Consortium for Educational Communication

Module on

Principles of various preservation techniques of meat.

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2.2. Text:

Meat is a highly perishable commodity due to nearly neutral pH (low acid food), high moisture content and rich nutrients. The diverse nutrient composition of meat makes it an ideal environment for the growth and propagation of meat spoilage micro-organisms and common food-borne pathogens. It is therefore essential that adequate preservation technologies are applied to maintain its safety and quality. The quality of meat and meat products degrade as a result of digestive enzymes, microbial spoilage and fat oxidation (Berkel et al., 2004). Lipid oxidation, protein degradation and the loss of other valuable molecules are the consequences of meat spoilage process. Proteins and lipids can break down resulting in the production of new compounds causing changes in meat flavour, tenderness, juiciness, odour and texture.

2.3. Principles of various preservation techniques:

A number of interrelated factors influence the shelf life and keeping quality of meat, specifically holding temperature, atmospheric oxygen (O_2), endogenous enzymes, moisture (dehydration), light and, most importantly, micro-organisms. All of these factors, either alone or in combination, can result in detrimental changes in the colour, odour, texture and flavour of meat. Although deterioration of meat can occur in the absence of micro-organisms (e.g., proteolysis, lipolysis and oxidation), microbial growth is by far the most important factor in relation to the keeping quality of fresh meat. Traditionally, methods of meat preservation may be grouped into three broad categories based on control by temperature, by moisture and, more directly, by inhibitory processes (bactericidal and bacteriostatic, such as ionising radiation, etc.), although a particular method of preservation may involve several antimicrobial principles. Various methods employed to prolong shelf life of meat are:

I. Refrigeration/Chilling:

Chilling can be defined as the fundamental operation in applying cold to meat to reduce its temperature quickly. Rapid cooling of the meat surface not only slows and nearly stops the development of surface micro-organisms but also reduces weight loss and discoloration of the surface owing to haemoglobin oxidation. Temperatures below or above the optimum range for microbial growth will have a preventive action on the latter. 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 (Cassens, 1994). 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 hours of slaughtering (USDC, 1995). Chilling is critical for meat hygiene, safety, shelf life, appearance and nutritional quality. It is employed by two methods: (a) immersion chilling, in which the product is immersed in chilled (0-4°C) water and (b) air chilling, in which the carcasses are misted with water in a room with circulating chilled air. Chilling in air reduces carcass surface temperature and enhances carcass drying; both of which reduce the growth of bacteria. Generally, fresh meat is maintained in good condition for a period of 5-7 days at a refrigerated temperature of 4±1°C. During storage, ageing (ripening) of the meat also occurs, progressively increasing tenderness and developing taste through the proteolytic activity of meat enzymes. Ageing depends on temperature and can be accelerated by increasing it, but for hygienic reasons it is recommended that 4°C be used with a relative humidity of 85–95 percent. In these conditions ageing takes place in a few hours for poultry, two to four days for pork, four days for mutton and two weeks for beef.

Cold shortening can often be seen in beef and mutton, when the meat, still in its pre-rigor phase, reaches temperatures of 10°C or lower. These conditions cause irreversible contractions of the muscle tissue which toughen the meat even after prolonged ripening.

II. Freezing:

Freezing is the method of choice for long term preservation of meat. Meat contains about 50-75% by weight water, depending on the species, and the process of freezing converts most of water into ice. During freezing most of the water content of the meat, about 80 percent, solidifies into pure ice crystals, accompanied by a separation of dissolved solids. It stops microbial growth and retards the action of enzymes. Meat freezing phenomenon is fast and almost 75% of tissue fluid freezes at -5°C. The freezing rate is increased with decrease 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 (Rosmini et al., 2004; Garthwaite, 1997). At -18°C, storage life of buffalo meat, beef, mutton and chevon is approximately 6 months, while that of pork and poultry is less (4 months) because of associated unsaturated fat, prone to rancidity development.

