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Major Causes Of Meat Spoilage and Preservation Techniques: A Review

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Abstract
Meat is a nutritious, protein-rich food which is highly perishable and has a short shelf-life unless preservation methods are used. The objective of this paper is to review the mechanisms of meat spoilage and preservation techniques. Pre slaughter handling of livestock and post slaughter handling of meat play an important part in deterioration of meat quality. Some of the pre slaughter handling that influence the spoilage of meat includes; nutrition, transportation, marketing, lairaging and stunning. The main causes of meat and meat products spoilage after slaughtering and during processing and storage are; microorganisms, lipid oxidation and autolytic enzymatic spoilage. Meat preservation became necessary for transporting meat for long distances without spoiling of texture, colour and nutritional value after the development and rapid growth of super markets. Traditional methods of meat preservation includes; drying, smoking, brining and canning. Current meat preservation methods include, controlling temperature by chilling, freezing and super chilling, controlling water activity with sodium chloride and sugars, and use of different chemicals such as chlorides, nitrites, sulfides, organic acids, phenolic antoxidant and phosphates to control growth of microorganisms to prevent oxidative spoilage and to control autolytic enzymatic spoilage.
Key words: Meat, Spoilage, Preservation

1. INTRODUCTION

Meat is a nutritious, protein-rich food which is highly perishable and has a short shelf-life unless preservation methods are used. It is the first-choice source of animal protein for many people all over the world. Consumption of meat is continuously increasing worldwide. Although consumption of meat is increasing world wide the significant portion of meat and meat products are spoiled every year. The significant portion of this loss is due to microbial spoilage (Heinz and Haut zinger, 2007).

The transformation of animals into meat involves several operations: (a) handling and loading of animals on the farm, (b) transporting animals to slaughterhouses, (c) off-loading and holding of animals and (d) slaughtering of animals. Poor operational techniques and facilities in any of these operations will result in unnecessary suffering and injuries to animals which can lead to reduced meat quality and spoilage of meat (Chambers and Grandin, 2001). Therefore, prevention of contamination after slaughtering, during meat cutting and processing is essential (FAO, 1991). Storage time can be extended through hygienic slaughtering and clean handling of the carcass (FAO, 1990).

Different technical operations are involved in slaughtering: (a) stunning, (b) bleeding, (c) skinning (d) evisceration and (e) carcass splitting. Inadequacy at one stage will result in a rigorous negative impact on the product and/or process in the following stage (FAO, 1991). In addition to the hygiene and storage temperature, the acidity of the meat and the structure of the muscular tissue also affect the rate of meat spoilage. For example, liver will spoil faster than the firm muscular tissue of beef (Berkel et al., 2004). After few hours of slaughtering of animals, muscles become firm and rigid, a condition known as rigor mortis. The process of rigor mortis depends on the stress induced on the animals during the slaughtering process (Miller et al., 2002). Raw meat quality is reported to be severely affected by the stress conditions during slaughtering process and the slaughtering methods (Chambers and Grandin, 2001).

Fat, protein, minerals, carbohydrate and water are the constituents of meat (Heinz and Hautzinger, 2007). The quality of meat and meat products degrade as a result of digestive enzymes, microbial spoilage and fat oxidation). Lipid oxidation, protein degradation and the loss of other valuable molecules are the consequence of meat spoilage process. Proteins and lipids can break down resulting in the production of new compounds causing changes in meat flavor, tenderness, juiciness, odor and texture. It is therefore, important to understand the causes of spoilage of meat and meat product in order to develop optimum preservation techniques to maintain the freshness of these food products (Berkel et al., 2004). In spite of the aforementioned prevailing situation, there is paucity of information on the major causes of beef spoilage and preservation techniques. Therefore, this seminar paper was designed to:

- Highlight on the major causes of spoilage of meat of cattle's (beef).
- Review some techniques that are used to preserve meat

2. MEAT QUALITY

Compared with SMY%, meat quality is a more difficult characteristic to tie down and explain because it is ultimately determined by the perceptions of the person who consumes the beef, and it is well known that such perceptions vary from person to person and also for the same person at different times and on different occasions. A further complication for meat quality characteristics is that they vary widely from muscle to muscle within the same carcass, and factors that have a major effect on the quality of one muscle or cut may have little or no effect on another. In considering factors that may be responsible for differences in the quality of beef the focus will be on the appearance and palatability characteristics. Nutritive value characteristics will receive some mention as they are becoming increasingly important to the average consumer, but generally the nutritive value of lean beef is consistently high and much less variable than characteristics such as tenderness or color. It is crucial to the meat industry that the safety and wholesomeness of beef is maintained, at the current high levels, by the continuing development of comprehensive inspection and hygiene standards (Warris, 1996).

