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Effect of Low Temperature Preservation on Quality Characteristics of Meat

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Abstract

Meat is highly perishable commodity due to higher moisture and nutrient content. The main causes of spoilage in meat are microbial, chemical and enzymatic. Various preservation techniques have been developed to preserve meat and meat products with ten advancement of technology, consumer awareness for healthy and safe product as well as increased socio-economic status of people. Still low temperature preservation techniques viz. chilling and freezing are the best methods for short and long term preservation of meat respectively. These methods are used to slow down the enzymatic reactions and microbial growth, but also effects the physico-chemical and sensorial properties of meat with progression of storage.

Keywords: Chilling, Freezing, Sensory properties, Physical and microbiological changes.

Introduction

The food processing industry is one of the largest sectors in India in terms of production, growth, consumption, and export. Food processing industry is widely recognized as the 'sunrise industry' in India and is of enormous significance for India's development because of the vital linkages and synergies that it promotes between the two pillars of the economy, namely Industry and Agriculture. As the country moves on the path of development, agricultural sector evolves from traditional level farming to commercial agriculture producing high value and processed products. Now a days, meat has become one of the staple food because of it's nutrients dense quality, high in protein, low in fat, high content of minerals and vitamins. The meat safety regarding its physical damage, chemical changes and microbiological quality has become crucial because of consumer awareness and competition in international food market. Adequate meat preservation complements a marketing system which by necessity has been adapted to a fast throughput of fresh meat and which does not facilitate the use of surplus meat in periods of meat shortage. Spoilage is the deterioration of food which makes it taste and smell bad (e.g. when it is sour, rotten or mouldy) and/or makes it a carrier of

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disease germs. The onset of spoilage in meat is seen by changes in colour, among other things.

Main causes of food deterioration

Preservation techniques are designed to counteract or slow the changes which cause deterioration by:

- Microorganisms
- Enzymatic Reactions
- Chemical Reactions

1) Bacteria are single-celled micro-organisms that are invisible to the naked eye. They break down the wastes and bodies of dead organisms. Some cause severe illness. Under favorable conditions microbiological spoilage starts quickly in fresh and non-acidic products such as fish and meat. Bacteria from the animal's skin or intestines can rapidly reproduce.

2) Enzymes are proteins which assist biological reactions, e.g. the conversion of certain organic substances into different ones. When fish or animals are killed, the enzymes inside them are still intact. Those enzymes start breaking down components into smaller parts. This affects smell, taste and texture. Several hours after death rigor mortis occurs (a stiffening of the flesh). After that the flesh gets softer again due to enzymatic reactions (autolysis). Heat treatment (e.g. pasteurization) can inactivate enzymes.

3) With fatty fish or meat, chemical reactions can take place between the fat and oxygen in the air (oxidation reactions). By exposing these products for a long time to air, e.g. during drying and smoking, the product acquires a rancid smell and taste. It is therefore better to use less fatty kinds or pieces of fish or meat for smoking and drying.

Food preservation

It involves preventing the growth of bacteria, fungi (such as yeasts), or other micro-organisms (although some methods work by introducing benign bacteria or fungi to the food), as well as retarding the oxidation of fats that cause rancidity. Food preservation may also include processes that inhibit visual deterioration, such as the enzymatic browning reaction in apples after they are cut during food preparation. Preservation is the processing of foods so that they can be stored longer. Man is dependent on products of plant and animal origin for food. Because most of these products are readily available only during certain seasons of the year and because fresh food spoils quickly, methods have been developed to preserve foods. Preserved meat can be eaten long after the fresh products would normally have spoiled. With the growth of towns, the need to preserve foods longer increased as some people could no longer grow their own vegetables nor keep animals. Preservation must be seen as a way of storing excess meat and meat products that are abundantly available at certain times of the year, so that they can be consumed in times when food is scarce. Meat preservation includes any method by which meat is protected against spoilage by oxidation, bacteria, molds, and microorganisms. Traditional methods include dehydration, smoking, salting, controlled fermentation (including pickling), and candying; certain spices have also long been used as antiseptics and preservatives. Among the modern processes for meat preservation are refrigeration (including freezing), canning, pasteurization, irradiation, and the addition of chemical preservatives.

