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PACKAGING AND STORAGE PRACTICES OF MEAT

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Abstract

Meat is a perishable product, it gets spoiled very soon if it is left uncovered and unprocessed in the ambient temperature. Meat can only be stored for future use through proper processing, packaging and storage. Though at present, processing of meat is very little in India, but rapid urbanization and changing life style demand ready to eat and convenient meat products. Due to the chemical composition and biological characteristics, meat is an excellent environment for microbial growth. The initial micro biota varies and contains mesophilic and psychrotrophic bacteria which can cause infections in humans and animals and spoilage of the meat. Thus, good manipulation practices and proper conservation methods are needed to put back or to inhibit the microbial growth. The currently employed consolidated preservation process is based on refrigeration and different types of packaging, which extends to a maximum shelf-life period.

Introduction

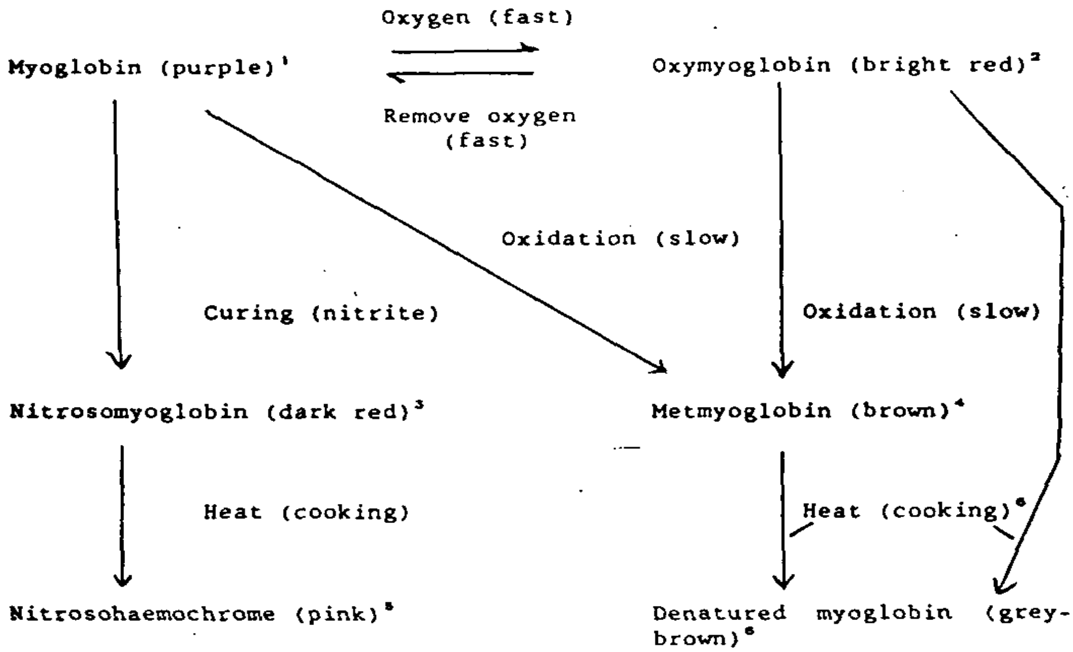
Meat production in India including poultry meat is estimated at 4.9 million tonnes (2010-11), standing eighth in rank in the world's meat production. Buffalo contributes about 30% of the total meat production in the country. Exports of Preparations of Meat in India averaged 5312.5 crore from 1996 until 2014, reaching an all time high of 13823 crore in 2010 and a record low of 122.5 crore in 1998. Imports of Preparations of Meat in India increased to 572200 crore in 2014 from 189 crore in 2013. Imports of Preparations of Meat in India averaged 30203.5 crore from 1996 until 2014, reaching an all time high of 572200 crore in 2014 and a record low of 0.5 crore in 1998. Export of meat is subjected to pre-shipment inspection and a certificate is required from State Animal Husbandry Department/ Directorate of Marketing and Inspection.

In the 1990s the average consumption of meat was 12 kg/ head per year for sub-Saharan Africa, 18 kg/head per year for Asia and 45 kg/head per year for Latin America (FAO, 1998) compared to an average of 76 kg/head per year in developed countries. Although a number of factors affect the long-term estimates for per capita demand for livestock products, the scenario predicted for changes in consumption patterns based on economic development has been considered (Bouwman, 1997) and the per capita demand (kg/year) for all the developing countries will increase from 17 kg in 1989/91 to 25 kg in 2010 and to 30 kg in 2025. It is considered that buffalo meat has a strong potential for meeting this requirement for increased per capita consumption. (Kondaiah and Anjaneyulu, 2003).