The perception of beef quality by consumers, however, is not determined totally by intrinsic properties. Extrinsic properties that require information about where the meat came from are becoming increasingly important to some consumers and such extrinsic aspects, that are usually not measurable on a piece of meat, include the type of farming system (e.g. organic farming practices), how the cattle were treated (particularly during the pre-slaughter period, and whether or not the cattle had received hormonal growth promotants (Warris et al, .1990)

3. CAUSES OF MEAT SPOILAGE

3.1. Pre-Slaughter Handling Effects on Meat Quality

Handling during the pre-slaughter period (that period after the animal is last removed from feed) is thought to have an effect on beef quality mainly through an effect on the ultimate pH of the beef by means of glycogen depleting events during this period. The different glycogen depleting events have an additive effect so that an animal that started the pre-slaughter period with a muscle glycogen at only 1% would have a muscle glycogen of 0.4% following a 0.6% glycogen depleting event, while an animal that started with 1.8% glycogen would have a muscle glycogen level of 1.2% following the same event (Jacobson, 1999).

This means that the same event has no effect on the ultimate pH of the latter animal but results in the former animal having a significantly elevated ultimate PH. If however, the latter animal was exposed to an additional 0.8% glycogen depleting event following the initial event, then it would have only 0.4% of glycogen at slaughter and would also have a significantly elevated ultimate PH. For most purposes an elevated ultimate PH results in beef of lower overall quality although some of the individual quality characteristics may be improved for certain purposes. Relative to beef with a normal rested ultimate pH of about 5.5, beef with an elevated ultimate PH will be characterized by:- A darker color, especially when the ultimate PH is above about 6.2, and this effect has given rise to the term "dark-cutting beef", A blander and usually less acceptable flavor. If foreign flavours are present, these become more apparent when the basic beef flavor is weaker, a shorter shelf life because some spoilage bacteria grow better at the higher PH and because fewer bacteria are needed to produce off-flavors when the pH is higher, A higher water-holding capacity, which may be an advantage for beef to be used for manufacturing purposes, Being tougher if the ultimate pH is in the intermediate range (PH of 5.8to 6.2), but as tender or more tender than an animal with a PH of around 5.5, if a high PH exists (PH of 6.5 to 7.0) (purchas,1991).

Overall, the aim during the pre-slaughter period, apart from maximizing the welfare of the animals should be to minimize the likelihood of elevated ultimate PH values. This can be done by a combination of having cattle accustomed to being handled, by avoiding excessively long holding times, by minimizing potentially stressful situations (strange noises , sights and mixing with strange animals), and by feeding animals well prior to this period so that muscle glycogen levels are not depleted or marginal. Bring cattle off pasture 4 hours or more before transport so they are easier to handle. However, minimize the fasting period to less than 8 hours to avoid carcass weight losses. Alternatively, provide hay or silage to avoid weight loss and improve behavior (Jacobson, 1999).

The glycogen content of animal muscles is reduced when the animal is exposed to pre-slaughter stress which changes the pH of the meat, to higher or lower levels, depending on the production level of lactic acid (Miller, 2002). Lactic acid is produced due to the breakdown of glycogen content of animal muscles via an anaerobic glycolytic pathway as shown in the following figure;

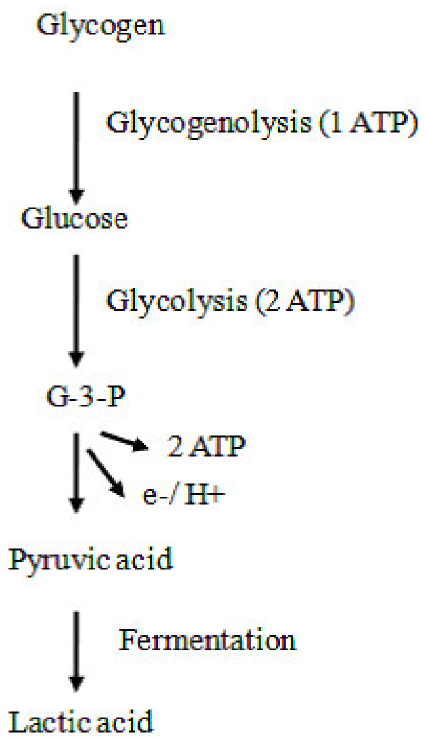
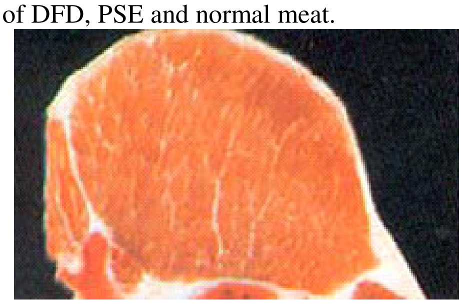


Figure 3: Anaerobic glycolytic pathway (Diwan , 2007).

