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RECENT TRENDS IN MEAT AND MEAT PRODUCTS PACKAGING – A REVIEW

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ABSTRACT

The aim of any packaging system for fresh muscle foods is to prevent or delay undesirable changes to the appearance, flavour, odour, and texture. Deterioration in these qualities can result in economic losses due to consumer rejection of the product. Therefore, a preservative packaging should ideally inhibit undesirable enzyme activities, but not interfere with, or inhibit, activities that are beneficial. The non-enzymatic reactions that affect the organoleptic qualities of raw meats are invariably undesirable, so these should preferably be slowed or prevented by a preservative packaging.

Keywords: meat, packaging, shelf-life

Meat packaging

Packaging is a scientific method of preserving the quality and safety of the food it contains from the time of manufacture to the time it is used by the consumer and also to display the product in the most attractive manner for consumer preference. 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 fresh meat is carried out to avoid contamination, delay spoilage, permit some enzymatic activity to improve tenderness, reduce weight loss, and where applicable, to ensure an oxymyoglobin or cherry-red colour in red meats at retail or customer level (Brody, 1997). When considering processed meat products, factors such as dehydration, lipid oxidation, discoloration and loss of aroma must be taken into account (Mondry, 1996). Many meat packaging systems currently exist, each with different attributes and applications. These systems range from overwrap packaging for short-term chilled storage and/or retail display, to a diversity of specified modified atmosphere packaging (MAP) systems for longer-term chilled storage and/or display, to vacuum packaging, bulk-gas flushing or MAP systems using 100 % carbon dioxide for long term chilled storage. Due to the diversity of product characteristics and basic meat packaging demands and applications, any packaging technologies offering to deliver more product and quality control in an economic and diverse manner would be favourably welcomed.

The most commonly used polymers for food packaging are low-density polyethylene (PE-LD), high-density polyethylene (PE-HD), polypropylene (PP), and polyamide (PA) (Jan et al., 2005). Polyesters (PET), PVC, poly (vinylidene chloride), PVdC, polystyrene (PS), and ethylene/vinyl acetate (EVAC) are also used with food (Marsh and Bugusu, 2007). Each type of packaging material has advantages, disadvantages, consumer and marketing issues, environmental considerations, and cost (Marsh and Bugusu, 2007). Fresh meat packaging is only minimally permeable to moisture and so surface desiccation is prevented (Faustman and Cassens, 1990), while gas permeability varies with the application. A single layer or type of plastic generally does not have all of the needed properties for a food package application, so lamination, coating or coextrusion is used to create layers of plastic with the desired properties (Jenkins and Harrington, 1991). Heat sealing and barrier properties are often improved by application of coatings to the surfaces of plastic films (Kirwan and Strawbridge, 2003). Therefore, most meat packaging films are of multilayer construction which incorporates a variety of polymer resins. However, to provide extended storage, low gas and moisture vapour transmission rates are essential (Stiles, 1990), since packaging effects on product storage life have been reported to be mostly related to the gas and moisture vapour permeability of the packaging materials (Halleck et al., 1958). Films used for retail packaging must have a high oxygen permeability (at least 51 mL/m2 /24 h/bar at 23 oC and 0 % RH) to prevent oxidative browning (Hood, 1984). However, only films with oxygen transmission rates of no more than 10 mL/m2/24 h/bar at 23oC and 0 % RH can be used for preservative packaging. Storage life can be increased 10–15 % by using films with oxygen permeabilities less than 2 mL/m2/ 24 h/ bar at 23 oC and 0 % RH. All plastics are permeable to gases to some degree. Film permeability varies with the partial pressures inside and outside the package, the type of plastic, the thickness of the plastic layers, and the temperature of the plastic. Some plastics are also markedly influenced by relative humidity and contamination with nutrients, such as fat (Gill, 1992). Oxygen permeable films, such as cellophane, cellulose, and polyethylene permit microbiological growth at maximal rates until dehydration or mould growth interferes (Halleck et al., 1958). Aerobic, high permeability, gas flushed, and tray overwrapped packages have relatively short storage lives, when compared to anaerobic packages or packages with low permeability (Cole, 1986). Bacterial growth in impermeable packages is dependent upon the atmosphere in the package and is characterized by longer lag phases (Halleck et al., 1958). Entrapped oxygen and oxygen ingress produce oxidation and pronounced surface discoloration (Hood, 1984). Oxygen ingress into a package can only be prevented by using completely gas impermeable packaging materials, with oxygen impermeable heat seals on all parameters (Jeremiah, 1997). Sealing of packages is a critical step, but several sealants can be used, and usually represent the thickest layer in laminates (Stiles, 1990). The use of aluminium foil in a laminate was required to prevent discoloration during storage of meat at 4 oC (Kraft and Ayres, 1952). Prolonged storage in PE bags or PVC film wrap should be avoided to prevent microbial growth (Rea et al., 1972). Storage of beef quarters or wholesale cuts in PVC film for more than 8 days increased both microbiological counts and the incidence of offodours. However, PE bags and PVC film wrap reduced shrinkage and improved muscle colour and the subcutaneous fat appearance of beef quarters and wholesale cuts during shipment (Smith and Carpenter, 1973). Beef quarters or cuts can be wrapped in PVC film and be shipped for up to 6 days in air, but shipments over 6 days in duration should be in modified atmospheres (Marriott et al., 1977). Polyethylene wrapped beef samples had lower weight losses and thiobarbituric acid (TBA) values than PE wrapped, vacuum packaged, and modified atmosphere packaged samples.