It was reported that an increase in pH in chicken breast meat due to the accumulation of amine and ammonia by psychotropic bacteria (Quio *et al*., 2002). Original quality of poultry meat can be evaluated by sensory attributes besides physical and chemical analysis (Balamatsia, *et al.,* 2006). To identify the first signs of meat alteration, different indicators were proposed for consideration, most important being pH, easily hydrolysable nitrogen and hydrogen sulphide identification (Halasz, *et al*., 1994).

Due to the diversity of product characteristics and basic meat packaging demands and applications, any packaging technologies offering to deliver more safe product and quality control in an economic and diverse manner would be favourably welcomed. 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).

Relationships between various forms of myoglobin (Egan *et.al*, 1988)



Spoilage of Meat

In air, aerobic bacteria predominate on meat. If nitrogen-containing compounds (i.e. amino acids) are used by these bacteria, the end products of microbial growth will include malodorous amines (ammonia, putrescine and cadaverine) and sulphur compounds. Together these cause 'off' odours and flavours that are typically described as putrid. These may become evident when bacterial numbers are as low as one million per cm (Husband, 1991). The economic and public health consequences of the presence of microorganisms in food depend on the species and quantity present. The number of microorganisms present in the product determines whether the contamination will cause microbial deterioration or disease. Fresh meat can be kept chilled or frozen; the maintenance temperature for the entire chain must be constant to ensure that the product keeps a uniform temperature (Fleet, 1999).Meat is considered chilled when it is kept between -1.5 to $+7^{o}$C for the entire time following the post mortem process (CSIRO, 2006). The optimum storage and transport temperature for chilled meat is the lowest possible temperature at which no freezing occurs. Non-vacuum packed meat begins to freeze at about –1.5°C, and vacuum packed meat starts to freeze at about –2°C (depending on the type of meat and pH) (Luchiari, 2006).

Packaging of Meat

Food is packaged for storage, preservation, and protection traditionally for a long time. These three are the basic functions of food packaging that are still required today for better maintenance of quality and handling of foods (Galić *et al.*, 2011). 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.

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)

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).

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Modified Atmospheric 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). The primary principle of MAP is the exclusion of oxygen (which limits the shelf-life of meat by causing oxidative rancidity and/or by enhancing the growth of spoilage microorganisms) by using a barrier film or by modifying the gaseous environment surrounding the meat. Modified atmosphere packaging may be defined as "the packaging of a perishable product in an atmosphere which has been modified so that its composition is other than that of air (Wolfe *et.al*, 1980)."

Temperature abuse of MAP products is particularly important in the case of *clostridia.* Most proteolytic strains of *C. botulinum* do not grow below 10.8^0 C; while non proteolytic strains grow at temperatures as low as 3.38^0 C (Sperber *et.al*, 1982).It has been reported that 3.38^0C is the minimum temperature at which growth and toxin production by *C. botulinum* type E take place (Schmidt *et.al.,* 1961). In a sense, the ability of non proteolytic strains to grow at low temperature may be more serious as the lack of proteolysis means that growth may not be organoleptically evident. Sausages and meat sandwiches inoculated with *C. botulinum* and stored at the lower temperature failed to become toxic within 60 days, whereas at 26^0C the toxin was detected after 6 days in aerobically stored samples and after 4 days in anaerobically stored samples. The anaerobic samples were considered organoleptically acceptable when toxic, whereas the aerobic were not (Kauter *et.al.,* 1981). These results suggest that thermal abuse even for short periods of time cannot be compensated by using a CO_2-containing atmosphere.

MAP (commonly 70-80% O_2 and 20-30% CO_2) and vacuum packaging are widely used methods for packaging meat. Packaging under high oxygen concentration, however, may cause an increase in the lipid and protein oxidation. These reactions affect the functional, sensory and nutritional quality of meat products. Lipid oxidation leads to discoloration, increase drip-loss, off-odors and production of toxic compounds. In addition, these modifications can negatively affect the sensory quality of meat products in terms of texture, tenderness and color (Rowe *et. al.,* 2004).

A major decision in choosing a MAP system is color of meat desired during transit and subsequent display. The packaging systems 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 (Carpenter *et al.*, 2001) and will avoid purchasing meat with 20% or more metmyoglobin (MacDougall, 1982). 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).

MAP applications may have thermoformed base trays made from unplasticizedPVC/polyethylene (PVCU/PE), poly(ethyleneterephthalate)/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).

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).

