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NOVEL TECHNOLOGICAL INTERVENTIONS IN MEAT PACKAGING: A REVIEW

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Abstract
The packaging of meat provides the same or similar benefits as other types of food packaging. Though air- permeable packaging is most prevalent but the advancements in meat packaging by active, antioxidant, antimicrobial and nanotechnology has modified the area of meat packaging. This article explores the novel technological interventions in packaging of meat to enhance the quality and safety of meat products. Innovative measures including active packaging, intelligent packaging, antioxidant packaging, antimicrobial packaging, modified atmospheric packaging (MAP) and nanotechnology are used in packaging of meat. These packaging methods are environment benign and ecofriendly. For food microbial safety and achieve longer shelf life, antimicrobial and antioxidant active packaging have been developed which positively change the conditions of the package to effectively improve the safety and quality of the food therein. Intelligent packaging is an emerging and exciting branch of packaging science and technology that offers great opportunities for enhancing food safety, quality, and convenience, and consequently decrease the number of retailer and consumer complaints. RFID technology is a form of electronic information that can be applied in intelligent packaging. Advancements made in nanotechnology field has modified the packaging industry to a greater extent. The most commonly used cellulose based food packaging substrate is cellophane, which is also referred to as regenerated cellulose in film.

Keywords: Active packaging, meat, intelligent packaging, ecofriendly.

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1. INTRODUCTION

Packaging of food extends beyond the basic function of protection and provides many functions for and about the packaged product (Han, chapter 1, 2005). Packaging and packaging-related product characteristics influence purchase intentions and decisions by consumers so appearance, water binding (or holding) capacity, color characteristics, microbiological quality, fat stability, nutritional value, and palatability (texture, flavor, aroma) are important meat properties (Verbeke et al., 2005; Grobbel et al., 2008; & Singh et al., 2005) .This requires fabrication of packaging materials to maintain and prevent loss of these functional attributes to provide consumer convenience and usability by the desired containment, product maintenance and protection, and information about products of the packages (Yam et al., 2005).

2. RESULTS AND DISCUSSION

Types of meat packaging

There are many packaging conditions for raw chilled and processed meat to imbibe the desired qualities for storage. Although all package systems could be applied for most meat based products, the selection of packaging material for particular products rely upon the properties recommended for storage and the consumer acceptability. Packaging types range from air-permeable packaging materials for short-duration storage and retail display of raw chilled meat products to the use of barrier materials in vacuum packaging, bulk-gas flushing, and modified atmosphere packaging for long duration storage of raw frozen products and for processed or cooked meat products depending upon the particular desired attributes and applications (Kerry et al., 2006). Air-permeable packaging permits for myoglobin and O_2 binding to form oxymyoglobin pigments, which are seen as a red color, until the reducing capacity is lost and the pigments change to brown metmyoglobin pigments. Raw chilled meat for long term storage and cooked or processed meats are usually packaged in materials providing for an anoxic environment, which causes formation of deoxymyoglobin pigments for raw meat and maintains the nitrosyl hemochrome pigments in cured meat.

The major packaging options reviewed previously as air permeable, vacuum, and modified atmosphere (MAP) with low as well as high levels of oxygen (McMillin 2008). Packaging with air permeability has film with pores, or perforations that allow oxygen to diffuse from the atmosphere to cause oxymyoglobin formation on the meat surface. Polyvinyl chloride (PVC) or polyvinylidene chloride (PVDC) films are shrunk around the meat on trays in conventional overwrap packages. Vacuum packaging depends upon negative pressure to remove ambient air with sealing of the pouches or roll stock formed packages while the vacuum state is maintained. MAP is the exclusion of the gaseous environment and replacing with a suitable gaseous atmosphere, usually with blends rather than a single type of gas, in pouches, trays with lidding film, or formed roll stock film. Oxygen (O_2) creates oxymyoglobin red pigments that eventually oxidize to a brown color. Nitrogen (N_2) is relatively good, used primarily either to flush air from vacuum packaging or as a filler gas to prevent pack collapse in MAP.

Different packaging systems allow for permutations of these options so that air permeable packaging could be used within a master pack or tray-in-sleeve systems. Meat designed into primal cuts during processing is often packaged into vacuum packages in the form of pouches for retail outlets. If the primal cuts are to be separated into retail cuts for display then air-permeable packaging is often used to retain the red color of meat for better consumer acceptance. Vacuum skin technologies produce aerobic packages depending upon the type of forming film used, barrier or air-permeable, but the effect is to enhance the appearance and desired characteristics of the packaged product (McMillin 2008).