Higher levels of pH (6.4-6.8) result in Dark, Firm and Dry (DFD) meat. Long term stress causes DFD meat which has a shorter shelf life. (Chambers and Grandin, 2001). Severe short term stress results in a Pale, Soft and Exudative (PSE) meat. PSE meat has a pH lower than normal ultimate value of 6.2 which is responsible for the breakdown of proteins, providing a favorable medium for the growth of bacteria (Miller, 2002). The following figures show the texture and color of DFD, PSE and normal meat.



(A) Normal meat.

(B) Pale Soft and Exudative (PSE) meat.

(C) Dark Firm and Dry (DFD) meat.
Figure 4: Meat texture and color (Chambers and Grandin, 2001).

3.1.1. Nutritional effects on meat quality

Nutritional effects can be divided into the effects of the level of nutrition and the effects of the composition of the diet. In both cases there will often be an effect on growth rate, so that in order to compare two animals at the same weight they will be at different ages. It is quite possible that even at the same weight they will have a different level of fatness so it is often difficult to distinguish between indirect effects of a nutritional treatment through differences in age and/or fatness, and direct effects (e.g. of specific nutrients).Not surprisingly, many trials have been conducted in this area and it is not possible to do justice to all the results that have been published, because for just about every significant effect that has been reported it is possible to find another similar trial where the effect did not occur(Schaefer et al.,1997).

The limited number of effects that have arisen with reasonable consistency, that would lead to beef from one animal being superior in one or more ways to that from another because of the amount of feed it received or because of the nature of that feed: 1) If one animal is fed in such a way that growth rates for the few months before slaughter are higher than those for another, some evidence suggests that the beef from the former animal is likely to be more tender. If the higher growth rates are the result of a high-grain ration (as is usual on a feedlot) the flavor of the beef will differ as well, but whether or not one is preferred will depend on the consumer involved. The greater tenderness may be due to several factors, but higher levels of marbling, and slightly more soluble collagen have both been suggested as possiblecauses.2) The effects of specific nutrients on beef flavor are less common than for meat from monogastric animals such as the pig because of the neutralizing effects of rumen metabolism, but some flavor effects have been reported, such as that associated with grain feeding (Voisinet and Grandin, 1997).

3.1.2. Transportation

Animals are reared on farms which may be situated far away from other farms, markets and slaughter plants. Therefore, they have to be transported over some distances to such locations either for better and less expensive feed, sale and slaughter. Transportation begins with loading and ends with unloading. Both thought to be done in a gentle manner and under a quieter environmental condition. (Adziteyand Nurul, 2011). During transportation, animals are exposed to environmental stress such as heat, cold, humidity, noise and overcrowding. Over speeding, sudden stops, rapid acceleration and long journey times without appropriate rest should be avoided as these will increase the spate of carcass and meat quality defects. Through the processes of rounding up, loading, transporting and off-loading cattle at the abattoir, there are animal welfare compromises. Fear of either the handling procedures and novelty of the environment makes the animal feel pain (Ohl& van der Staay, 2012).Transportation conditions appear to be by far the most common reported by most workers. This indicates that transportation is a critical point in the life of an animal prior to slaughter. Transportation is strange and life threatening to animals. During transportation, animals can do little to help themselves when they are in danger or discomfort due to confinement. In farms, markets and lair age, animals have much freedom of movement and could avoid certain uncomfortable conditions. Other conditions such as starvation, dehydration, injury, suffocation, heat or cold stress, overcrowding, death and many more do prevail in transportation (Warriss, 2000).

3.1.3. Marketing

Animals are either sold at the markets or sent directly from farms to abattoirs for slaughter. In the markets they may be kept in groups and in open pens which may expose them directly to the sun or cold. They may encounter stresses such as noise, unfamiliar environment and social regrouping. They can also be starved or dehydrated if feed and water is redrawn longer than recommended. Various degrees of bruising can occur on their skin at the market depending on the way they are handled (McNally, 1995). Stress experienced during routine handling and restraint procedures reduces productivity and Apart from causing poor meat quality and economic losses, stress has negative implications on animal welfare (Hemsworth et al., 2011).