Preservation of meat- classified on the basis of these principles

1) Temperature controlled

Low temperature- chilling, freezing

High temperature- pasteurization, canning

2) Moisture control

Drying

Freeze drying

Curing

IMF

Smoking

3) Direct microbial inhibition

Irradiation

Use of chemicals and preservatives

Antibiotics

Bio preservation

Organic acids

4) Atmosphere control

Vacuum packaging

Modified atmospheric packaging

5) Newer methods

High pressure processing

Pulse electric field

Refrigeration and freezing

Meat is a highly perishable product and soon becomes unfit to eat and possibly dangerous to health through microbial growth, chemical change and breakdown by endogenous enzymes. These processes can be curtailed by reducing the temperature sufficiently to slow down or inhibit the growth of micro-organisms, to inactivate the enzymes and to slow down the rate of chemical reactions.

While mechanical refrigeration is a modern process it is known that the ancient Romans kept food cool with ice. "Chilled" meat is usually stored at temperatures around 1°C to +4°C when it keeps well for several days. Provided that the meat is kept very cool (1°C to 0°C) and that slaughter and meat cutting are carried out under strict hygienic conditions, modern packaging techniques including storage under carbon dioxide or nitrogen or in vacuum can extend this period to about 10 weeks. Chilling at temperatures very close to the freezing point of meat, -15°C diminishes the dangers of most pathogens and slows the growth of spoilage organisms; growth of some organisms, moulds, virtually ceases at -10°C. Most pathogens *(Salmonella, Staphylococcus species and Clostridium perfringens)* are inhibited by cooling but *Listeria monocytogenes* can grow at + 2°C, some *Salmonella* species at +5°C and *Campylobactor* at +7°C. Non-pathogens include *Pseudomonas* species which predominate on the exposed surface of chilled meat. Freezing - commercially at -29°C and domestically at -18°C - is now a standard method of preserving for periods of 1-2 years but there is some deterioration of eating quality compared with fresh or chilled meat.

However, there are problems in chilling and freezing meat. If it is cooled too rapidly below 10°C before the pH of the muscle has fallen below a value of about 6, the muscle fibres contract (cold shortening) and the meat is tough when cooked. This problem applies more to small animals, such as lamb, which cool down rapidly. The modern procedure is to cool the carcass to 10-15°C ("conditioning") and to hold that temperature for a few hours until the pH has fallen to 6. Beef carcasses can be suspended in such a way as to exert a pull on certain muscles to prevent contraction. Another method is to apply electrical stimulation to the carcass after slaughter (low volt) or after evisceration (high volt) for 2-4 minutes to bring down the pH rapidly.

Another problem can arise during thawing of pre-rigor frozen meat when the muscle contracts and exudes a substantial part of its weight as tissue fluids (thaw rigor) (Lawrie, 1991). Clearly, freezing of meat is not a straightforward procedure and calls for certain expertise. Only post-rigor meat should be frozen.

Physical changes

There is not much change in physical state of meat during chilling condition, but dung freezing ice formation involves a series of physico-chemical modifications that decrease meat quality. The principal physical changes in frozen meat and other food products are freeze cracking, moisture migration, recrystallization of ice and drip loss during thawing. During chilling, there may be problem of chiller loss due to temperature fluctuation and high RH.

Freeze cracking- in general, high freezing rate leads to small ice crystals and better quality meat. However, some products may crack when they are submitted to very high freezing rates or at very low temperature. The crust formed during freezing on the surface of a product serves as a shell that prevents further volume expansion, when the internal portion of the unfrozen stress is higher than the frozen material undergoes phase transition. If the internal stress is higher than the frozen material strength, the product will crack during freezing. Precooling prevents it because it reduces the differences in temperature between products and freezing medium.