Bulk ground beef or individual cuts may be wrapped on polystyrene trays or in easy to peel (open) and freezer ready packages (Salvage et al., 2014). Most consumers anticipate purchasing ground (minced) beef in overwrap packaging while chub packages of ground beef, the least expensive way to buy ground meat, was purchased by 54% of consumers. Of consumers who planned to make burgers, 39% purchased pre-formed patties. Refrigerated burgers may be packaged in multiple cavities in polypropylene ethylene vinyl alcohol MAP trays while frozen burgers may be in VP. However, only 12.5% of consumers purchased VP ground beef. Shoppers of ground beef are most influenced by meat color and date code on the package, with price per pound and leanness also considered, but of lesser importance (Salvage et al., 2014). In a study of European consumers, 73% accepted vacuum packaging and 54.7% accepted modified atmosphere packaging (Van Wazemael et al., 2011). Safety of beef is implicitly expected by European consumers so less familiar modifications to packaging were less easily accepted by European consumers. A majority of consumers disliked (41%) or had a neutral opinion (35.9%) on the concept of preservative food additives being released form packaging materials. Packaging with natural agents had 36.6% acceptance and 40.3% neutral opinion while packaging with protective bacteria had 30.4% acceptance and 35.5% neutral reactions (Van Wazemael et al., 2011). U.S. consumers prefer longer shelf life as long as they understand the technology. Consumers in Europe and the U.S. prefer ground beef that is cherry red in color. Levels of CO not to exceed 0.4% of the MAP gas mixture are allowed to maintain wholesomeness of meat products in the U.S. but there are no reliable estimates on the types or quantities of meat that use CO in case-ready meat (FSIS, 2017). Providing information on CO use in packaging decreased U.S. consumer willingness to pay while some

German consumers willingness to pay was increased with information on CO even though CO is not allowed in Germany (Grebitus et al., 2013).

Active packaging

Active packaging is a technique in which the product, package and package environment interact to create a conducive environment for the food. This can be achieved by incorporating active compounds into the packaging materials to imbibe substances from the food or environment or to release components from the packaging into the environment or food. Protection and shelf life of the product in relation to interactions of the product, package and environment are often the functions of active packaging technologies, but other functions may also be employed (Yam et al., 2005). Active packaging may include chemo active and/or bioactive components.