Vacuum Packaging

Vacuum packages for fresh meat increase the shelf life and thus improve the distribution efficiency and marketing of the product. Vacuum packaging is defined as "the packaging of a product in a high barrier package from which air is removed to prevent growth of aerobic spoilage organisms, shrinkage, oxidation, and color deterioration" (Genigeorgis *et.al*, 1986).

Brown discolouration of fresh meat (due to formation of metmyoglobin) normally occurs before unacceptable bacterial growth has occurred. The onset of discolouration occurs more rapidly at higher temperatures, and also in meat that has been stored for extended periods in vacuum packs (Bentley *et.al*, 1989).

Deterioration problems are minimized when the pH of the meat to be packaged is controlled and ideal storage temperatures are accurately maintained. Even at suitable refrigeration temperatures, however, meat may be subject to deterioration by microorganisms that are able to grow under these conditions in the absence of oxygen (Maria Lucila Hernández- Macedo *et.al.*, 2010). The packaging of poultry meat and meat based products has always been challenging because of their perishable nature due to high sensitivity of spoilage and pathogenic organisms (Fontes *et. al.*, 2011).

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).

Active packaging	Smart packaging

According to Gallas *et. al.* (2009), CO_2 is produced by microorganisms, because tissue anaerobic metabolism produces mainly lactic acid. In this packing technique, carbon dioxide (CO_2) concentration rapidly increases in 10 to 20% during the first four hours, reaching a maximum level of approximately 30%. At the same time, oxygen level is reduced to 1-3% due to the activity of meat enzymes.

A modern quality and safety assurance system should prevent contamination through the monitoring, recording, and controlling of critical parameters during a product's entire life cycle, which includes the post processing phase and extends over the time of use by the final consumer (Koutsoumanis *et. al.*, 2005).

In vacuum packing, air is removed from gas impermeable packages, which are immediately sealed. During storage of vacuum-packed foods, CO_2 level increases as a result of tissue and microorganism respiration (Gallas *et al*., 2009). This modified gas environment hinders the development of rapidly-growing mesophilic heterotrophic aerobes and stimulates the growth of slow-growing lactobacilli. The shelf life of vacuum packed meats in gas-impermeable packages is much longer compared with meats packed in the presence of atmospheric air (Oluwafemi, 2013).

Antimicrobial Packaging

Microbial contamination reduces the shelf-life of foods and increases the risk of food borne illness. Traditional methods of preserving foods from the effect of microbial growth include thermal processing, drying, freezing, refrigeration, irradiation, modified atmosphere packaging, and adding antimicrobial agents or salts. Unfortunately, some of these techniques cannot be applied to some food products, such as fresh meats and ready-to-eat products. Appendini and Hotchkiss (1997) investigated the efficiency of Lysozyme immobilized on different polymers. It is known that cellulose triacetate (CTA) containing Lysozyme yields the highest antimicrobial activity. Research is essential to identify the types of food that can benefit most from antimicrobial packaging materials. It is likely that future research into a combination of naturally-derived antimicrobial agents, biopreservatives and biodegradable packaging materials will highlight a range of antimicrobial packaging in terms of food safety, shelf-life and environmental friendliness (Coma *et.al*, 2001).

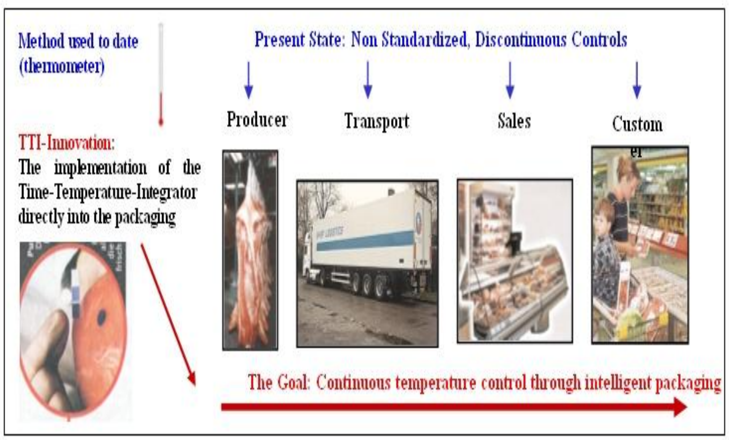
Antimicrobial packaging is a promising form of active food packaging, in particular for meat products. Since microbial contamination of these foods occurs primarily at the surface, due to post-processing handling, attempts have been made to improve safety and to delay spoilage by use of antibacterial sprays or dips. However, direct surface application of antibacterial substances onto foods have limited benefits because the active substances are neutralized on contact or diffuse rapidly from the surface into the food mass. On the other hand, incorporation of bactericidal or bacteriostatic agents into meat formulations may result in partial inactivation of the active substances by product constituents and is therefore expected to have only limited effect on the surface microflora (Stefania Quintavalla,*et.al,* 2002).

