaged foods are a priority (Brody et al., 2008). However, meat packaging in modern times should play a role not only in quality preservation, but also in an increase of commodity values and promotion of sales and information delivery (Han, 2005). Moreover, factors, including convenience of use, eco-friendliness, logistics, high-functionality, and safety of packaging materials, are more emphasized than before.

Presently, various packaging films are available to satisfy consumer's particular needs for various applications. The selection of an appropriate film for packaging of fresh and processed meat products would be an initial step in the storage of distributed products. Before selecting a packaging material and method, it is essential to understand their properties and the effect they might have on product quality and shelf-life. For instance, physical properties of storage film, including its thickness, tensile and impact strength, transparency, and permeability, are the important factors, which affect the stability and quality of packaged fresh and processed meat products.

Packaging Options

The most common and typical formats for packaging and distribution of fresh meat currently applied in the markets include the APP, MAP, and VP systems. Among them, VP is primarily used for wholesale meat, while APP is the most popular packaging method for retail meat. For processed meat products, VP, including skin and shrink packaging, is the most prevalent packaging system. Moving on, MAP is also used for the purpose - albeit less frequently - where O_2 is often substituted by N_2. These three different packaging systems are typically characterized by the concentration and composition of gas inside of the package and the packaging materials used.

In case of APP system, wrapping films are typically made up of plasticized polyvinyl chloride (PVC). The trays are made of polystyrene paper (PSP), pulp mold, and rigid or foamed polyethylene (PE) or polypropylene (PP). The packages can also be produced, using trays made up of relatively thick gauges of PP or/and PE sheet that are hermetically sealed with a top film made of PP or/and high-density polyethylene (HDPE).

For the wrapping film, PVC films are still the most prevalent in the retail meat markets. It might be because of their superior mechanical properties, such as sheet flatness and less wrinkling, and cheap price as compared to other alternative films, such as linear low-density polyethylene (LLDPE), polyolefin (PO), or ethylene vinyl acetate (EVA) films, although these substitutes can also provide equivalent O_2 and water vapor permeability just like the PVC film (Eilert, 2005). Commercial wrapping films often have O_2 permeability higher than 15,000 $cm^3/m^2/d/atm$. The average water vapor transmission rate (WVTR) of PVC and LLDPE wrapping films obtained from a Korean local market was reported to be 786 $g/m^2/d/$ and 99 $g/m^2/d$, respectively (Lee and Yoon, 2001a). Wrapping films must possess an O_2 permeability higher than 5,000 $cm^3/m^2/d/atm$ to guarantee bright red oxymyoglobin color and to prevent browning of the surface of fresh meat (Jeremiah, 2001). However, the ingress of O_2 through an air-permeable film can promote the growth of aerobes and oxidative enzyme activity, which in turn, induces short shelf-life of meat products. The WVTR of such air-permeable films should lie in a range that enables them to maintain the required level of relative humidity (RH), balance the prevention of drying and accumulation of dewed moisture on the meat surface.

The packaging films used for VP systems should possess low gas permeability; therefore, they are usually multilayered, with a layer of polyamide (PA) as a gas barrier and that of PE as a heat sealer. Less frequently, polyethylene terephthalate (PET) or PVC are used as barrier layers, while PP is used as the sealing layer. Ethylene vinyl acetate (EVA) and ionomer films can be used for better sealability than PE films, even when the sealing layer is contaminated with food components, such as fat or powder. Ethylene vinylalcohol (EVOH) and polyvinylidene chloride (PVDC) layers are also often incorporated to enhance the gas barrier property. They are combined by extrusion, lamination, or coating to create the desired properties. Recently, composite films incorporated with inorganic fillers (clay, glass flakes, and nanoparticles) are becoming popular in the market of fresh and processed meat products owing to their advantages of microwaveability, the ability to work as gas barrier in low gauges, and/or transparency (Lee, 2010). Among the various inorganic fillers, silica oxide is most widely used to achieve low oxygen permeability, typically down to 1 $cm^3/m^2/d/atm$, along with superior transparency, microwaveability, and eco-friendliness (Lange and Wyser, 2003; Lee, 2010).

The principal purpose of introducing vacuum inside the packaging is to shift the internal gas composition to that of O_2-depletion, which makes the environment favorable for the growth of lactic acid bacteria, but suppresses the growth of aerobic and putrefactive microorganisms, such as *Pseudomonas* (Labadie, 1999; Lee, 1985). An advantage of applying vacuum in fresh meat packaging would be a longer shelf-life and, additionally, improved tenderness. However, a principal drawback of vacuum-packaged meat in the retail market is a purplish red color, which is not preferred by consumers, although it blooms after exposure to air. Recently, the retail market for vacuum-packaged fresh meat is increasing due to its extended shelf-life, especially for pork and poultry meat in which the deoxygenated myoglobin color is not as prominent as in beef.