EU regulations give specific rules on new types of materials and compounds to actively improve condition of the food, encompassing antioxidant, preservative, and flavor components (EU 2011). The approaches for active packaging are to incorporate the active compounds into a sachet for use with the packaging, to release active compounds, usually of nanometric size, into the polymer matrix or to imbed the inorganic particles into the package surface for controlled release. The EU guidance also includes the function of package absorption of chemicals from the food or package environment (Fang et al., 2017). Active packaging functions and technologies include control of moisture, control of oxygen diffusion into packages, control of carbon dioxide and ethylene diffusion from packages, scavengers or absorbing of oxygen, generation of oxygen or carbon dioxide, control of odors, enhancing of flavors, antimicrobial agents, and microwave susceptors in addition to indicators of specific compounds (Brody 2005 & Kruijf, et al., 2002). The most common active packaging modes are for antioxidant or antimicrobial purposes although other purposes may also be accomplished. Active packaging types and commercial applications for muscle foods were categorized into moisture absorbers, antimicrobial packaging, CO_2 emitters, O_2 scavengers, antioxidant, and other groups (Realini et al., 2014). Emitting sachets or pads may produce and release the active agent or carry and release the active agent, such as antimicrobial ingredients or antioxidant compounds of essential oils, allyl isothiocyanate, chlorine dioxide, and ethanol. Absorbent pads may absorb liquids or gases and be impregnated with silver, copper, or copper oxide nanoparticles (Otoni et al., 2016). The MAP headspace is reduced with CO_2 emitters by reducing the gas to product volume ratio while having direct antimicrobial effects on some microorganisms. Sealant film extruded with nitrite crystals for vacuum packaging promotes a prolonged red color to meat and extends shelf life about 10 times longer than overwrapped products, or 21 days for refrigerated ground beef, providing an alternative to MAP using PVC film and expanded polystyrene tray resin technology in master bags for case-ready raw chilled meats (Reynolds, 2012). Enzymatic reactions between the nitrite crystals and meat form nitric oxide to produce the red nitroxymyoglobin color (Higgins, 2012). In the U.S., red meat packaged in a film containing sodium nitrite must be coded with a "Use or Freeze by" date not to exceed 34 days after packaging for ground red meat and 36 days for whole muscle cuts of red meat (FSIS 2017). Fresh and frozen beef in nitrite-embedded film (~119 mg/m2 giving less than 2 ppm nitrite in the product) maintained acceptable red color through 19 and 39 days of retail display at 2°C, respectively (Claus & Du 2013). Oxygen in packages compromises the shelf life of meat and eventually causes quality deterioration due to oxidative processes so removal of O_2 from vacuum or MAP packaging is highly desired. Oxygen scavengers are used to reduce O_2 residuals to as low a level as possible since even 0.05% residual O_2 may induce oxidation of pigments and lipids (McMillin 2008). Oxygen scavengers are most commonly iron or ferrous oxide fine powders, although ascorbic acid, sulphites, catechol, ligands and enzymes like glucose oxidase may also be used (Brody et al., 2008). Glucose oxidase and catalase enzymes from A. niger with a dextrose energy source and sodium bicarbonate buffer can be incorporated into absorbent pads for meat packaging or applied to the product surface at levels less than 0.03% by weight of the meat or poultry (FSIS 2017).A cobalt (II) complex with ligand L-threonine was incorporated into organic polar polymer poly (vinyl alcohol) by casting and the oxygen consumption of the active film was equal to the complex alone (2.5 mg O_2 per g) after water activation (Damaj et al., 2015). Film (LDPE) containing powdered activated carbon impregnated with sodium erythorbate enhanced the heat resistance of the sodium erythorbate at the temperatures typical for LDPE manufacture and these films absorbed 3.57 mg O_2 in 11 days, about 80% of the O2 in the package headspace, but 20% of the absorbers by weight decreased the film tensile strength by 53% (Joven et al., 2015).The radical scavenging of tyrosyl acetate, hydroxytrosyl acetate, poly (tyrosyl) acrylate and poly(hydroxytyrosyl) acetate were maintained in the corresponding monomers and polymers while polyacrylate films did not exhibit cytotoxic activities (Fazio et al., 2017). Capacity of O_2-scavenging polymers, i.e. the amount of oxygen that can be scavenged, is a major consideration for scavenger use (Crews, 2016). Zero valent nanoscale iron particles blended with silicone matrix absorbed O_2 in wet and dry conditions and the absorption rate was 10 times higher at 100% relative humidity compared to that of a commercially available iron-based O_2 scavenger in a PE or PP polymer matrix (Foltynowicz et al., 2017). Another use of scavengers in barrier packaging is eradication of confinement odors created by normal meat respiration although care must be taken that spoilage odors are not also absorbed. This could be resolved by combining odour scavenging technologies with spoilage sensing smart labels. A difficulty in using aroma-based sensors for indicating product freshness is identifying a single volatile component that is related to consumer perceptions of quality or spoilage or detecting multiple indicators of spoilage. Ethylene scavenging materials are being incorporated into the film used for fruit and vegetable packaging. Incorporating antioxidants of natural extracts such as rosemary and oregano into films are being examined because there are regulatory concerns with use of heavy metals as antioxidants in packaging materials. Self-heating packages are being used for beverages and foods like eggs with fluid properties, but have yet to be designed for meat (Crews 2016). In addition to measuring conditions that might cause quality changes, processing and packaging attempt to inhibit or delay those factors. Shelf life of packaged fresh meats is often determined by microbiological activity or biochemical factors such as oxidation. There are many strategies of using antimicrobial and antioxidant compounds to extend shelf life of meat (Sun & Holley, 2012).