However, PE wrapped and vacuum packaged samples had higher reflectance values. Polyethylene wrapped cow beef samples, however, had higher bacterial counts than vacuum packaged and modified atmosphere samples, packed in carbon dioxide, even after 3 months of frozen storage (Gokalp et al., 1978).

Shrink Packaging: Plastic shrink films are used for wrapping large and uneven cuts of fresh meat. It is a technique in which heat shrinkable polymer film is shrunk around the meat product by application of heat to achieve a skin-tight and compact pack. The packaging film should have structural strength. It should be a good water vapour barrier and be capable of withstanding storage temperature of about – 45 °C. The advantages of plastic shrink film include neat appearance, ease in handling and a contour fit. Hot tunnels are used to effect a tight wrap. Heat shrinkable poly(vinyl chloride) (PVC), polypropylene (PP), irradiated polyethylene (PE) and poly(vinylidene chloride) (PVdC) are used to shrink wrap fresh meat.

Skin Packaging: Another development that offers advantages for presentation as well as packaging design variety is skin packaging. The process allows the packaging film to conform exactly to the profile of the product. This gives rise to many opportunities for enhanced product presentation as well as further improving the integrity of the pack itself. In a skin pack, the product becomes the die for the thermoform packaging operation. The semi-rigid bottom web may or may not be thermoformed. The top web is heated in an evacuating chamber until it is near its melting point, at which it drapes over the product and forms a skin around all the contours. Upon sealing and cooking, it retains its new shape, ensuring intimate contact with the product, irrespective of surface irregularities. Skin packs are prepared with an oxygen barrier plastic film.

There are four categories of preservative packaging that can be used with raw muscle foods (Table 1). These are vacuum packs (VP), high oxygen modified atmosphere packs (high O2 MAP), low oxygen modified atmosphere packs (low O2 MAP), and controlled atmosphere packs (CAP).

Table 1: Forms of preservative packaging (Gill and Gill, 2005)

Type	**Packaging gases**	**Film gas permeability**	**Atmosphere**
Vacuum pack	Residual air	Low	anaerobic
High O2 MAP	O2, CO2, N2	Low	aerobic
Low O2 MAP	CO2, N2, residual O2	Low	anaerobic
Controlled atmosphere packaging (CAP)	CO2, N2	Impermeable	anaerobic

Vacuum packaging

Shelf life of PVC wrapped meats is only 5-7 days for steaks or roasts and less for ground meats. When surface browning due to metmyoglobin exceeds 40 %, retail meats typically are discounted or discarded (Greene et al., 1971). Brown discoloration can be avoided or minimized by vacuum packaging, which is an acceptable method for lightly pigmented cuts of pork and chicken. Vacuum packaged meats have been marketed successfully for years in many countries. However, the dark-purplish colour of deoxymyoglobin in vacuum packaged retail beef has not been accepted by consumers. To prevent browning, meat package oxygen levels must be less than 0.15 %. Oxygen levels of 0.15 - 2.0 % predispose fresh beef products to browning (Mancini and Hunt, 2005). Aerobically packaged pork had a storage life of 12– 14 days (Hermansen, 1980). Vacuum packaged pork loins sustained less shrinkage than pork loins wrapped in parchment paper and exhibited less surface discoloration and were more acceptable in appearance than pork loins wrapped in PVC film or parchment paper. Vacuum packaged loins also produced retail cuts (chops) with less surface discoloration, less prevalent off-odours, lower bacterial counts, and greater consumer acceptability than chops cut from loins wrapped in PVC film. However, vacuum packaging of wholesale cuts produces subsequent steaks with an additional day of display life after 7 days of storage, and steaks from vacuum packaged wholesale cuts were preferred by consumers for appearance and palatability after 17 days of storage over steaks cut from wholesale cuts stored in carbon dioxide. Vacuum packaged beef rounds also had more desirable muscle colour and fat appearance, lower bacterial counts and less prevalent off-odours, required much less trimming and provided longer display life than rounds stored in carbon dioxide (Smith and Carpenter, 1973). Vacuum packaged cuts have also been reported to be equivalent to PVC wrapped cuts in all appearance traits, after 5–9 days of shipment, but to have lower weight losses after 5–6 days of shipment (Marriott et al., 1977). Pork chops stored in vacuum were also more desirable in appearance and had more acceptable colour than aerobically stored chops (Doherty et al., 1996; Doherty and Allen, 1998). Beef, processed and vacuum packaged under appropriate commercial conditions had a storage life of 70 days (Bell and Garout, 1994), and vacuum packaged beef stored at 1 oC had a storage life of 11 weeks, but off-flavours were perceived after 11 weeks and discoloration was occasionally a problem after 8 weeks. Occasional brown or brownish-black spots on the fat of vacuum packaged beef cuts have also been observed after 6 weeks of storage, which were attributed to breakdown of myoglobin in the drip (purge) (Johnson, 1974). Other reports have indicated vacuum packaged beef had a storage life of 28 days and vacuum packaged pork had a storage life of 21 days (Young et al., 1988), but steaks cut from vacuum packaged beef stored for up to 60 days, were acceptable after 72 h of aerobic display (Gill and Jones, 1994b). Fresh lamb cuts, however, were more desirable than vacuum packaged lamb cuts (Jeremiah et al., 1972a), and chops cut from vacuum packaged lamb cuts were also less desirable than chops cut from fresh lamb cuts, but the colour of chops cut from vacuum packaged lamb cuts did not deteriorate more rapidly than the colour of fresh chops (Jeremiah et al., 1972b). The maximum aerobic display life of vacuum packaged lamb was 2 days (Jeremiah et al., 1972a), and storage in vacuum shortened the retail case-life of cuts subsequently produced, especially from the standpoints of odour and flavour, after 5 days of display (Jeremiah et al., 1972b). Prolonged vacuum packaged storage resulted in higher psychrotrophic counts on lamb cuts, which reduced the maximum storage life of vacuum packaged lamb to 8 days (Reagan et al., 1971). Lamb leg roasts stored for less than 7 days in vacuum were more desirable than leg roasts stored for longer periods, but even short periods of vacuum packaged storage, at low storage temperatures produced detrimental effects on subsequent retail case-life and palatability of lamb (Jeremiah et al., 1972b). In no instance, did vacuum packaged lamb cuts have a retail case-life in excess of 2 days (Jeremiah et al., 1972a). In addition, retail cuts could not be successfully pre-cut, display ready packaged, and stored for 7 - 21 days in vacuum, due to extensive discoloration of the meat surfaces. Such discoloration resulted in unacceptable appearance, even after 7 days of storage and 1 day of aerobic display (Seideman et al., 1980). Vacuum packaged lamb primals also sustained 0.5 - 1.1 % greater purge (drip) losses than their counterparts stored in gaseous atmospheres (Doherty et al., 1996).