3.1.4. Lairaging

Animals are held temporarily in the lairage prior to slaughter. It serves as a collection point for different animals just before slaughter. The lairage is also used to provide animals with some amount of recovery from stress during transport. Animal’s movement should be observed for any possible injury or infection. They should also be given adequate amount of suitable feed and water if they will be kept in the lairage longer than expected. Although lairaging is to enable animals to rest and to recover from transportation stress, it can be a major source of meat quality problems. Animals may suffer from different degree of bruising and injury as a result of fighting or overcrowding. Lairage can also act as reservoirs of infection by pathogenic bacteria and there is evidence that longer holding times increase the risk of carcass contamination (Warriss, 2003).
Careless and improper handling of animals in the lairage such as the use of electrical goads, abstracting the movement of animals through race, beating and firm grip of the coat with the hand, exposure of animals to microbial contaminations will adversely have effect on the carcass and meat quality. Conditions in the lairage therefore need to be conducive to prevent infections and the animals from being stressed further after vigorous transportation but to recover from transportation stress. During lairage, animals are subjected to ante-mortem inspection with the following aims: a) demanding and checking the health and vaccine certificates of the cattle; b) identifying the hygienic and health status to aid, with informative data, the post-mortem inspection tasks; c) identifying and isolating sick or suspicious animals before slaughter, as well as late pregnancy and recently calved cows; d) verifying the hygiene conditions of the pens and annexes (Snijders, 1988).

3.1.5. Effects of stunning and slaughter on meat quality

Stunning methods can have adverse effects on carcass and meat quality and cause downgrading. These could be visual effects such as bruising and hemorrhages, pelt burn in sheep, bone fractures, color changes caused by DFD as well as those manifested in eating quality such as toughness. During electrical stunning blood pressure changes, muscle spasms and convulsions can cause ruptures and hemorrhages in vessels and muscle as well as fractures (Gregory 1998). Post-mortem metabolism can be influenced by indirect stimulation by nerves. Broken vertebrae can occur when stunned with head to back electrode positioning if the voltage and the current is too high (Wotton et al., 1992).

Although hemorrhages can be induced by stunning and killing, the underlying mechanism is thought to be multi factorial. Histological studies on structures where hemorrhages occurred showed that blood leaking out of vessels is determined by the type of surrounding tissue and also the amount of blood leaving the circulation. Some hemorrhages were associated with hyper contracted and disrupted muscle fibers, indicating that they were caused by severe muscular strain. Many hemorrhages were found near venules or veins where rupture was observed, not in arterial vessels. This indicates that venous blood pressure increase can cause rupture of venules and small veins. In order to reduce petechial hemorrhages and bruising following can be considered: 1) Shorten stunning to sticking interval so that blood leakage through ruptured vessels is reduced.2) Captive bolt stunning may be preferable to electrical stunning if blood splash is a problem as muscle spasms are less pronounced after captive bolt.3) Electrical stunning currents are applied in a continuous and uninterrupted manner.4) In lambs electrical stunning with cardiac arrest may reduce blood pressure and blood splash (Kranen et.,2000).

4. POST SLAUGHTER HANDLING OF MEAT

There are three main mechanisms for meat and meat products spoilage after slaughtering and during processing and storage: microbial spoilage, lipid oxidation and autolysis enzymatic spoilage.

4.1. Microbial Spoilage

Meat and meat products provide excellent growth media for a variety of micro flora (bacteria, yeasts and molds) some of which are pathogens (Jay et al., 2005). The intestinal tract and the skin of the animal are the main sources of these microorganisms. The composition of micro flora in meat depends on various factors: (a) preslaughter husbandry practices (free range Vs intensive rearing), (b) age of the animal at the time of slaughtering, (c) handling during slaughtering, evisceration and processing, (d) temperature controls during slaughtering, processing and distribution (e) preservation methods, (f) type of packaging and (g) handling and storage by consumer (Cerveny et al., 2009).

The most common genera of bacteria found in meat before spoilage is Staphylococcus, Bacillus, Campylobacter, Clostridium, Listeria, Salmonella etc. Mold species found in meat include Cladosporium, Geotrichum, Penicillium and Mucor while yeasts species include Candida spp and Cryptococcus sp (Garcia-Lopez et al., 1998). The storage conditions affect the type of microbes found in meat and meat products. The favorable pH for the growth of spoilage bacteria for meat is in the range of 5.5-7.0. Slime formation, structural components degradation, off odors and appearance change were found in meat as a result of microbial growth within this pH range (Russell et al., 1996).

4.2. Lipid Oxidation;

Autoxidation of lipids is natural processes which affect fatty acids and lead to oxidative deterioration of meat and off-flavours development (Simitzis and Deligeorgis, 2010). After slaughtering of animals, the fatty acids in Tissues undergo oxidation when the blood circulation stops and metabolic processes are blocked (Linares et al., 2007). Oxidation of lipids in meat depends on several factors including: fatty acid composition, the level of the antioxidant vitamin E and prooxidants such as the free iron presence in muscles. Poly saturated fatty acids are more susceptible to lipid oxidation. Hydro peroxides are produced due to the lipid oxidation of highly unsaturated fatty acid fractions of membrane phospholipids, which are susceptible to further oxidation/ decomposition (Enser, 2001). Their breakage produce oxygenated compounds such as aldehydes and ketones. These secondary products can cause loss of color and nutritive value due to sever effects on lipids, pigments, proteins, carbohydrates and vitamins (Simitzis and Deligeorgis, 2010).