Antioxidant packaging

Another promising aspect of active packaging is the application of antioxidants in the packaging materials to enhance the oxidative stability of muscle foods. Residual oxygen level in the package causes lipid oxidation, microbial growth, textural changes, discoloration, off-flavors development, toxic aldehydes formation and nutritional losses (i.e. polyunsaturated fatty acid degradation), and is the primary cause of shelf life reduction of meat, poultry and seafood (Liu et al., 2010, Vital et al., 2016 & Gomez et al., 2014). Hence, it is important to control the level of O_2 in meat packaging in order to minimize spoilage and deteriorative reactions. Various types of antioxidants either synthetic or natural have been employed to prevent or delay the oxidative damage of lipids, nucleic acids and proteins by reactive free radicals (superoxide, peroxyl, hydroxyl and alkoxyl) and nonradicals (hypochlorous, hydrogen peroxide, etc.). These antioxidants scavenge radicals by inhibiting initiation and splitting propagation of chain or suppressing free radicals formation by chelating action, quenching superoxide and reducing hydrogen peroxide (Gomez et al., 2014, Mitsumoto et al., 2005 & Shi et al., 2001). Several beneficial aspects of this technology have been identified compared to the direct inclusion of antioxidants, for example, lower concentrations of active agents are needed, controlled antioxidants release, localized activity, and exclusion of certain processing steps (spraying, mixing or immersion (Bolumar et al., 2011). Synthetic antioxidants such as butylated hydroxyanisole (BHA), butylated hydroxytoluene (BHT), tertiary butyl hydroquinone (TBHQ) and propyl gallate (PG) are used extensively to enhance the shelf life of food products, typically of fat and fat containing products by providing oxidative stability. Though, the use of BHA and BHT in the formulation of foods may improve the quality parameters of the food, but are also known to have toxic and carcinogenic effect. Therefore, synthetic antioxidants are discouraged due to the increased consumer interest in safer and natural foods (Kerry et al., 2006).

Antioxidant Packaging (AP) could possibly be used with other types of treatment concurrently for the purpose of improving functionality and/or minimizing the negative effect of others. For instance, the shelf-life of chicken meat is extended substantially by employing rosemary extract in combination with high hydrostatic pressure (800 MPa) (Bolumar et al., 2011). More recently, Grossi et al (2016) compared vacuum packaging (as a control method), rosemary AP and O_2 scavenger packaging for their capability to counteract oxidation of lipid in pork patties upon storage at refrigeration temperature for two months, following high pressure processing (700 MPa, 10 min, 5 C). The progression of lipid oxidation was evaluated at the surface and the inner parts of the samples by measuring secondary lipid oxidation products and the propensity to form radicals via electron spin resonance spectroscopy. Oxidation of lipids was lower in the inner part as compared to the surface for all the three packaging systems. Rosemary AP showed very effective against high pressure-induced lipid oxidation compared to O_2 scavenging packaging. Besides preservative roles, the usage of EOs and other natural extracts in the packaging also provide health benefits to the consumer through their antioxidant and antimicrobial activities with no side effects and are therefore of great interest in the meat industry.

Antimicrobial packaging

Antimicrobial packaging is one of the most indispensable aspects in active packaging of meat. This is because meat provides the conducive environment for the substantial growth of microorganisms, therefore careful attention need to be given to reduce the bacterial growth in order to produce safe and wholesome product to the consumers. Spoilage microorganisms including bacteria, yeast and molds, and disease producing microorganisms, specifically Salmonella spp., Staphylococcus aureus, Listeria monocytogenes, Clostridium perfringens, Clostridium botulinum, and Escherichia coli O157:H7 are of major concern as they lead to quality deterioration and food safety issues in meat (Jayasena et al., 2013). The main objective of using antimicrobial packaging is to enhance the shelf stability in order to ensure the safety of meat and meat based products.

Adhering of antimicrobial components into a sachet/pad inside the package. The sachet/pad can be produced by generating antimicrobial compounds in situ with subsequent release, or by using sachets to carry and then release the antimicrobials (Otoni et al., 2016). A large number of antimicrobial agents, including ethanol, carbon dioxide, silver ions, chlorine dioxide, antibiotics, bacteriocins, organic acids, essential oils, and spices have been tested for the purpose of inhibiting the growth of microorganisms in foods (Suppakul et al., 2003 & Zhao et al., 2013). Among these antimicrobial active packaging studies, plant extracts (e.g. rosemary extract), peptides, and nisin have been used as antimicrobial agents (Arvanitoyannis et al., 2012). For example, nisin antimicrobial packaging has been used to retard the proliferation of the total proliferation of bacterial count and lactic acid bacteria of beef burger kept at 4°C and prolong its storage life (Ferrocinoa et al., 2016). Recently, packaging embedded with nanoscale silver coating has been used to fresh pork sirloin and the proliferation of the meat microbiota (mostly consisting of bacteria) is inhibited or retarded (Kuulialaa et al., 2015). In addition, essential oils have received great significance as natural antimicrobial substances for meat and meat based products. The phenolic compounds in essential oils, such as carvacrol, eugenol and thymol, are considered accountable for the observed antimicrobial property (Jayasena et al., 2013). The proposed mode of action is that these compounds enhance the permeability of cell membranes of microorganisms leading to the loss of microbial cellular constituents. Several organizations and companies have now commercialized various antimicrobial packaging concepts that can be applied to meat and meat based products and the major purpose is to enhance the food safety and extend shelf life.