Vacuum packaging is well suited for use with large primal cuts with normal muscle pH, and when appropriately applied to these cuts is capable of providing sufficient storage life for all commercial applications, except retail display, when combined with stringent temperatures and hygienic control. However, vacuum packaging is not well suited for applications involving irregularly shaped cuts, bonein cuts, or small cuts of any shape. Vacuum-skin barrier packs are an alternative to conventional vacuum packaging for retail portions. A further enhancement of this approach is to use special peelable films. In these systems, air is evacuated and packs are sealed using an O2-permeable film overlain with a peelable O2-impermeable film to maintain the oxygen-free environment of the pack. Prior to retail display, the outer impermeable film is removed and the meat blooms on exposure to air. The actual cooking of raw foods under vacuum in the package – so-called ‘sous-vide’ cooking – has been developed in France and has gained fairly wide acceptance as a means of producing high quality cooked foods of limited refrigerated shelf-life. As the name implies, the raw material is packed under vacuum, in multi-layer plastic packaging, and cooked in water, by air/steam mixtures or by microwaves at temperatures below 100 ºC, removing oxygen. It is cooled rapidly to + 3 ºC in a blast chiller or in ice water. Loss of nutrients is minimised and an excellent quality obtained. In addition, risks of post processing contamination are reduced and flexibility and product range in catering increased. Vacuum packaging can prevent the growth of some food borne pathogens and spoilage bacteria commonly present on meat (Church and Parsons, 1995; Labadie, 1999; Barros-Velazquez et al., 2003; Venter et al., 2006; Rubio et al., 2006; Parra et al., 2010), and so is widely used for packaging primal cuts and dry-cured products for distribution to retailers.

Master pack

The master pack system consists of four to eight air permeable overwrapped packages that are placed in a large pouch (master pack or mother bag) that is impermeable to oxygen and moisture. The master pack is evacuated to remove air and then back flushed with the desired gas mixture. Typical gas mixtures range from 100 % to 80 % carbon dioxide with nitrogen used as the remaining gas. The presence of CO2 inhibits the growth of bacteria and therefore extends shelf-life. When a retailer needs product to stock the shelf, he/she opens the master pack and removes the packages from the bag with the CO2 gas blend. The product blooms in approximately 30 minutes from the atmospheric O2 it is exposed to after removal from the bag and forms the desirable, bright, cherry-red colour. The expected shelf-life of products packaged in a master pack system is ten to 14 days with a retail display-life of two to seven days (Buffo and Holley, 2005).

Controlled atmosphere packaging (CAP)

The only types of controlled atmosphere packaging currently used with raw meats are those in which an anaerobic atmosphere is maintained indefinitely. Controlled atmosphere packaging may be used for bulk product or items of irregular shape, such as whole lamb carcasses, or as master packs for retailready product. Controlled atmosphere packaging is not suitable for individual trays of retail-ready product because of the undesirable colour of anoxic meat, and because packaging materials that are impermeable to gases are mostly opaque. Readily available films that are essentially gas impermeable are laminates that incorporate a layer of aluminium foil, laminates with two layers of a metallised film, or laminates with unusually thick layers of plastics with high barrier properties (Kelly, 1989). Controlled atmospheres may be of carbon dioxide or nitrogen, or mixtures of the two gases. Nitrogen can provide an anaerobic atmosphere, but does not otherwise affect the muscle tissue or the microflora. Thus, the storage life of meats in a controlled atmosphere of nitrogen is similar to that of meats in vacuum pack; although in a gas impermeable, controlled atmosphere pack there is no oxidation of myoglobin in exudate or muscle tissue, which eventually become evident with meat in vacuum packs as the result of small quantities of oxygen permeating the packaging films (Jeremiah et al., 1992).