In meat, lipid hydrolysis can take place enzymatic ally or non-enzymatic ally. The enzymatic hydrolysis of fats is termed lipolysis or fat deterioration and is governed by specific enzymes such as lipases, esterase and phospholipase. Lipolytic enzymes could either be endogenous of the food product (such as milk) or derived from psychrotrophic microorganisms (Ghaly et al., 2010). Lipases enzymes are present in the skin, blood and tissue of animals. During lipolysis, lipases split the glycerides forming free fatty acids which are responsible for common off-flavour, frequently referred to as rancidity (FAO, 1986). The main enzymes involved in meat lipid hydrolysis are phospholipase A1 and phospholipase A2 (Toldra, 2006). The non-enzymatic hydrolysis is caused by heme proteins such as hemoglobin, myoglobin and cytochrome which are susceptible to oxidation and produce hydroperoxides (Kanner, 1994.

4.3. Autolytic Spoilage

Enzymatic actions are natural process in the muscle cells of the animals after they have been slaughtered and are the leading cause of meat deterioration. The enzymes have the ability to combine chemically with other organic compounds and work as catalysts for chemical reactions that finally end up in meat self deterioration. In the autolysis process, the complex compounds (carbohydrates, fats and protein) of the tissues are broken down into simpler ones resulting in softening and greenish discoloration of the meat. These autolysis changes include proteolysis and fat hydrolysis which are prerequisite for microbial decomposition. Excessive autolysis is termed "souring. Postmortem breakdown of polypeptides are the result of tissue proteases and is responsible for flavor and is textural changes in meat (Toldra and Flores, 2000). The enzymes calpains, cathepsins and amino peptidases are found to be responsible for the post mortem autolysis of meat through digestion of the z- line proteins of the myofibril (O'Halloran et al., 1997). Among these enzymes, calpains has been described as a preliminary contributor to the proteolytic tenderization process of meat. Proteolytic enzymes are active at low temperatures (5°C) which lead to deterioration of meat quality due to growth of microbes and biogenic amines production (Kuwahara and Osako, 2003).

5. PRESERVATION OF MEAT:

Meat preservation became necessary for transporting meat for long distances without spoiling of texture, colour and nutritional value after the development and rapid growth of super markets (Nychas et al., 2008). The aims of preservation methods are to inhibit the microbial spoilage and to minimize the oxidation and enzymatic spoilage. Traditional methods of meat preservation such as drying, smoking, brining and canning have been replaced by new preservation techniques such as chemical, biopreservative and nonthermal techniques. Current meat preservation methods are broadly categorized into three methods (Zhou et al., 2010). Controlling temperature, controlling water activity and use of chemical or biopreservatives and combination of these preservation techniques can be used to diminish the process of spoilage (Bagamboula et al., 2004).

5.1. Low Temperature Methods:

The basic aim of cooling techniques is to slow or limit the spoilage rate as temperature below the optimal range can inhibit the microbial growth. Low temperature methods of storage are used in three levels: chilling, freezing and super chilling. All these levels help to inhibit or completely stop bacterial growth (Zhou et al., 2010).

5.1.1. Chilling

Chilling is employed at slaughtering plants immediately after slaughtering and during transport and storage. It is necessary to reduce the temperature of carcass immediately after evisceration to 4°C within 4 h of slaughtering (USDC, 1995). Chilling is critical for meat hygiene, safety, shelf life, appearance and nutritional quality (. Zhou et al., 2010). Chilling also helps to prevent denaturing of proteins which may lead to bacterial attack as they are more susceptible to denaturated protein than native protein. On the other hand, cold-shortening and toughening may result from ultra-rapid chilling of pre-rigour meat (Ockerman and Basu, 2004). It is employed by two methods: immersion chilling, in which the product is immersed in chilled (0- 4°C) water and air chilling in which the carcasses are misted with water in a room with circulating chilled air (Carroll and Alvarado, 2008). Carcass surface temperature is reduced at faster rate by air chilling which improves carcass drying and minimizes microbial spoilage (Ocker man and Basu, 2004). The microbial quality of the air-chilled product is better than that of a water-chilled product (Barbut, 2002). The air-chilled carcasses lost 0.68% of their post slaughter weight in storage prior to cutting but lost no more during cutting or post cutting storage. On other hand water chilled carcasses absorbed 11.7% moisture in the chillers, of which 4.72% is lost within 24 h of intact carcass storage, 0.98% is lost during cutting and 2.10% is lost during storage resulting in 3.9% net water retention (Young and Smith ,2004).