Another problem with vacuum-packaged meat is increased purge loss during storage, which makes the meat visually unattractive and causes a loss of nutrients and color pigment. Purge loss from meat is increased owing to cutting it in smaller portions, temperature fluctuations, and pressure on the products (Gill, 1996). It can be reduced by minimizing the surface area and by cutting the meat longitudinally rather than in transverse direction (McMillin, 2008). Thus, careful handling and less damage to the muscle fiber and fascia during preparation of meat for packaging are required to lessen purge loss. The extent of purging is increased with an increase in storage temperature. This increase is noticeable, when the temperature increases from 0 to 5℃, but it increases significantly, when the temperature rises from 5 to 10℃ (O'Keeffe and Hood, 1980). In this regard, in the last few decades, a variation of vacuum packaging, the skin pack, has gained popularity in the retail meat market by virtue of its smart shape, attractiveness for display and POP (Point of Purchase), and also with its increasing market volume as case-ready packaging.

Considering the drawbacks of APP and VP systems, such as short shelf-life and purplish-red color, respectively, the MAP system could be a packaging technology that provides a compromise between these disadvantages in the form of a bright red color and an intermediate shelf-life. In most MAPs of processed meat products, three major gases are used, either individually or in combination. Carbon dioxide is used to provide an antimicrobial effect, especially to suppress aerobic putrefactive spoilage bacteria (Ooraikul, 2003). On the other hand, N_2 is an inert gas, which is used in MAP as a filler gas, either to substitute other gases or to prevent the package from deformation (Bell and Bourke, 1996). The major role of O_2 in MAP is to convert purplish red myoglobin to bright red oxymyoglobin. The use of CO at 1-5% concentration in MAP was first introduced in 1976 (Wolfe et al., 1976); it is known to be effective in inhibiting browning of meat by converting meat color to carboxymyoglobin, which is more stable against oxidation to metmyoglobin than reduced myoglobin (Wolfe et al., 1976). Argon was recently recommended because of its better effectiveness in retarding enzymatic activities, microbial growth, and chemical spoilage as compared to N_2 (Spencer, 2002).

Gas compositions used in MAP are different depending on the meat species. For instance, the common concentration mixture of gases for fresh beef is 60-80% O_2 and 20-40% CO_2 (Hood and Mead, 1993), and occasionally, an additional 10% N_2 (Lee et al., 1999). On the other hand, for cooked meats, the gas is composed of 70% N_2 and 30% CO_2 (Smiddy et al., 2002). As compared to VP, MAP is less efficient because it needs more time to package the product as well as more investment in its operation. However, the application of MAP is expanding due to its value-added retail format, particularly, with regard to shelf-life, which satisfies the requirements of both the consumer and the retailer. Therefore, the MAP system might be recognized as a best way to find a compromise between the advantages and drawbacks of APP and VP for retail fresh meat. Currently, trays used for MAP are formed by thermoforming web film made of various sheets, such as PET/PE (PP), PS/EVOH/PE, PS foam/EVOH/PE, PET/EVOH/PE, PP/EVOH/PP, PVC/PE (PP, EVA), and EPP (expanded polypropylene)/EVOH/PE etc., with thickness of 300-800 ㎛. Thermoforming of the tray preferentially requires a rigid polymer, such as PP, PA, PET, and PVC, which can be molded via heating to form a cavity of the desired size and shape of the product.

There are some drawbacks of the MAP system, which are as follows: 1) oxidation of lipid, protein, and cholesterol in the presence of high O_2 concentrations, 2) premature browning on cooking, 3) discoloration of the bone marrow to a brown color due to oxidation, and 4) growth of psychrotrophic pathogens, such as *L. monocytogenes*, *Aeromonas hydrophila*, and *Yersinia enterocolitica*, especially the growth of *C. botulinum* and potential toxin production by it in anaerobic conditions (Clausen et al., 2008; Farber, 1991; King and Whyte, 2006; Mancini, 2009).

In order to select the optimal packaging system for preservation of meat quality, it is essential to understand the functions of packaging in terms of deterioration processes, hygienic condition of the product before packaging, and the storage temperature (Jeremiah, 2001). At present, many different kinds of commercial packaging materials and equipment have been developed over the last several decades, which further propelled the advancement of packaging systems and the quality of packaged processed meat products. However, the key factor to consider, when selecting a packaging system for fresh meat, is how it will meet the requirements of specific commercial applications of maintaining quality, while minimizing packaging costs (Gill, 1992; Jeremiah, 2001).