Radio frequency identification (RFID) tags

RFID technology is a form of electronic information that can be applied in intelligent packaging. Compared with barcodes, the RFID tag is a more advanced data carrier for identification of products with several specific characteristics, such as significantly larger data storage capacity, non-contact, non-line-of-sight ability in gathering real-time data (Mennecke & Towsend, 2005). Nevertheless, the RFID tag is not considered as a replacement for the barcode, mainly because of its relatively higher cost and the requirement for a more powerful electronic information network. It is anticipated that both RFID and barcode data carriers will continue to be used in the meat processing industry either alone or in combination, depending on the situation (Yam et al., 2005).

In a basic RFID system, an RFID tag contains a tiny transponder and antenna that have a unique number or alphanumerical sequence; a reader emits radio waves to capture data from the RFID tag and the data are then passed through a real time database server onto a host computer (that may further connect to a local network or the internet) for analysis and decision making (Want, 2004). The RFID tags may be classified into passive and active tags. The passive tags have no battery and are powered by the energy supplied by the reader whereas the active tags have their own battery for powering the microchip's circuitry and broadcasting signals to the reader. The more expensive active tags have a reading range of more than 50 m, while the less expensive passive tags have a reading range of up to 5 m. The actual reading range depends on factors such as the frequency of operation, the power of the reader, and the possible interference from metal objects (Yam et al., 2005). Low frequency (~125 kHz) tags are cheaper, less energy consumption and are better able to penetrate non-metallic objects. These tags are most appropriate for use with meat based products, particularly where the tags might be obscured by the meat itself and are suitable for close-range scanning of objects with high water content (Kerry et al., 2006).

Intelligent packaging concepts

Intelligent packaging represents sensors or indicators that then signal a needed change or actually initiate a needed change in the package environment or package. Although the EU legal definition is on materials and items that monitor the composition of the food a more generally accepted characterization is a packaging system that can make use of intelligent functions to enhance decisions concerning shelf stability, safety, quality, and information about the food. The traceability, tracking, and recordkeeping of products through logistical chains could be improved through collection and integration of data obtained from identification and sensing devices such as barcode labels, radio frequency identification tags, time-temperature indicators, gas indicators, and biosensors (Yam et al., 2005).

Sensors and indicators are used in intelligent packaging systems, with examples being fluorescence-based O_2 measuring, detection of gases, monitoring of temperatures, toxins, freshness by tracking particular components, integrity of packages, and identification. Other technologies involved in intelligent packaging are remote based calculation of headspace gases by fluorescent sensors for O_2, package leak or integrity loss through sophisticated indicators, sensing of target metabolites or indicator substances that indicate freshness, and time-temperature indicators (TTI) based upon diffusion-based or enzymatic platforms. The devices used in intelligent packaging include barcodes, radio frequency identification (RFID) tags, time-temperature indicators (TTI), gas indicators, freshness or microbial growth indicators, and pathogen indicators. Each relies on different scientific and technological principles, giving information defined by the specific application (Fang et al., 2017).

Time-temperature indicators (TTI) have been developed to aid processors and consumers when there have been temperature conditions that reduce quality or may result in food safety concerns. There are many examples of commercially marketed TTIs. The concepts of diffusion-based, polymeric, enzymatic, bio-based, and electronic technologies for TTI have been reviewed (Wang et al., 2015). They concluded that TTI cannot precisely reflect the thermal history of food and forecast shelf stability because food package temperature and not product temperature is measured, few TTI can fulfill expectations, a more applicable kinetic model of food quality should be used in TTI development, and the cost should be reduced to promote application with food packaging. The application of thermochromics materials like photonic crystals, nanomaterials, and other new materials would solve problems in safety, accuracy, and cost to ensure safe and reliable food. European consumers appreciate and understand TTI technology and associate differing benefits with it, but the TTI concept and the commercial TTI based on pH decreases and structural changes of photochromic crystals did not meet all consumer expectations (Pennanen et al., 2015). Use of a consistent temperature and continual monitoring of temperature and O_2 in packages with built-in sensors can increase the storage period of fresh pork longer than 56 days (Petrak, 2016).