Modified atmosphere packaging (MAP)

MAP may be used for bulk or retail ready product (Jeremiah, 2001). Several trays of retail ready

product may be placed in a master pack which is filled with the modified atmosphere (MA), or individual, sealed trays may contain the MA (Wilkinson et al., 2006). Typically fresh red meats are stored in modified atmosphere packages (Table 2) containing 80 % O2 : 20 % CO2 (Georgala and Davidson, 1970) and cooked meats are stored in 70 % N2 : 30 % CO2 (Smiddy et al., 2002). The function of carbon dioxide in MAP is to inhibit growth of spoilage bacteria (Seideman and Durland, 1984). Nitrogen is used in MAP as an inert filler gas either to reduce the proportions of the other gases or to prevent pack collapse. The major function of oxygen is to maintain the muscle pigment myoglobin in its oxygenated form, oxymyoglobin. Low oxygen concentrations favour oxidation of oxymyoglobin to metmyoglobin (Ledward, 1970). Therefore, in order to minimise metmyoglobin formation in fresh red meats, oxygen must be excluded from the packaging environment to below 0.05 % or present at saturating levels (Faustman and Cassens, 1990). High oxygen levels within MAP also promote oxidation of muscle lipids over time with deleterious effect on fresh meat colour (O’Grady et al., 1998). Lipid oxidation is a major quality deteriorative process in muscle foods resulting in a variety of breakdown products which produce undesirable off-odours and flavours. In cooked cured packaged meat products, for example, cooked hams, factors such as percentage residual oxygen, product to headspace volume ratio, oxygen transmission rate of the packaging material, storage temperature, light intensity and product composition are critical factors affecting colour stability and ultimately consumer acceptance (Mrller et al., 2003).

Table 2. Gas mixture used in modified atmosphere packaging for meat and meat products (Georgala and Davidson, 1970; Watkins, 1984; Parry, 1993; Smiddy et al., 2002)

Product	Gas composition (%)

	O2	CO2	N2
Red meat	60-85	15-40	-
Pork steak	80	20	-
Beef /venison portion	80	20	-
Game	20	30	50
Joints	80	20	-
Cooked meats	-	30	70
Cooked ham in slices	-	40	60
Chops/Slices	69	20	11
Poultry	-	75	25
Processed meats	-	-	100

MAP applications may have thermoformed base trays made from unplasticized PVC/polyethylene (PVCU/ PE), poly(ethylene terephthalate)/polyethylene (PET/PE), polystyrene/ethylene/ vinyl alcohol/polyethylene (PS/EVAL/PE), or poly(ethylene terephthalate)/ethylene/ vinyl acetate/polyethylene (PET/EVAC/PE) while preformed base trays are often made from PET, PP, or PVC-U/PE. Lidding films are often PVdC coated PP/PE, PVdC coated PET/PE, or polyamide/polyethylene (PA/PE). Flow wrap films may be PA/PE, polyamide/ionomer, or PA/EVAC/PE (Mullan and McDowell, 2003). Antifogging agents are externally applied to the polymer surface by dip coating or spraying or blended into the polymer for migration to the surface. Antifog agents lower the surface tension of water that condenses on the inside surface of films when there is a temperature differential between the film surface and the surrounding environment. Commonly used agents to prevent film fogging are glycerol esters, polyglycerol esters, sorbitan esters and their ethoxylates, alcohol ethoxylates, and nonyl phenol ethoxylates (Osswald et al., 2006).

The materials used to form modified atmosphere packs must provide a barrier to the exchange of gases between the pack and the ambient atmosphere. However, the gas barrier properties of the packaging materials differ for different types of packaging and differing commercial functions of the packs. Bulk and master packagings which are expected to contain product for only a day or two are often laminates composed of a strong material with limited gas barrier properties, such as polyamide (PA), and a sealable layer of a material such as polyethylene (PE). Such materials may have nominal oxygen transmission rates (OTR) of more than 100 cm3/m2/24h/bar under stated conditions of humidity and temperature. However, films used for MAP usually have OTR between 10 and 100 cm3 O2/m2/24h/bar, while packagings designed to contain product for the longest possible times are likely to be composed of materials with OTR less than 10 cm3/m2/24/bar (Jenkins and Harrington, 1991).