Packaging and Shelf-life of Products

The shelf-life of meat packaged in a plastic film is dependent upon the micro-climate established within the package (Lee and Yoon, 2001b). Quality-related characteristics of meat products, such as growth of aerobes, fat oxidation, discoloration, and purge loss, are affected by the packaging method (Table 1). Film composition, temperature, and RH affect O_2 permeability of VP films (Eustace, 1981). The positive effect of reduced permeability on storage life of chilled meat was established by Newton and Rigg (1979).

Table 1. Various quality parameters of meat products as affected by different packaging methods

Packaging method	Quality parameter			
	Growth of aerobes	Fat oxidation	Discolora-tion	Purge loss
None	+++	+++	+++	++++
Air-permeable (Wrap)	++++	+++	+++	++
MAP	++	+++	++	++
Vacuum	+	+	+	++++

++++ Extremely high +++ high ++ moderate + low

Various quality attributes, such as color, odor, flavor, and water holding and binding capacity, of meat deteriorate with extended storage time after animal carcasses are subjected to wholesale and then further to retail meat. Therefore, preservative packaging for raw meat must fulfill the responsibilities of delaying physicochemical deterioration of the product as well as retarding the onset of bacterial spoilage. The principal factors that must be taken into consideration, when applying any packaging technology on raw retail meats, are the retention of an attractive and fresh appearance, delay in microbial spoilage, and minimization of purge losses (Gill, 1996).

Quality and shelf-life of fresh and processed meat products are affected by various intrinsic factors (food composition, components, structure, initial microbial load, pH, water activity, redox-potential), processing factors (degree of heat treatment, level of salting, types and amounts of additives, smoking etc.), and extrinsic factors (storage temperature and RH, packaging methods, lighting, pressure etc.). Moreover, some implicit factors, such as growth conditions and rate of growth of microorganisms, are also involved.

The shelf-life of vacuum-packaged meat is preferentially influenced by the factors, including the storage temperature, the size of meat cut, initial levels of contaminating microorganisms, and the O_2 permeability of packaging material (Koch et al., 2009; Labadie, 1999; Lee, 1985). Longer shelf-life of fresh meat can be achieved with a lower O_2 permeability of packaging film, storage temperature approaching freezing point of meat, i.e., around -1.5℃, and a lower initial bacterial load of raw meat before packaging (Lee, 1985).

The average shelf-lives of various types of meat and meat products packaged by different methods are summarized in Table 2-3. Lee and Yoon (2001c) reported that boxed beef chucks imported from the US, which were vacuum-packaged in heat-contractile gas barrier films and kept at -1.5℃ during shipment until inbounding custom clearance for a total of 37 days, could maintain a marketable quality for an additional 29 days at 0℃ in the Korean market.

Table 2. Estimated shelf-lives of different processed meat products depending on packaging methods

Product		Temp(℃)	Packaging method	Shelf-life*
Beef	Half, quarter carcass	4	Air-perm. packaging (APP; wrap)	10~14 d
		-1.5~0	APP	3~5 w
		-1.5~0	10% CO_2	9 w
	Boxed	2	Vac.	4~8 w
		-1.5~0	Vac.	8 ~12 w
	Retail meat	4	APP	1~4 d
		4	Vac.	2~3 w
		2	MAP (80% O_2 + 20%CO_2)	9~12 w
		2	Vac.	3~5 w
		0	Vac.	4~8 w
		0	APP	3~6 d
	Ground meat	4	APP	1 d
		4	Vac.	7~14 d
		2	MAP (80% O_2 + 20% CO_2)	3~5 d
Pork	Half, quarter carcass	4	APP	8 d
		-1.5~0	APP	2~3 w
	Boxed	-1.5~0	Vac.	4~6 w
	Retail meat	4	APP	3 d
	Ground meat	4	APP	1 d
Mutton	Carcass	4	APP	1~2 w
		-1.5~0	APP	3~4 w
	Boxed	-1.5~0	Vac.	10 w
Veal	Carcass	4	APP	6~8 w
		-1.5~0	APP	3 w
Intestines		2	APP	3 d
		-1.5~0	APP	6~7 d

* Dependent on the initial bacterial load

Table 3. Estimated shelf-lives of different processed meat products depending on packaging methods