Gas indicators, freshness indicators, and pathogenic microorganism indicators and biosensors have been described in numerous reports, but there are few being used commercially. The addition of alginate polymers to zein-based colorimetric oxygen indicator films prevented leaching of dye that usually occurred when water contacted the films (Vu et al., 2013).This is only one of many difficulties in applying these technologies in practice and so research of the effects on sensory quality of packaged meat, integration of active and intelligent technologies for synergy, use of renewable resource materials, anti-counterfeit and tamperproof packaging, and multifunctional sensors is needed (Fang et al., 2017).

Modified Atmospheric Packaging (MAP)

Modified atmosphere packaging (MAP) is the exclusion and/or substitution of the atmosphere surrounding the product prior to sealing in vapor-barrier materials (McMillin et al., 1999). MAP can be vacuum packaging (VP), which expels most of the air before the product is enclosed in barrier materials, or forms of gas replacement, where air is removed by vacuum or flushing and replaced with another gas mixture. The headspace environment and product may change during storage in MAP, but there is no additional manipulation of the internal environment while controlled atmosphere packaging (CAP) uses continuous tracking and control of the environment to maintain a stable gas atmosphere and other conditions such as temperature and humidity within the package. CAP has most often been used to control ripening and spoilage of fruits and vegetables, usually in containers larger than retail-sized packages although some research has been conducted on packaging for individual fruits and vegetables (Ben-Yehoshua et al., 1989).

A major drift in packaging has been from passive to active (Yam et al., 2005).Active packaging is the embedment of specific compounds into packaging materials to maintain product quality and shelf stability while intelligent or smart packaging reveals information about the food profile or package condition to provide status of the environment or food to the consumer (Kerry et al., 2006). In active packaging, the primary active technologies mostly impart protection or shelf life of the product in response to interactions of the product, package and environment, although active packaging may perform other functions. Active packaging may also involve the intentional manipulation of the package environment at a particular time or condition passively or actively, but without the inputs and continuous monitoring needed with CAP (Zhao et al., 1994). Intelligent packaging systems have components that sense the environment and process the information and then allow action to protect the product by conducting communication functions.

MAP for meat based product needs a barrier for both moisture and gas permeation through packaging materials to maintain a sustainable package environment during storage. With any type of MAP, removal or changing the normal composition of atmospheric air is necessary and encompasses both aerobic and anaerobic types of packaging for meat. The major gases in dry air by volume at sea level are nitrogen (N_2, 78%), O_2 (20.99%), argon (0.94%) and CO_2 (0.03%), but the percentages vary when calculated by weight (Frick et al., 1981).

For successful active packaging, MAP must be seen as interrelated with other processing conditions, distribution and display of the entire fresh-meat marketing chain (Zhao et al., 1994). Successful development of MAP systems needs high O_2 or low O_2 for meat color during transit and display, postmortem age of whole muscle cuts, injected and improved products, phosphate types, use of vitamin E, slicing method for bone-in products, bone discoloration, package seal integrity, pre-pricing and dating, freight, cube (Smith, 2001). Other considerations of meat for MAP include globin state as raw or cooked, time after harvest, conditions at harvest, temperature of storage, anatomical muscle location, intact or ground, headspace to product volume, exposure to light and heat, anaerobic or aerobic atmospheric conditions (Siegel, 2001). Enhancement of shelf stability with MAP needs matching product and packaging materials through careful choice, suitable gas mixes, online monitoring of the packaged products, identification of leaker packages, and off-line analysis for general quality control (Stahl, 2005).

A major decision in choosing a MAP system is based on color of meat desired during transit and subsequent display. The packaging technique that provide meat for retail display with a red color are more highly used because consumers will discriminate against beef that is not red during display and sale and will avoid purchasing meat with 20% or more metmyoglobin (Carpenter et al., 2001). Even though a limiting value of about 5% O_2 partial pressure is required to maintain oxymyoglobin, O_2 higher than 13% will provide predominant oxymyoglobin pigments (Siegel, 2001).This is readily achievable with air-permeable overwrap packaging or high O_2 MAP and use of 0.4% or higher CO in any anaerobic packaging system will produce red carboxymyoglobin (Cornforth & Hunt, 2008).

MAP packaging concepts for raw chilled meat

The package prevents products against spoilage, which may include discoloration, off-flavor and off-odor development, nutritional loss, textural changes, pathogenicity, and other determining factors (Skibsted et al., 1994). The characteristics of meat that are significant in determining shelf life include water binding (or holding) capacity, color, microbiological quality, lipid stability, and palatability (Zhao et al., 1994). Shelf life is the period of time between packaging of the product and its use that the product properties remain acceptable to the product user, with shelf life properties being appearance, texture, flavor, color, and nutritive value. The factors that affect the shelf life factors of packaged fresh meat products are mixture of gases, package and headspace, packaging machinery and temperature of storage (Hotchkiss, 1989).The quality of packaged food is directly dependent on the food and packaging material characteristics so packaging materials have been fabricated to retain the desired qualities of meat during storage and distribution.