Moisture migration- during freezing, supercooling of cell contents can lead to moisture movement through an osmotic mechanism. The driving forces for this are the temperature difference and resultant vapour pressure difference. Moisture migration in meat products produce surface desiccation and freezer burn, along with formation of ice inside the package. During thawing, it produces drip, which leads to nutrients loss, affects texture and juiciness and modifies the appearance of the products. Various components in meat products, which differ in their water activity, produce moisture redistribution and textural characteristics are lost. This condition is minimized by maintained small temperature fluctuation and small temperature gradients, and by the inclusion of internal barriers within the product and within the packaging.

Recrystallization of ice crystallization- it is defined as the increase in the average size of the ice crystals. The driving force for this phenomenon is the difference in the surface energy of two adjacent crystals, this energy being proportional to the crystal curvature.

The increase in ice crystal diameter during recrystallization leads to the redistribution of this solution around the tissue; its interaction with the protein structure contributes to denaturation, which also produces an increase of the exudate released by the tissue after thawing. Commonly hydrocolloids are recommended as ice crystal inhibitors.

Drip loss- During freezing, pure water is separated from the system in the from of ice crystals. Solute concentration increases and melting temperature decreases following the thermodynamic equilibrium line. With regard to exudates production, in frozen meats a slow thawing process at low temperatures is sometimes recommended to permit water diffusion in the thawed tissue and its relocation in the fibres.

Chemical changes

As the freezing process converts a large proportion of liquid water into ice, it also concentrates the remaining solution. Enzymes increase the possibility of water being in contact with different substrates. The most common chemical changes that can proceed during freezing and frozen are following:

Lipid oxidation- It is a complex phenomenon. A free radical process is the basic mechanism upon which lipid oxidation proceeds and the process includes a number of stages. One electron transfer from metal ions like haem and non-haem iron would dominate hydroperoxide breakdown during frozen storage. The occurrence of lipid oxidation in frozen meat leads to loss of quality:- flavor, appearance, nutritional value and protein functionality (Estevez, 2011). Decomposiiton of hydro peroxides of hydroperoxides of fatty acids to aldehydes and ketones is responsible for the characteristic flavors and aroma known as rancidity.

Protein denaturation- The main causes of freeze-induced damage to proteins are ice formation and recrystallization, dehydration, salt concentration, oxidation, changes in lipid groups and the release of certain cellular metabolites. This is very much common in frozen fish, meat, poultry, egg products and dough. Freezing has an important effect in decreasing water holding capacity of muscle systems on thawing.

Enzyme activity- Storage at low temperatures can slow (but not inactivate) the enzymes in the tissue; enzymatic reaction (hydrolyses like lipases, phoslipases, proteases etc., which catalyse the transfer of groups to water) may remain active during frozen storage. Hydrolytic enzymes can produce quality deterioration. Lipolytic enzymes, like lipases and phoslipases, hydrolyse ester linkages of triglycerols and phospholipids respectively. Hydrolytic rancidity, textural softening and color loss are direct consequences of hydrolytic enzymes activities.

Microbiological changes

Chilling is important for prevention of many spoilage and pathogenic batcteria, but there are some microorganisms which can grow at chilling temperature, like pseudomonas, *Listeria monocytogenes, Clostridium botulinum type E, Aeromonas hydrophila, Achromobactor* etc. which can cause spoilage in meat and meat product at chilling temperature. Sometimes mould can also grow when RH is much higher.

Freezing doesn’t cause destruction of bacterial cells, but inactivate them at this temperature, which can be activated during thawing. Meat freezes at -1.5^{0}C, at this temperature microorganisms are inactivated. At -10^{0}C almost all the microorganisms are not grown but the commercial temperature is set at -18^{0}C, because at this temperature almost all the chemical reactions are inhibited. At -38^{0}C all chemical reactions are complelety inhibited but, economy is not upto the mark.