Product	Temp.(℃)	Packaging method	Shelf-life
Boiled, smoked domestic sausages & hams	5	Normal vac.	5~6 w
	5	Vac. with low gas permeable film	6~8 w
	10	Normal vac.	3~4 w
Fermented sausages & hams	RT	None-vac.	1 m~1 y*
Dried products (e.g. jerkies)	RT	None-vac.	3~12 m
		Vac.	1~2 y
Canned product	RT	TFS, Tin, Al can	2~3 y**
Retorted product in Al-pouch	Frozen	PET/PA/CPP (F_0= 0.1)	1 y**
	Chilled	PET/Al/PA/CPP (F_0=1-3)	1 y**
	RT	PET/Al/PA/CPP (F_0=8-10)	1.5~ 2 y**

* Dependent on the initial bacterial load

By virtue of modern packaging technologies, the shelf-life of chilled meats has been considerably extended. However, excessively extended preservation of meat is sometimes not preferred in local markets because it could cause an undesirable soft texture and excessive exudate. The deterioration in quality of vacuum-packaged chilled meat during storage is attributed to some physicochemical changes, such as discoloration, sour odor, off-flavor, and increased purge loss (Hotchkiss, 1995; Husband, 1982). Additionally, under evacuated state, growth of *C. botulinum* in the package poses a potential threat, when the storage temperature exceeds 3℃ (Gill and Gill, 2005). After evacuation for VP, 0.3-3% air may remain in the package (Sanjeev and Ramesh, 2006). In the VP, residual O_2 is consumed to release CO_2 as a result of active metabolism in muscle tissues and the growth of microorganisms (Gill, 1996; Lee and Lee, 1998). The O_2 proportion inside the vacuumed package can decrease to less than 1%, when CO_2 level rises (Ledward, 1979). Seideman et al. (1979) reported that CO_2 ratio increased to more than 61% or 78% for vacuum-packaged pork and beef, respectively, during storage.

The blooming capability of meat decreases with extended storage. Discoloration and inferior blooming was reported in 1-day old beef after opening the vacuum pack (Lee and Lee, 1998). Nevertheless, this transient discoloration is a possible problem only when the vacuum-packaged meat has to be displayed as a retail-ready product within a short time after packaging because, otherwise, it can be resolved within 2-4 days, if the amount of residual O_2 inside the package is not excessive (Gill, 1996). When the vacuum packaging film cannot pose sufficient barrier to prevent further ingress of O_2 (<30 $cm^3/m^2/d/atm$) or the vacuum applied is not sufficient to lower residual O_2 concentration to the critical range, formation of metmyoglobin on the surface of vacuum-packaged meat is prone to occur. Furthermore, this phenomenon is also observed when the meat is exposed to air for too long before packaging as it allows excessive O_2 to absorb in the meat and later be released into the package (Kropf, 2004). Therefore, it has been recommended that the earlier application of vacuum packaging after preparation of cut meat is favorable to prevent the meat surface from discoloration.

The shelf-life of processed meat products is largely dependent on various factors, including the heat treatment conditions, the addition of chemical additives (sodium nitrite, sodium sorbate, antioxidants etc.), storage temperature, and O_2 permeability of the film used. Generally, the shelf-lives of processed meat products treated under commercial pasteurization temperature conditions, i.e. ca. 70-80°C/30-120 min, are in a range between 3 and 6 weeks at chilling storage temperature. To achieve extended shelf-life beyond this range, more severe heat treatment, including post-pasteurization after packaging or retorting along with the use of gas barrier films, is essential. For instance, retorted ready-to-eat chicken porridge packaged in a multilayer film containing an EVOH layer can be stored for at least 24 weeks at 25°C (Jang and Lee, 2012).

The dominant microflora in MA packaged meat was reported to be lactic acid bacteria (Christopher et al., 1979a,b) with a concomitant growth of *B. thermosphacta* (Lee et al., 1999). It has also been reported that the aerobic plate counts were higher than those for lactic acid bacteria in Spanish beef packaged with MAP (60% O_2, 30% CO_2, and 10% N_2). In the presence of O_2 in the MAP, the Gram-negative bacteria, such as *Pseudomonas, Enterobacteriaceae, Acinetobacter*, and *Moraxella*, are more sensitive to CO_2 than the Gram-positive bacteria such as lactic acid bacteria.