Materials used in food packaging are glass, metal, paper, and plastic (Marsh & Bugusu, 2007). Properties of plastic make them highly compatible for food packaging (Jenkins & Harington, 1991). Plastics exhibit properties of low density, resilience to breaking, no sharp edges, good heat sealability, fabrication flexibility, environmental friendly, barrier and permeability properties, printability and metal coating receptivity, resistance to tear and puncture, and flexibility at low temperatures that makes them suitable for packaging of foods. The essential properties of plastics for food applications are glass transition temperature, crystalline melting point, flexural modulus, tensile strength, tear strength, impact strength, flex life, water vapor transmission rate, O_2 permeability, optical properties, heat sealing properties, and bonding strength . Plastic film properties of thickness (1 – 2 mils), shrinkage (hour glass distortion on certain trays), clarity (haze, gloss), strength (tear, puncture), O_2 transmission, moisture transmission, and shelf life of anti-fog agents are important for meat package materials (Smith, 2001). The most conventionally preferred polymers for packaging of foods are low-density polyethylene, high-density polyethylene, polypropylene, polytetrafluoroethylene, and polyamide (nylon) (Jan et al., 2005). Polyesters, PVC, polyvinylidenechloride, polystyrene, polyamide, and ethylene vinyl acetate are also used in combination with food. Each kind of packaging material has advantages, disadvantages, consumer and marketing issues, environmental considerations, and cost. Fresh meat packaging is only partly permeable to moisture and so case hardening is prevented, while gas permeability differs with the application. The Irish Food Packaging Database indicated that the polymer types used as contact layers for chilled and frozen fresh meat were 79% polystyrene, 38% PVC and polyvinylidenechloride, 13% polypropylene, and 8% polyethylene (Duffy et al., 2006). A single layer or type of plastic generally doesn't have all of the needed characteristics for food packaging application, so lamination, coating or co-extrusion is used to create layers of plastic with the desired properties (Jenkins & Harrington, 1991). Heat sealing and barrier properties are often improved by application of coatings to the surfaces of plastic films (Kirwan & Strawbridge, 2003).

MAP applications may have thermoformed base trays prepared from unplasticized PVC/polyethylene, polyethylene terephthalate/ polyethylene, polystyrene/ethylene vinyl alcohol/polyethylene, or polyethylene terephthalate /ethylene vinyl acetate/polyethylene while preformed base trays are often made from polyethylene terephthalate, polypropylene, or unplasticized polyvinyl chloride/ polyethylene. Lidding films are often polyvinylidene chloride coated polypropylene/polyethylene, polyvinylidene chloride coated polyethylene terephthalate/polyethylene, or polyamide/ polyethylene. Flow wrap films may be polyamide/polyethylene, polyamide/ionomer, or polyamide/ethylene vinyl acetate/polyethylene (Mullan & 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 difference between the film surface and the surrounding atmosphere. Commonly used agents to prevent film fogging are glycerol esters, polyglycerol esters, sorbitan esters and their ethoxylates, alcohol ethoxylates, and nonyl phenol ethoxylate (Osswald et al., 2006).

Application of carbon monoxide in Meat packaging

Carbon monoxide (CO) has a history of application within the meat industry as a color enhancer due to its color stabilizing effects coupled with its antioxidant abilities. The use of CO as a packaging gas has many benefits including increased color stability, shelf-life extension due to microbial inhibition properties, enhanced flavor, reduced protein oxidation and lipid oxidation, improved tenderness and prevention of premature browning (Cornforth & Hunt, 2008). The application of low concentrations of CO (0.4%) for fresh muscle cuts and ground meat prior to vacuum packaging can maintain product freshness and wholesomeness, assist flexibility during distribution and prevent meat shrinkage (FDA, 2012). However, there is no consistency worldwide in the regulation of its use within the meat processing industry and the use of CO is currently receiving attention among researchers and within industry. Differing regulations globally can be a non-tariff barrier to trade limiting the possibilities for exports between countries (Grebitus et al., 2013).