Carbon dioxide, the essential component of any effective modified atmosphere for meat is highly soluble in both muscle and fat tissues (Gill, 1988). The solubility in muscle tissue decreases with decreasing pH and increasing temperature but, within the chill temperature range, solubility in fat increases with increasing temperatures. Because of the dissolution of carbon dioxide in the product, the initial atmosphere in a pack should contain a higher concentration of carbon dioxide than the 20 % that it is desirable to maintain after equilibration for maximum inhibition of the aerobic spoilage bacteria. The smaller the volume of the atmosphere in relation to the product mass, the higher the carbon dioxide concentration needed in the input gas, and the greater the decrease in the volume of the atmosphere as carbon dioxide dissolves in the tissues after the pack is sealed. Unlike carbon dioxide, the solubility of oxygen in muscle and fat tissues is low. However, oxygen is converted to carbon dioxide by the respiratory activities of both muscle tissue and bacteria. Although both gases are lost through packaging films when both are at concentrations above those of air, the carbon dioxide dissolved in tissue buffers decreases in carbon dioxide concentrations. Thus, with MA rich in oxygen it is usually found that oxygen concentrations decline with time of storage, but that carbon dioxide concentrations alter little after the initial dissolution of the gas in the tissues (Nortje and Shaw, 1989). If packs with oxygen-rich atmospheres are to be stored for relatively long times, the volume of the pack atmosphere should be about three times the volume of the product, to avoid excessive decreases of oxygen concentrations (Holland, 1980). The solubility of nitrogen in tissues is low, and the gas is metabolically inert. Thus, the only function of nitrogen in a pack atmosphere is to buffer against changes in the volume of the atmosphere that could lead to pack collapse, with crushing of the contained product. If carbon monoxide is included in a pack atmosphere it is at concentrations less than 1 %. The gas will be removed from the pack atmospheres as it reacts rapidly and essentially irreversibly with myoglobin. The changes in pack atmosphere volumes as a result of the binding of carbon monoxide are trivial in comparison with the volume decreases arising from dissolution of carbon dioxide. MAP for bulk meats are usually intended only to enhance stability for short times during the distribution of product from slaughtering or carcass breaking facilities to retail packing facilities. Protection of the product from crushing by its being in a pillow-pack is often considered to be as important as any effects of the atmosphere on the colour or microbiological condition of the product. Optimized storage of fresh meat can yield 9 – 15 weeks of useful product life if meats are held at - 1.5 +/- 0.5 oC in atmospheres saturated with CO2 and devoid of O2. These systems are most useful for longterm storage and the intercontinental transport of primal cuts of meat (Tewari et al., 1999). Due to residual O2 present in the package, some surface discoloration occurs due to the oxidation of myoglobin to form metmyoglobin (brown).

The use of carbon monoxide in modified atmosphere is not permitted in most countries, because of the highly poisonous nature of that gas. Despite that, the risks to consumers from the presence of small amounts of carboxymyoglobin in raw meat appear to be small, and carbon monoxide is a common component of the modified atmospheres used with raw meats in Norway (Sorheim et al., 1997). As carboxymyoglobin confers a red colour on meat irrespective of the presence of oxygen, a modified atmosphere with carbon monoxide need contain no oxygen. The input gas then typically contains 60 % carbon dioxide and 40 % nitrogen, with carbon monoxide at 0.3 to 0.5 %. The major components of the input gas are at concentrations that will give the maximum carbon dioxide concentration after equilibration without the risk of pack collapse. Thus, the carbon dioxide concentration can be maintained at levels above that required for maximum inhibition of aerobic spoilage organisms for relatively long times, without resort to volumes of atmosphere much greater than the volumes of product. Therefore carbon monoxide/high carbon dioxide atmospheres stabilise meat colour and delay microbial spoilage, and so preserve the product in an acceptable condition even when delivery is relatively infrequent and display is prolonged.

High O2 MAP system

The elevated oxygen levels used in high-oxygen MAP will delay browning of fresh meats, compared with PVC packaging, because the depth of the bright red surface oxymyoglobin layer is increased by 3 - 5 mm (MacDougall and Taylor, 1975). This type of packaging system has been known to the meat industry for many years. It keeps the colour of the meat bright red throughout the storage period. Aerobic bacteria tolerate high concentrations of O2, thus, their growth can be reduced by including CO2 (typically 80 % O2/20 % CO2) in the gas mixture (Gill and Molin, 1991). This system is able to extend the shelf life of beef by 2 weeks while maintaining an acceptable red colour at - 1.5 oC (Gill and Jones, 1994). Yet the shelf life is considerably less than that given by anoxic atmospheres due to the oxidative rancidity (lipid oxidation) induced by O2 and the rapid growth of psychrotrophic bacteria (Cole, 1986). There have been successful applications of this system. For example, a large British supermarket chains, converted its entire fresh meat operation into a high O2 MAP centralized operation (Brody, 1996) or, has combined vacuum-skin packaging (VSP) and high O2 MAP for the delivery of fresh meat cuts. Each cut is first vacuum-skin packaged in an O2-permeable film, and then bagged in an O2-impermeable PA pouch with a gas mixture of 80 % O2 and 20 % CO2 (Jayas and Jeyamkondan, 2002).

Typically, co-extruded PA/PE films are used for high-oxygen MAP (Sorheim et al., 1999; John et al., 2004). The PA provides strength, and the PE provides gas and water vapour barrier properties and heat sealability. Meats packaged in high oxygen MAP typically retain acceptable red colour for 10 - 14 days of retail display, compared with 3 - 7 days for PVC packaged meats. The MAP film is more puncture-resistant than PVC film, but the primary economic advantage of MAP is the additional 7 – 10 days of red colour stability, allowing retail meat packaging to occur in large volumes at central packaging facilities. Retail packages are shipped to stores in a “case-ready” format for retail display. This allows supermarkets to offer retail fresh meat products at lower cost because the expense of in-store retail meat packaging is avoided (Cornforth, 1994). Disadvantages of high-oxygen MAP include accelerated lipid oxidation and off-flavour development (Jakobsen and Bertelsen, 2000; Jayasingh et al., 2002), bone darkening of bone-in cuts (Mancini et al., 2005), and premature browning during cooking (Torngren, 2003; Seyfert et al., 2004a,b; John et al., 2004; John et al., 2005). Ground beef from high-oxygen MAP developed objectionable oxidized flavours upon cooking after as few as 6 days in an 80 % oxygen environment (Jayasingh et al., 2002).