Nutritional Changes

Meat is frozen without any prior treatment, unlike vegetables which have to undergo a preliminary blanching process to destroy enzymes involving considerable loss of water-soluble nutrients. So there is little or no loss of nutrients neither during the freezing procedure, nor, so far as there is reliable evidence, during frozen storage - apart from vitamin E.

Proteins are unchanged during frozen storage but fats are susceptible to rancidity. Pork and poultry meat are more susceptible since they are richer in unsaturated fatty acids than other meats, and comminuted meat is also very susceptible to rancidity because of the large surface area which is accessible to oxygen. The vitamin E is damaged because the first products of fat rancidity, hydroperoxides, are stable at the low temperature and oxidize the vitamin. At room temperature they break down to harmless peroxides, aldehydes and ketones, so that vitamin E is more stable at room temperature than during frozen storage. The losses incurred in frozen meat mostly take place when the meat is thawed, and juices are exuded containing soluble proteins, vitamins and minerals. This is termed "drip thaw" and the amount depends on the length of time of ageing (time between slaughter and freezing), whether frozen as carcass or meat cuts, conditions of freezing and speed of thawing; it varies between 1% and 10% of the weight of the meat and is usually about 5%. There is some loss of nutrients when the meat is cooked after thawing; results published in the scientific literature tend to measure the combined losses from the original fresh meat to the final cooked product. Unfortunately the results vary so much that it is not possible to draw conclusions.

It must be emphasized that the variations are largely due to difficulties in analysis of the B vitamins, and to differences in conditions and methodology - even results from the same laboratories are inconsistent. This is illustrated very clearly by results published from one group of investigators who examined pork loin after freezing and storage at -12°C and 24°C and subsequent cooking at regular intervals over one year for changes in thiamin, riboflavin and pyridoxine. Despite constant experimental conditions analyses at two monthly intervals showed wide fluctuations, especially for thiamin, which were attributed by the authors to difficulties in analytical methods.

It was tentatively concluded after storage at -12°C and cooking that about 90% of the thiamin was retained but no firm conclusions could be drawn about other vitamins. No conclusions could be drawn about storage at the lower temperature. For riboflavin about 90% was retained at -12°C and 100% after storage at -24°C and cooking, although these results were also variable. For pyridoxine 80% was retained when stored at -12°C and cooked but the results were erratic. In the same report ground beef was examined only after 1 year storage and showed 80% retention of thiamine, 85% of riboflavin and 100% of pyridoxine at both temperatures. Akhtar *et al.* (2013) suggested that losses during freezing and storage of meat and poultry for 6 - 12 months at -18°C but excluding subsequent cooking, ranged between zero and 30% for thiamin, riboflavin, niacin and pyridoxine. A survey of frozen meals analyzed after freezing, storage and cooking reported losses of up to 85% of thiamin, 55% of vitamin A, 33% vitamin E, 25% niacin and pyridoxine (De Ritter *et al*., 1974).

Sensory Changes

Some muscles are susceptible to cold shortening and thaw rigor, and in general allowing the muscle to undergo rigor mortis prior to freezing is recommendable. Due to lipid oxidation and protein denaturation there is liberation of free fatty acids and amino acids, which cause sensory and flavor changes. Metmyoglobin formation in red meats and caretenoids bleaching in fish and poultry tend towards parallel fat oxidation. In case of fish, the major problems found during freezing are oxidative deterioration, dehydration, toughening, loss of juiciness and excessive drip. Low temperature preservation is also one of the most commonly used processes commercially and domestically for preserving a very wide range of food including prepared meat and various meat products. Cold stores provide large volume, long-term storage for strategic food stocks in international global food market.

Conclusion

Meat is highly perishable commodity as it contains more moisture and nutrient content. These properties make it more prone to lipid oxidation and microbial spoilage. Therefore it becomes necessary to preserve meat and meat products to maintain quality and retard various physico-chemical changes and enzymatic reactions. Low temperature preservation viz. chilling and freezing is the best method of short and long term preservation of meat upto a prescribed time period. Low temperature preservation enhances the acceptability of meat and meat products in terms of sensorial and microbiological quality characteristics.

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