5.1.2. Freezing

Freezing is an excellent method of keeping the original characteristics of fresh meat. Meat contains about 50-75% by weight water, depending on the species, and the process of freezing converts most of water into ice (Heinz and Hautzinger, 2007). Meat freezing phenomenon is fast and almost 75% of tissue fluid freezes at -5°C. The freezing rate is increased with decreases in temperature, almost 98% of water freezes at -20°C and complete crystal formation occurs at - 65°C (Rosmini et al., 2004). However, more than 10% of muscle bound water (chemically bound to specific sites such as carbonyl and amino group of proteins and hydrogen bonding) will not freeze. Freezing rate (slow and fast) affects the quality of frozen meat significantly. Fast freezing produce better quality meat than slow freezing (Garthwaite, 1997).

The preservation capacity of frozen meat is limited because the physical, chemical or biochemical reactions that take place in animal tissues after slaughtering do not stop absolutely after cold treatment (Rosmini et al., 2004). Microbial growth stops at -12°C and total inhibition of the cellular metabolism in animal tissues occurs below -18°C (Perez-Chabela and Mateo- Oyague, 2004). Complete quality changes of meat can be prevented at a temperature of-55°C (Hansen et al., 2004). However, enzymatic reactions, oxidative rancidity and ice crystallization will still play an important part in spoilage (Zhao et al., 2010). During freezing, about 60% of the viable microbial population dies but the remaining population gradually increases during frozen storage (Rahman, 1999b).

Pathogenic microorganisms are commonly isolated from thawed frozen meat (Perez-Chabela and Mateo-Oyague, 2004). The shelf-life of vacuum-packaged fresh beef is approximately 35-45 days; longer shelf-life of 70-80 days is possible with refrigeration of 0-2.3°C. Vacuum packaged frozen, whole-muscle beef has a recommended shelf-life of 12 months (Delmore, 2009). Low (-18°C) and constant storage temperature substantially increase the shelf life of meat. Shelf life of red meat stored at 15°C-30°C normally ranges from 6 months to 24 months (Perez-Chabela and Mateo Oyague, 2004).

5.1.3. Super chilling

Super chilling is a different concept than refrigeration and freezing and it has the potential to reduce storage and transport costs (Reynolds, 2007). Super-chilling refers to the temperature zone below its initial freezing point (1-2°C) but where ice crystals are not generated. In this process, instead of adding external ice to the food product, part of the internal water is frozen and works as a refrigeration reservoir, ensuring its refrigeration during distribution and transportation (Bahuaud et al., 2008). The main advantage of this method of preservation over traditional methods is that it increases the shelf life of meat for up to 4 times. Although most microbial activities are stopped or inhibited, chemical and physical changes may progress and in some cases are even accelerate (Magnussen et al., 2008).

5.2. Controlled Water Activity Methods

Microbiological safety of food is directly influenced by the water activity (aw). The term water activity (aw) refers to water which support the growth of microorganisms. It represents the ratio of the water vapour pressure of the food to the water vapour pressure of pure water under the same conditions (Ghaly et al., 2010). Water activity in meat products is equivalent to the relative humidity of air in equilibrium with the product (Comaposada et al., 2000). Most fresh meats, fruits and vegetables fall into moist food category, have a water activity more than 0.85 and require refrigeration or another barrier to control the growth of pathogens (Smith and Stratton 2006). Each microorganism has minimum, optimum and maximum water activities. Micro-organisms generally grow best between aW values of 0.980-0.995 and growth ceases at aW<0.900. Yeasts and molds can grow at a low aW of 0.6. However, growth of pathogens is prevented at aW of 0.85 (Ghaly et al., 2010). In processed and cured meats, the growth of gram negative bacteria (that can tolerate an aW of 0.94-0.97) can be suppressed with reducing water activity (Dillon, 1996).

Table 1: The minimum water activity for growth of the most common microorganisms associated with dried meat products (USDA, 2005).

Microorganisms	Water activity
Campylobacter	0.98
Pseudomonas	0.97
Clostridium botulinum(non proteolytic)	0.96
Clostridium botulinum(proteolytic)	0.93
Salmonella	0.94
Clostridium perfringens	0.93
Escherichia coli 0157:H7	0.95
Listeria monocytogens	0.92
Staphylococcus aeurus(anaerobic)	0.90
Staphylococcus aeurus	0.86
Aspergilus flavus	0.80

Water activity in meat is controlled by drying, refrigeration, adding chemicals or a combination of these methods. Sodium chloride and sugar are used to control water activity as free water binds up in their presence which results in an osmotic imbalance and finally inhibition of cell growth (Ray, 2004).

5.2.1. Sodium chloride

Sodium chloride (NaCl) in growth media or foods can be a source of osmotic stress by decreasing water activity. Salt-sensitive microorganisms, such as Pseudomonas spp. do not grow in meat when the water activity (aW) is reduced from 0.99 to 0.97 with the addition of 4% sodium chloride. However, salt tolerant microorganisms such as lactic acid bacteria and yeasts could grow at that level of water activity (Doyle, 1999).