Anti-microbial	Time–temperature indicators
Ethylene scavenging	Microbial spoilage sensors/ Indicators
Heating/cooling	Physical shock indicators
Moisture absorbing	Leakage sensors
Odour and flavour absorbing/ Releasing	Allergen sensor
Oxygen scavenging	Microbial growth sensors
Spoilage retarder	Pathogens and contaminant Sensors

Antimicrobial edible films and coatings are presented as an emergent technology capable of increasing the safety and shelf-life of food products upon direct contact (Atarés, De Jesús, Talens, & Chiralt, 2010; Du *et al.*, 2009; Fernández-Pan, Royo, & Maté, 2012; Hosseini, Razavi, Mousavi, Yasaghi, & Hasansaraei, 2008).

Intelligent Packaging

The headspace of food packages undergoes changes in their composition over time. Devices capable for identifying, quantifying, and/or reporting changes in the atmosphere within the package, the temperatures during transfer and storage and the microbiological quality of food are the basis of intelligent packaging.

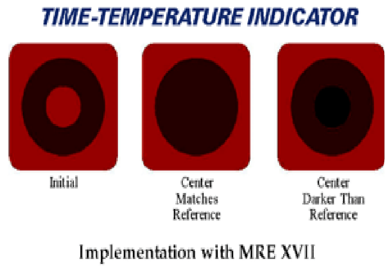


The indicators should be easily activated and exhibit a change (or show an indication) that is easily measurable and irreversible, time- and temperature- Examples of Active and Smart Packaging (Kit *et.al,* 2005) dependent changes must be reproducible and ideally matched or readily correlated with the food quality, and also provide information regarding the status of the package (Yam *et .al* 2005).

i.)Time-Temperature Indicators

They are of two types: visual indicators and radio frequency identification (RFID) tag. The visual indicators change color in response to cumulative exposure to temperature. The main mechanisms of action include enzymatic reactions, polymerization, or chemical diffusion. These products are used to monitor exposure to unsuitable temperatures during transport and storage and are an indication of quality for the producer because they ensure that the product reaches the consumer in optimal conditions (Welt *et al.*, 2003).

RFID tags are an advanced form of data information carrier that can identify and trace a product. They are currently used for tracking expensive items and livestock (Anonymous, 2007). In a typical system, a reader emits a radio signal to capture data from an RFID tag. The data is then passed to a computer for analysis. RFID tags contain a microchip connected to a tiny antenna. This allows for the tags to be read for a range of 100 feet or more in more expensive tags, to 15 feet in less expensive tags (Yam *et .al.*, 2005).



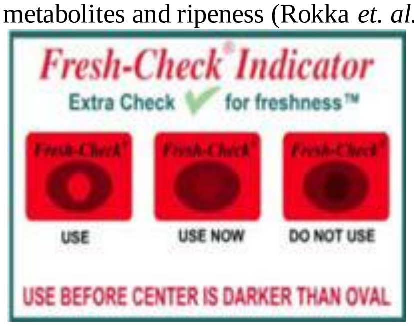
ii.) Seal and Leak Indicators

The gas composition in the package headspace often changes as a result of the activity of the food product, leaks, nature of the package, or environmental conditions. O_2 and CO_2 can be used to monitor food quality, as seal indicators (leaks), or to verify the effectiveness of an oxygen absorber. Most O_2 or CO_2 indicators change color as a result of chemical or enzymatic reactions. A color change indicates when the oxygen concentration exceeds the limit established in a sealed food package (Hu *et. al.,* 2009). A major problem with such indicators is that they require storage under anaerobic conditions, since they quickly deteriorate in air (Huang *et al.,* 2009).

iii.) Freshness Indicators

Freshness indicators provide an indication of the deterioration or loss of freshness of packaged foods. They are described as indicating different mechanisms of volatile metabolites, such as diacetyl, amines, carbon dioxide, (Nopwinyuwong *et. al.,* 2010) ammonia and hydrogen sulfide, produced during the aging of foods (Smolander *et. al.,*2002).

Changes in the concentration of hydrogen sulfide or organic acids such as *n*-butyrate, L-lactic, D-lactate, and acetic acid during storage are offered as viable indicators of the formation of metabolites in meat products, fruits, and vegetables (Wanihsuksombat *et .al.,* 2010). Indicators based on color changes due to changes in pH are of great potential use as indicators of microbial metabolites and ripeness (Rokka *et. al.,* 2004, Hong and Park 2000).