In an atmosphere of 20% CO_2, the growth of aerobic bacteria, including *Pseudomonas,* is effectively inhibited. However, above this concentration, the inhibitory effect does not increase notably with an increase in the CO_2 concentration (Clark and Lentz, 1969). In MAP, headspace to meat volume ratio is the most influencing factor to dictate CO_2 volume change in the package, followed by surface area and meat volume (Zhao and Wells, 1995). The higher the initial CO_2 concentration, the greater is the change in its concentration during storage (Zhao and Wells, 1995). The gas ratio of 80:20:0 for O_2:CO_2:N_2 was found to be the most effective packaging combination for maintenance of the color of MA-packaged lamb and hogget meat. Besides, the ratio of 2:1 for headspace to meat volume was the most effective for a decrease in *Pseudomonas* growth and an increase in growth of lactic acid bacteria in both lamb and hogget meat (Kennedy et al., 2004). High O_2 concentration accelerates the lipid oxidation rate to cause rancidity (Lund et al., 2007). It was reported that an atmosphere with high O_2 causes protein oxidation, which leads to decreased palatability, such as reduced tenderness and juiciness, flavor deterioration, and discoloration (Lund, et al., 2007; Xiong, 2000). To avoid the negative effect of O_2 in MAP, the use of 100% CO_2 or N_2 packaging is proposed, especially for pork and poultry meats. When sealed, the packaging atmosphere should have a residual O_2 concentration of no more than 0.1% - preferably no more than 0.05% - to prevent the irreversible discoloration of meat (Gill, 1996). Longer shelf-life was observed with an increase in the CO_2 proportion in the MA-packaged meat (Skandamis and Nychas, 2002). Other researchers found the optimum CO_2 concentration in MA-packaged meat to be generally below 40% (Satomi, 1990; Selman, 1987). Gill (1996) reported that increasing the CO_2 concentration above 20% produced little additional inhibition.

Moving on, APP is the most prevalent packaging for distribution of retail meat. When APP system is applied with air-permeable wrap film and trays, O_2 is abundant, and thus, the bright red color is preserved after packaging, which is attractive to the consumer. However, this advantage is diminished with prolonged storage time, resulting in a short shelf-life. For instance, shelf-life is typically 3-4 days for beef and 2-3 days for pork at refrigeration temperatures. Furthermore, high O_2 permeability of wrap film favors the growth of aerobic microorganisms, such as *Pseudomonas*. Therefore, spoilage phenomena typical of the APP system are putrefactive odor, slime formation on the surface, and discoloration in the form of browning, etc. In households, left-over meat is usually kept in a refrigerator after either packing in a PE bag or placing in an air-tight PP container, oroccasionally, it is vacuum-packaged with a household vacuum-packaging machine. Quality changes of pork loins in terms of off-odor and discoloration were detectable earlier in the meat packed in PE bag as compared to those packaged with vacuum films or in PP container (Lee and Jang, 2013).

Innovative Packaging Technologies

Traditional packaging technologies have been successfully devised in the fresh and processed meat products sector, but these packaging technologies are continuously developed to improve equipment, packaging material, and methodology, in order to be commercialized in the meat science field. The positive effects of various innovative packaging technologies that use barrier-films, active packaging, nanotechnology, microperforated films, far-infrared (FIR) radiation, and plasma treatment for quality improvement and shelf-life extension of fresh and processed meat products have been verified (Lee, 2010). The concepts of these technologies can be characterized by the way they regulate gas permeability or WVTR (passive packaging) and also by the way they incorporate bioactive ingredients into or onto the packaging materials (active packaging). Some innovative approaches have been developed by improving the control of gas permeability or WVTR (microperforation of film, high gas-barrier film, and nanotechnology etc.), by the functional improvement in the packaging material itself (nanotechnology, FIR radiations, plasma treatment, and irradiation), and by application of active packaging systems (Kerry et al., 2006).

The active packaging system can be classified in terms of the mode of application, which includes a direct incorporation of active agents into the packaging materials; an incorporation of active agents into a sachet, patch, or tablet; and the use of edible films and coatings with active agents (Lee, 2010). However, up until now, not many active packaging systems, except the O_2 scavenger and moisture absorber systems, have found extensive use in the meat industry. Presumably, this is owing to various problems, such as cost, effectiveness, consumer acceptance, or applicability in the production line etc. Nonetheless, active packaging system has significant potential to help the meat industry and consumers by establishing a new platform for preservation and packaging of meat products (Han and Floros, 2007). These advances have contributed effectively to meet the consumer demands for better quality and longer shelf-life of meat products.

CONCLUSIONS

Currently, diverse packaging materials and systems for fresh and processed meat products are available. The choice of appropriate packaging system should be based on the product’s characteristics and requirements for commercial applications; the main aim is that quality and extended shelf-life are maintained and packaging costs are minimized. The increment of costs induced by the application of innovative packaging systems can be compensated for with quality improvement and the shelf-life extension of products, which will ultimately result in the reduction in waste loss and enhanced consumer satisfaction.

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