Low-Oxygen Packaging of Fresh Meat with Carbon Monoxide

The most recent meat packaging technology is anaerobic (essentially no oxygen) MAP with low levels (0.4 %) of CO, 20 to 30 % CO2 and the remainder nitrogen (CO-MAP). This packaging method offers several advantages over aerobic packaging with PVC or high-oxygen MAP including:

- Desirable red colour stability (El-Badawi et al., 1964; Gee and Brown, 1978; Brewer et al., 1994; Jayasingh et al., 2001; Kusmider et al., 2002; Krause et al., 2003; Hunt et al., 2004) associated with microbial plate counts below spoilage levels for as long as 28 days for ground beef and 35 days for steaks or roasts (Jayasingh et al., 2001; Hunt et al., 2004).

- Better flavour acceptability, no oxidized flavours (Jayasingh et al., 2002).
- No bone darkening (relative to high-oxygen MAP; Mancini et al., 2005).
- No premature browning during cooking (relative to highoxygen MAP; Torngren, 2003; Seyfert et al., 2004a,b; John et al., 2004, 2005).
- Decreased growth of spoilage organisms and pathogenic bacteria in MAP compared with PVC due to combined effects of anaerobic conditions, refrigeration, and elevated CO2 (Silliker et al., 1977; Silliker and Wolfe, 1980; Sorheim et al., 1999; Nissen et al., 2000; Cornfort and Hunt and 2008). High-oxygen MAP and CO-MAP both share this advantage compared with meats in PVC wrap.
- Increased tenderness, due to less protein oxidation in an anaerobic environment (Lund et al., 2007), and also due to longer shelf life, allowing continuous action of endogenous tenderizing enzymes (Torngren, 2003; Grobbel et al., 2007).

Disadvantages of CO-MAP are:

1. Negative image of CO by consumers because it is a potentially hazardous gas.

2. Concern that products might look fresh even though bacterial levels are high and the product is spoiled.

Active packaging - oxygen scavengers

Interest in the use of active and intelligent packaging systems for meat and meat products has increased in recent years.

Active packaging refers to the incorporation of additives into packaging systems with the aim of maintaining or extending meat product quality and shelf-life. Active packaging systems include oxygen scavengers, carbon dioxide scavengers and emitters, moisture control agents and antimicrobial packaging technologies. Intelligent packaging systems are those that monitor the condition of packaged foods to give information regarding the quality of the packaged food during transport and storage. The potential of sensor technologies, indicators (including integrity, freshness and time-temperature (TTI) indicators) and radio frequency identification (RFID) are evaluated for potential use in meat and meat products. Recognition of the benefits of active and intelligent packaging technologies by the food industry, development of economically viable packaging systems and increased consumer acceptance is necessary for commercial realisation of these packaging technologies (Kerry et al. 2006). Various studies have been conducted to determine if oxygen scavengers might be used to prevent

permanent discolouration of red meats in atmospheres with initial concentration about 1 %, or transient discolouration of meats in atmospheres with very low concentrations of residual oxygen. Although some success with the atmospheres of the former type has reported (Doherty and Allen, 1998), the general utility of such an approach must be doubted because the muscle tissue itself acts as a very efficient oxygen scavenger. Certainly, findings with the use of oxygen scavengers in atmospheres of very low initial oxygen concentration have been that numerous, fast reacting oxygen scaverages must be employed if transient browning is to be prevented (Tewari et al., 2002).

Carbon dioxide scavengers and emitters

Since the permeability of carbon dioxide is 3 – 5 times higher than that of oxygen in most plastic

films, it must be continuously produced to maintain the desired concentration within the package

(Ozdemir and Floros, 2004). High carbon dioxide levels (10 - 80 %) are desirable for foods such as meat and poultry in order to inhibit surface microbial growth and extend shelf life. Removal of oxygen from the package creates a partial vacuum, which may result in the collapse of flexible packaging. Also, when a package is flushed with a mixture of gases including carbon dioxide, the carbon dioxide dissolves in the product creating a partial vacuum. In such cases, the simultaneous release of carbon dioxide from inserted sachets, which consume oxygen, is desirable. Such systems are based on either ferrous carbonate or a mixture of ascorbic acid and sodium bicarbonate (Rooney, 1995).

This innovative package consists of a standard MAP tray but has a perforated false bottom under which, a porous sachet containing sodium bicarbonate/ascorbate is positioned. When juice exudates from the packaged meat drips onto the sachet, carbon dioxide is emitted, thus replacing any carbon dioxide absorbed by the meat and preventing package collapse. The inhibition of spoilage bacteria utilising active packaging technology may reduce bacterial competition and thus permit growth and toxin production by nonproteolytic C. botulinum or the growth of other pathogenic bacteria (Sivertsvik, 2003). Lovenklev et al. (2004) reported that while a high concentration of carbon dioxide decreased the growth rate of nonproteolytic C. botulinum type B, the expression and production of toxin was greatly increased which means the risk of botulism may also be increased, instead of reduced if used in MAP systems.