Products formed during microbial growth (carbon dioxide and hydrogen sulfide) and biogenic amines are of great potential use in indicating the freshness of meat and fish (Kerry *et al* 2006, Smolander *et al* 2002). Biogenic amines (putrescine, cadaverine, histamine, and others) are formed by degradation of protein-containing food to amino. Thus, biogenic amines are an indicator of food deterioration and only an indirect indicator of food freshness in meat (Rokka *et al* 2004) and fish (Pacquit *et al* 2006, Pacquit *et al* 2007).

Storage Trends Of Meat

Meat is a highly perishable product and must be stored under refrigerated conditions to control microbiological growth and other deteriorative changes. For consumers, assessing the overall quality of meat based on its appearance, especially since more and more appreciate refrigerated poultry meat both nutritionally and also the foods hygienic safety characteristic (Hui *et al.,* 2001). Meat with low pH has also been reported to decrease tenderness and increase shelf-life (Froning *et al.,* 1978, Barbut., 1993). During storage, in meat and meat products it me develop highly toxic substances such as ammonia, hydrogen sulphide, peroxidase, and biogenic amine (cadaverine, putresceine and other) that can appear because decarboxylation of amino acids in meat (Maria Kosova et.al, 2009).

The end of a product's storage life can be difficult to define accurately as changes that are acceptable to one person may not be acceptable to another. Storage life can be limited by adverse changes in colour rather than by changes in odour and flavour. In our experience, downgrading or rejection is usually based on visual assessment rather than on odour or flavour. Practical storage life (PSL) defined by the International Institute of Refrigeration

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(1986) as 'the period of storage during which the product retains it characteristic properties and remains suitable for consumption or the intended process'.

The time for which meat can be stored at chill temperatures is influenced mainly by the species of animal, pH, initial level of bacterial contamination, storage temperature and the type of packaging. High pH (6.0 or higher) meat will spoil quicker than meat with a pH of 5.3 to 5.7. Also, high initial levels of bacterial contamination on the surface of the meat will reduce the storage life because spoilage numbers of bacteria are reached sooner (Bem *et.al.*, 1995).

Microbiological spoilage is characterised by off-odours, slime formation and discolouration, and generally, spoilage occurs when the microbial population reaches around 100 million per cm^2. For these two reasons, beef will keep longer than lamb, because lamb has a higher pH and because of differences in the slaughter and dressing process, lamb carcasses tend to have higher numbers of initial bacteria (Kelly *et.al*., 1982). Chilled meat should be stored as cold as possible to maximise the storage period. A temperature of –1ºC to 0ºC is desirable and practical. Vacuum packaging and packaging in a modified atmosphere of 100% CO_2 will greatly extend storage life (Egan *et.al.*, 1988).

During frozen storage microbiological growth is arrested, but meat will slowly deteriorate due to oxidative and other changes. Frozen storage life is normally limited by the development of adverse flavours caused by oxidative rancidity of fat (Bill *et.al.*, 1988). The temperature of storage, method of packaging and degree of saturation of the fat all affect the onset of these changes. There is also evidence that a longer chilled storage time before freezing will reduce the frozen storage life - for instance, if chilled meat has been aged in vacuum packs and then frozen. The frozen storage life may also be reduced if the product is comminuted, because this process exposes more meat surfaces to air (Gill *et.al.*, 1985). Some people are more sensitive to alterations in flavour than others, so practical storage periods for frozen meat may depend on the market destination and the end specific use for the product (ASHRAE, 2002).

Microbial Profile of Meat (Afshin *et.al, 2011)*

Group	N	% of contamination	Mean	Std. Deviation	Std. Error
Total bacterial count	80	100%	5. 06515	0.17855	0.13891
Staphylococcus	80	65%	4.79575	0.92024	0.145505
Clostridium perfringens	80	83%	1.2749	0.273385	0.484805
Streptococcus	80	100%	4.074	0.5104	0.406955
Salmonella	80	-	-	-	-
Coliforms	80	100%	4.038	0.82892	0.131065

Conclusion

In order to keep our competitiveness and expansion in the chicken meat market, storage and preservation methods must be improved, supplying meat with adequate quality standards, long shelf life and widely accepted by the consumers. The retail display life of consumer portions of meat is normally limited by colour changes. Modified atmosphere packaging (MAP) in an atmosphere high in oxygen will extend display life. Due to the need of supplying safe products to final consumers, technologies that increase food shelf life have become increasingly important, including packaging. Therefore, products with consistent quality and safety standards should be offered to the consumers to maintain this market position

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