Globally, the European Food Safety Authority (EFSA), European Commission (EC) and Food and Drug Administration (FDA) are important regulatory authorities. Their responsibilities include adherence to consumer safety and protection, and ensuring quality products which promote human health. EFSA are the foundation of the European safety system and provide scientific advice to the European Commission (EC) prior to policy making. However, the regulations of these authorities differ regarding the acceptance of certain additives, more specifically, the acceptance of CO as a packaging gas. Krause et al., (2003) reported that CO-MAP with mixtures of 0.5% CO, 70% and 29.5% N_2 significantly enhanced the color and sensory attributes of pork chops in comparison to overwrap, VP and MAP. Additionally, lipid oxidation was reduced when compared to overwrap packaging. While numerous studies have revealed the effects of CO on improved color stability, additional benefits of the application of CO have also been reported. Woodruff and Silliker., (1985) reported a concentration of 10% CO can penetrate 0.63–0.94 cm beneath the surface of meat, forming a bright stable red carboxymyoglobin layer while inhibiting microbial growth, further preventing odour and slime by-products. Brooks et al., (2008) concluded similar results with CO-MAP systems with a 0.4% CO concentration where pathogenic salmonella and E. coli O157 were reduced in comparison to packaging systems without CO.

Nanotechnology

Nanotechnology is an interdisciplinary area involving the utilization of materials with one or more dimensions that are less than 100 nm**.** Nanotechnology in food packaging is an advanced field in which packaging materials can be altered for improving the barrier characteristics, and mechanical and heat-resilience features, biodegradability, and flame retardation compared to conventional polymer. It also assures choices for designing antimicrobial and antifungal surfaces and sensing as well as signaling microbiological and biochemical changes. The food packaging industry could develop the capability to attract the largest market share for nanotechnology. The most prolific developments launched in the market till date are likely to increase the quality and shelf-stability of meat based products profoundly, by enhancing barrier characteristics and embedment of biologically active nanocompounds into or onto the packaging film commonly known as nanocomposites.

Cellulose nanofibers in packaging applications

Cellulose fibers have conventionally been used in food packaging for a wide range of processed foods namely dried food products, frozen or liquid foods, beverages and fresh foods. The fundamental role of packaging is protection and preservation of food, maintain its quality and safety, and reduction in food waste. The most commonly used cellulose based food packaging substrate is cellophane, which is also referred to as regenerated cellulose in film. A number of cellulose derivatives such as carboxymethyl cellulose,

methyl cellulose, ethyl cellulose, hydroxypropyl cellulose, hydroxyethyl cellulose and preparation of cellulose based films. Cellulose acetate is also widely used as a rigid wrapping film along with cellulose triacetate than other derivatives, since they possess low gas and moisture barrier properties. In 2008, a company from the United States, Innovia Films, released NatureFlex™ a cellulose film that offers an extremely diverse heat sealing property, printability, extended shelf life and excellent gas barrier properties. These extraordinary properties have allowed NatureFlex™ to find scope in various Food Processing sectors, such as dried cereal based products, confectionary, fresh produce, milk products, meat, pouches and tea packaging.
Application of nanoparticles as fillers or additives in polymers has gained great acceptance and significance in recent years. Nanoclays are relatively advanced substances that have been adhered into packaging materials for varied purposes. Polymer clay nanocomposites is a substitute to conventional polymers due to development of nanoscale dispersion that led to prolific developments in mechanical strength, barrier properties and physical characteristics and heat stability of the polymer films. Moreover, nanoclays can also aid in release of active substances for longer durations by increasing their solubility (controlled release) in the polymer matrix and thereby provide preservation of foods for longer duration of time. Montmorillonite (MMT), a hydrated alumina-silicate layered clay, is the most widely studied clay type in food nanocomposite preparation. Halloysite (HT) is two-layered alumina-silicate clay that has a tubular structure with varying internal diameter from 20 to 50 nm and length up to 10 mm.

3. CONCLUSION

Meat and meat products are highly nutritious foods that however also favour the growth and proliferation of spoilage and pathogenic microorganisms, making them high risk in terms of quality deterioration and food safety. To ensure food microbial safety and achieve longer shelf life, antimicrobial and antioxidant active packaging have been developed which positively change the conditions of the package to effectively improve the safety and quality of the food therein. Intelligent packaging is an emerging and exciting branch of packaging science and technology that offers great opportunities for enhancing food safety, quality, and convenience, and consequently decrease the number of retailer and consumer complaints. The sales of food packaging in all of its aspects will continue to grow in areas of packaging that provide safety, convenience, and quality of meat to consumers, but refinements are necessary before implementation is feasible and cost effective.

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