Moisture absorbers

A major cause of food spoilage is excess moisture. Soaking up moisture by using various absorbers or desiccants is very effective at maintaining food quality and extending shelf life by inhibiting microbial growth and moisture related degradation of texture and flavour. In addition to moisture absorber sachets for humidity control in packaged dried foods, several companies manufacture moisture drip absorbent pads, sheets and blankets or liquid water control in high aw foods such as meats, fish, poultry, fruit and vegetables. Basically they consist of two layers of a microporous non-woven plastic film, such as PE or PP, between which is placed a superabsorbent polymer that is capable of absorbing up to 500 times its own weight with water. Typical superabsorbent polymers include polyacrylate salts, carboxymethyl cellulose (CMC) and starch copolymers, which have a very strong affinity for water (Day, 2003; Reynolds, 2007).

Antimicrobial packaging

Traditional methods of preserving foods from the effect of microbial growth include thermal processing, drying, freezing, refrigeration, irradiation, MAP and addition of antimicrobial agents or salts. However, some of these techniques cannot be applied to food products such as fresh meats (Quintavalla and Vicini, 2002). Antimicrobial packaging is a promising form of active packaging especially for meat products. Since microbial contamination of meat products occurs primarily at the surface, due to post-processing handling, attempts have been made to improve safety and to delay spoilage by the use of antibacterial sprays or dips. Limitations of such antibacterials include neutralisation of compounds on contact with the meat surface or diffusion of compounds from the surface into the meat mass.Incorporation of bactericidal agents into meat formulations may result in partial inactivation of the active compounds by meat constituents and therefore exert a limited effect on surface microflora (Quintavalla and Vicini, 2002).

Antimicrobial food packaging materials have to extend the lag phase and reduce the growth phase of microorganisms in order to extend shelf life and to maintain product quality and safety (Han, 2000). Comprehensive reviews on antimicrobial food packaging have been published by Appendini and Hotchkiss (2002) and Suppakul et al. (2003). The classes of antimicrobials listed range from acid anhydride, alcohol, bacteriocins, chelators, enzymes, organic acids and polysaccharides. Antimicrobial packages have had relatively few commercial successes except in Japan where Agsubstituted zeolite is the most common antimicrobial agent incorporated into plastics. Ag-ions inhibit a range of metabolic enzymes and have strong antimicrobial activity (Vermeiren et al., 1999). Coating of films with antimicrobial agents can result in effective antimicrobial activity. Natrajan and Sheldon (2000) carried out a study to evaluate the potential use of packaging materials as delivery vehicles for carrying and transferring nisincontaining formulations onto the surfaces of fresh poultry products. The efficacy of nisin coated (100 µg/mL) polymeric films of varying hydrophobicities (PVC, PE-LLD and PA) in inhibiting Salmonella typhimurium on fresh broiler drumstick skin was evaluated. It was concluded that packaging films coated with nisin were effective in reducing S.

typhimurium on the surface of fresh broiler skin and drumsticks. Ha et al. (2001) examined the effect of grapefruit seed extract (GFSE), a natural antimicrobial agent, incorporated (0.5 % or 1 % concentration) by co-extrusion or a solution-coating process in multilayered polyethylene (PE) films, on the microbial status and quality (colour (L, a, b), thiobarbituric acid reactive substances (TBARS) and pH of fresh minced beef. The antimicrobial activity of the fabricated multilayer films was also evaluated using an agar plate diffusion method. It was reported that coating the PE film with GFSE with the aid of a polyamide binder resulted in greater antimicrobial activity compared to GFSE incorporation by co-extrusion (Kerry et al. 2006).

The use of naturally derived antimicrobial agents is important as they represent a lower perceived risk to the consumer (Nicholson, 1998; Skandamis and Nychas, 2002) studied the combined effect of volatiles of oregano essential oil and modified atmosphere conditions (40 % CO2 : 30 % O2 : 30 % N2, 100 % CO2, 80 % CO2, vacuum packaged and aerobic storage) on the sensory, microbiological and physicochemical attributes of fresh beef stored at 5 and 15 oC. Filter paper containing absorbed essential oil was placed in the packages but not in direct contact with the beef samples. The shelf life of beef samples followed the order: aerobic storage < vacuum packaged < 40 % CO2 : 30 % O2 : 30 % N2 < 80 % CO2 : 20 % air < 100 % CO2. Longer shelf life was observed in samples supplemented with the volatile compounds of oregano essential oil (Kerry et al., 2006).

Freshness indicators

The information provided by intelligent packaging systems on the quality of meat products may be either indirect (i.e. changes in packaging oxygen concentration may imply quality deterioration through established correlation) or direct (Kerry et al., 2006). Freshness indicators provide direct product quality information resulting from microbial growth or chemical changes within a food product. Microbiological quality may be determined through reactions between indicators included within the package and microbial growth metabolites (Smolander, 2003). As yet the number of practical concepts of intelligent package indicators for freshness detection is very limited. Despite this, considerable potential exists for the development of freshness indicators based on established knowledge of quality indicating metabolites. The chemical detection of spoilage of foods (Dainty, 1996) and the chemical changes in meat during storage (Nychas et al., 1998) provide the basis for which freshness indicators may be developed based on target metabolites associated with microbiologically induced deterioration. Using the marker concept in this manner may result in the more widespread commercial development of freshness indicators for meat products in the not too distant future. A number of validation studies have been undertaken in order to establish the usefulness of TTIs in food products (Riva et al., 2001; Shimoni et al., 2001; Welt et al., 2003). Yoon et al. (1994) showed a positive correlation between oxidative stability and TTI colour change using a phospholipid/phospholipase-based TTI in frozen pork.