5.2.2. Sugars

Sugars have the capabilities to bind with moisture and reduce water activity in foods. Dextrose, sucrose, brown sugar, corn syrup, lactose, honey, molasses and starches are generally used in dried meat processing as a source of sugars or carbohydrates to enhance flavor, reduce harshness of salt and lower water activity (USDA, 2005).

5.3. Chemical Methods

5.3.1. Chemical Methods for Controlling Microbial Spoilage
Energy intensive freezing operations are the greatest way to preserve carcass, meat and meat products for a longer time which inhibits bacterial growth, but not the psychrophiles and the spores. Most of these survive freezing and grow during thawing (Neumeyer et al., 1997). Traditional methods for preservation of meat by salting and picking are well accepted procedures. Other chemicals have been used as food additives for preservation of meat but every country has drawn its rules and regulations and established limits for the purpose of prevention of harmful effects to human (Cassens, 1994).

Antimicrobial preservatives are substances which are used to extend the shelf life of meat by reducing microbial proliferation during slaughtering, transportation, processing and storage. Growth of bacteria and spoilage of meat is depending on the species of bacteria, nutrients availability, pH, temperature, moisture and gaseous atmosphere (Cerveny et al., 2009). Antimicrobial compounds added during processing should not be used as a substitute for poor processing conditions or to cover up an already spoiled product (Ray, 2004). They offer a good protection for meat in combination with refrigeration. Common antimicrobial compounds include: Chlorides, Nitrites, Sulfides and Organic acids (Chipley, 2005).

Sodium chloride
Sodium chloride has a long history of use in food preservation in sufficiently high Concentrations. It inhibits microbial growth by increasing osmotic pressure as well as decreasing the water activity in the micro-environment. The combination of sodium chloride with other antimicrobial agents may have an impact on the overall inhibitory effect. A combination of NaCl and sodium lactate is more effective than lactates alone in delaying the onset of meat spoilage and its effects on its color and fat stability (Tan and Shelef, 2002). The use of sodium chloride in combination with sodium lactate reduces the microbial growth, maintain the chemical quality and extend the shelf life of ground beef during refrigerated storage (Sallam and Samejima, 2004).

Nitrites
The nitrites used in meat preservation industry are always in the form of salts such as sodium nitrite or potassium nitrite. Nitrites provide stabilized red meat color, cured meat flavor and rancidity retardation (Jay, 2005). Nitrite salts are effective in controlling color, lipid oxidation and odor in addition to controlling the anaerobic bacteria (Sindelar and Houser2009).

Nitrites affect the growth of microorganisms in food through several reactions including: (a) reacting with alpha-amino groups of the amino acids at low pH levels, (b) blocking sulfhydryl groups which interferes with sulfur nutrition of the organism, (c) reacting with iron-containing compounds which restricts the use of iron by bacteria, and (d) interfering with membrane permeability which limits the transport across cells (Ray, 2004).

Sulphites

As antimicrobial agent, sodium sulfite is efficient against aerobic Gram-negative bacilli, molds and yeasts in meat and meat products (Ray, 2004). The antimicrobial activity is the result of the un dissociated sulfurous acid which enters the cell and reacts with thiol groups of proteins, enzymes and cofactors. Yeast cells are attacked by sulfite because sulfite reacts with cellular Adenosine Triphosphate (ATP) and blocks the cystine disulfide linkages (Davidson et al., 2005).

Lactic acid

Lactic acid is shown antimicrobial activities against many pathogenic organisms such as Clostridium botulinum because of its abilities to reduce pH level, exert feedback inhibition and interferes with proton transfer across cell membranes .The salt of lactic acid (lactate) is used in the meat industry as an antimicrobial agent (Doores, 2005). The use of lactic acid bacteria as inoculums is a newly developed approach for food preservation. Lactic acid bacteria are effective in inhabiting undesirable microorganisms in food by producing a wide range of substances (such as lactic acid, acetic acids and hydrogen peroxide,) which inhabit the growth of other microorganisms (Matamoros et al. 2009).

Sorbic acid

Sorbic acid (2, 4-hexadienoic) and its salts are widely used throughout the world as meat preservatives for inhibiting bacteria and fungi (Feiner, 2006). A concentration of 0.3% sorbates in food is high enough to inhibit the microorganisms. The sorbic acid has an inhibitory mechanism via depression of internal pH. Sorbates can interfere with the bacterial spore germination, inhibit the activity of several enzyme systems and interfere with substrate and electron transport mechanisms (Davidson et al., 2005).

5.3.2. Chemical Methods for Controlling Oxidative Spoilage

Freeze storage cannot prevent oxidative spoilage and microbial/enzymatic spoilage (Jay et al., 2005). Thus, chemical preservation methods are quite beneficial in combination with refrigeration in order to optimize stability, product quality while maintain freshness and nutritional value (Cassens, 1994). Thorough understanding of lipid oxidation and its inhibition is necessary to prevent the development of rancidity, off flavor and discoloration in meat. Antioxidants can be classified as primary or long term antioxidants and secondary or processing antioxidants. Primary antioxidants include phenolic compounds while the secondary antioxidants include phosphates (Andre et al., 2010). Among the widely used lipid oxidation inhibitory additives in meat are: phenolic antioxidants (primary antioxidants) and phosphates (secondary antioxidants).

Phenolic antioxidants

Derivatives of phenol such as Butylated Hydroxyanisole (BHA) and Proply Gallates (PG) are referred to as synthetic phenolic antioxidants. Their use is extensive with the intention to delay, retard or prevent the negative effects of lipid per oxidation by scavenging chain-carrying peroxyl radicals or diminishing the formation of initiating lipid primary radicals (chain- breaking) and secondary radicals (preventive antioxidants) (Simitzis and Deligeorgis, 2010).

Phosphates

Among the antioxidants in food additives, a phosphate is one of the first investigated for their potential antioxidant activities in meat products (Trout and Dale 1990). A range of functionalities is provided by phosphates to enhance meat, poultry and sea food products. Functionalities of phosphate salts vary with the type of phosphate salt or combination of them. Phosphates critical functions include: (a) optimizing the water binding capacity of the muscle proteins by influencing pH, (b) interacting with muscle fibers for improved emulsification of fats, (c) maintaining the stability of the protein-fat-water system, (d) chelating divalent cations and retard rancidity which increase shelf life and (e) binding iron into the system and reducing oxidation (ICLPP, 2006).

5.3.3. Chemical Methods for Controlling Autolytic Enzymatic Spoilage

Autolysis is a term used to describe a series of postmortem chemical changes in the tissues of animals after death due to the presence of the enzymes (lipolytic, amylolytic and proteolytic) responsible for the metabolic process during the life of animals which are responsible for degradation of fats, carbohydrates and proteins after the death of animal. Lypolytic enzymes are responsible for the fat deterioration or lypolysis (oxidation) while amylolytic enzymes are responsible for the change of glycogen to lactic acid. The enzymatic activities of calpain, cathepsins and aminopeptidases enzymes are affected by pH and temperature. The membrane of the lysosomes becomes leaky as the pH of the meat decreases post mortem and the enzymes are released (O'Halloran et al., 1997). Moderate rates of postmortem pH decline (from 6.9-6.2after 3 h) allows for greater postmortem protein degradation and increased tenderization while rapid rates (from 6.9-5.8 in 3 h) and slow rates (from 6.9-6.6 in 3 h) produce less tender meat. Curing salts and acids have been used to inhibit the activity of such autolytic enzymes and prevent or slows degradation and spoilage (Maddock et al., 2005).

6. CONCLUSIONS AND RECOMMENDATIONS

Meat which is the main source of protein for human being is highly vulnerable to spoilage. Stress of animal's prior slaughter, causes glycogen depletion which play great role in the process of meat spoilage. Some of the main preslaughter stress that causes glycogen depletion are; prolonged transportation without rest, bruising, improper feeding, unusual sound and grouping in market and improper stunning. In addition to this meat provides favorable environment for the growth of microorganisms which lead to meat detoreriation. Fat in meat undergo auto oxidation which can also causes meat spoilage. Enzymatic autolysis can also minimize the shelf life of meat. Due to its short shelf life meat needs proper handling and preservation methods. The traditional methods such as drying, smoking, brining and canning are used to preserve meat. However; currently the widely used meat preservation techniques includes; water controlling activities, temperature controlling activities and use of chemicals. Generally, the animals should be properly handled prior to slaughter to reduce stress as low as possible and meat should be eaten when it is fresh, unless otherwise meat preservation techniques should be used so that spoilage of meat can be reduced. Thus based on the above facts and conclusions the following recommendations are forwarded:

- ✓ Cattles should be properly handled, by avoiding excessively long holding times, by minimizing potentially stressful situations (strange noises and sights, frantic activity and mixing with strange animals), and by feeding animals well prior to slaughter period so that muscle glycogen level are not depleted or marginal for the purpose of obtaining optimized beef and carcass quality.
- ✓ Specific training of slaughter men and abattoir staff, regarding management in key areas (such as animal handling, restraint, signs of stress and pain, times of unconsciousness and signs of loss of consciousness should be practiced as these points are vital to ensure good animal welfare and increase quality of products.
- ✓ Meat should be stored under proper temperature, as improper storage temperature and improper handling lead to meat spoilage.
- ✓ Meat should be eaten as fresh as possible, unless otherwise meat preservation techniques such as drying, smoking, freezing, chilling, chemical application etc should be used to avoid spoilage of meat.

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