Presently, although several prototypes are being developed, commercial biosensors for intelligent

packaging are not available. For example, a biosensor/barcode called Food Sentinel System is being developed to detect pathogens in food packages. A specificpathogen antibody is attached to the barcode's membrane-forming part; the presence of contaminating bacteria will cause the formation of a localized dark bar, rendering the barcode unreadable upon scanning. A diagnostic system called Toxin Guard is being developed that incorporates antibodies into plastic packaging films to detect pathogens. When the antibodies encounter a target pathogen, to alert the consumer, inspector, or retailer the packaging material displays a clear visual signal. This system is planned for detecting gross contamination, because it is not sensitive enough for detecting very low levels of pathogens that can cause disease (Ayala and Park, 2000).

Environment friendly bio-degradable packaging

The actual tendency in packaging research is to develop and promote the use of “bio-plastics” which are useful in reducing waste disposal and are good replaces of petroleum, a nonrenewable resource with diminishing quantities (Ruban, 2009) (Souza et al., 2010). The problems in disposing of the huge quantities of waste generated by non biodegradable food packaging have led to the study of biopolymers as materials to be used as edible coatings in food packaging (Azeredo et al., 2012). Development of materials from natural polymers for different applications has been a hot topic for several years due to increasing prices of petrochemicals and increasing environmental concerns (Farris et al., 2009) (Laine et al., 2012). For more natural products, bio-based films or biopolymers, improving the quality of many products is important to satisfy the consumers demanding of more environmentally friendly packaging. This approach will continue to play an important role in the food industry (Cutter, 2006), (Satyanarayana et al., 2009). Today the use of polymers from renewable sources in food packaging is growing (Mensitieri et al., 2011). To enlarge the shelf-life of all types of foods with increasing the preservation and protection from oxidation and microbial spoilage the tendency is to use more natural compounds. The use of synthetic films has led to big ecological problems because this materials are non-biodegradable (Sabiha-Hanim and Siti-Norsafurah, 2012).

The natural biopolymers that are used in food packaging have the advantages to be available from replenishable resources, biocompatible, biodegradable, and all this characteristics led to ecological safety (Prashanth and Tharanathan, 2007). The structure of monomer used in polymer preparation is directly effective on the properties that are required in different areas of work, such as: thermal stability, flexibility, good barrier to gases, good barrier to water, resistance to chemicals, biocompatibility, biodegradability. (Mensitieri et al., 2011) says that polymers extracted or removed from natural resources can be degraded and transformed under different environmental conditions and under the action of different microorganisms.

Edible packaging

In world practice different film-forming materials used for food packaging which are produced as synthetic and biogenic composites. The leadingtrend of scientific developments in this direction is the creation of edible coatings. The edible films can be obtained from protein, polysaccharide and lipid substances. Among them, the most attractive are the edible protein-based films. They have higher barrier properties than films produced from lipids and polysaccharides. However, poor stability of the protein films to water vapor and their low mechanical strength are limited their using in food packaging. Thus, modification of protein-based films must be aimed primarily at improving the mechanical strength and barrier properties of the packaging material with respect to moisture (Bourtoom, 2009).

Chemical modification helps to achieve increasing plasticity (Park et al., 2008). The most commonly used plastisizers include various polyols (glycerine), oligosaccharides and lipids (monoglycerides, phospholipids) that are destroying the hydrogen bonds between polymer chains, make structure more fluid, thereby increasing the elasticity. However, the barrier properties of the film are reducing (Hettiarachchy, Eswaranandam, 2005); besides these agents significantly increase the hydrophilicity of the material and as a result, increase its vapor permeability. Successful attempts of increasing the elongation at break of the films were obtained when was applied formaldehyde and ethylene glycol (Wu, Zhang, 2001), however, due to the high toxicity of these compound, they can't use in the food industry.

Conclusions

Changes in consumer preferences have led to innovations and developments in new packaging technologies. Active packaging is useful for extending the shelf life of fresh, cooked and other meat products. Forms of active packaging relevant to muscle foods include; oxygen scavengers, carbon dioxide scavengers and emitters, drip absorbent sheets and antimicrobial packaging. Recognition of the benefits of active packaging technologies by the food industry, development of economically viable packaging systems and increased consumer acceptance opens new frontiers for active packaging technology. Commercially, there is widespread use of oxygen scavengers in pre-packed cooked sliced meat products. Antimicrobial packaging is gaining interest from researchers and industry due to its potential for providing quality and safety benefits. Future research in the area of microbial active packaging should focus on naturally derived antimicrobial agents, biopreservatives and biodegradable packaging technologies. The possibility of utilising additional active packaging technologies, as currently applied to other foodstuffs, for safe and effective storage of meat and meat products also merits investigation.

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