Freezing rate (slow and fast) affects the quality of frozen meat significantly. Fast freezing produce better quality meat than slow freezing. During slow freezing formation of large ice crystals damages the cell and results in protein denaturation. Slow freezing facilitates the separation of solution and the migration of water out of the muscle cells which is subsequently frozen, forming rather large crystals. Quick freezing conversely produces many small ice crystals, mainly formed within the muscle cells, and reduces water migration and separation of solution. It is obvious that the latter technology will preserve the meat closer to its original quality and, particularly during thawing, moisture loss will generally be lower.

The main problem with frozen storage is deterioration in organoleptic quality. There may be changes in meat texture, fat can become granular and crumble, and there can also be some discoloration of the meat. Fat modification induced by air oxygen produces rancidity and acidity, and a disagreeable taste. Microbial enzymes also remain active, especially those that attack the fat. As in chilled storage, there are also weight losses through evaporation. This can be seen as freezer burn, i.e. superficial desiccated areas which can occur even in packaged meats when the packaging film is loose and temperature fluctuates inside the chamber. Weight loss, which can be between 1 and 4 percent in unpacked meat, favours organoleptic deterioration. The surface of the meat grows dry and porous, encouraging rancidity and transfer of aromas.

III. Superchilling:

The process of superchilling was described as early as 1920 by Le Danois, even though he did not actually use the terms ‘superchilling’, ‘deep-chilling’ or ‘partial ice formation’. The terms ‘superchilling’ and ‘partial freezing’ are used to describe a process where a minor part of the product’s water content is frozen (Magnussen et al., 2008). During superchilling, the temperature of the product is lowered, often 1–2 °C, below the initial freezing point of the product. After initial surface freezing, the ice distribution equilibrates and the product obtains a uniform temperature at which it is maintained during storage and distribution (Magnussen et al., 2008). Respiratory metabolism and aging process are repressed but cell activity is maintained during the storage period of superchilling. The main advantage of this method of preservation over traditional methods is that it increases the shelf life of meat for upto 4 times (Magnussen et al., 2008).

IV. Curing:

It means the addition of salt, sugar and nitrite or nitrate for the purposes of preservation, flavour and colour. Preservation of meat by heavy salting is an age old practice, as at concentrations greater than 4% in the aqueous phase it inhibits the growth of most spoilage organisms. Further addition of sodium nitrite resulted in comparatively improved products. The two main ingredients that must be used to cure meat are salt and nitrite. However, other substances can be added to accelerate curing, stabilize colour, modify flavour, and reduce shrinkage during processing. Salt is the primary ingredient used in meat curing. Originally it served as a preservative by dehydration and osmotic pressure which inhibit bacterial growth. The main function of salt in cured products is to add flavour.

Nitrates and nitrites, either potassium or a sodium salt, are used to develop cured meat colour. They impart a bright reddish, pink colour, which is desirable in a cured product. Nitrite is broken down to nitric oxide, which reacts with the red colouring matter in muscle, myoglobin to form deep-red nitrosomyoglobin. In addition to the colour role, nitrates and nitrites have a pronounced effect on flavour. They further affect flavour by acting as powerful antioxidants. Antioxidants are compounds that prevent the development of oxidative rancidity, which would reduce the keeping quality. Nitrite also reacts with proteins when heated to form compounds (called Perigotype factors) that inhibit the development of spores of *Clostridium botulinum*, the cause of botulism, the most serious type of food poisoning. Cured flavour develops due to reaction between fatty acids and sodium nitrite resulting in the formation of benzonitrile and phenylacetonitrile. Under certain conditions nitrite can form nitrosamines, some of which can be carcinogenic in the long term. However, nitrosamines can only be found in strongly cooked or fried meat products which were previously cured with nitrite. Nitrates and nitrites must be used with caution during curing. They are toxic when used in large amounts. The Federal and State Meat Inspection regulations limit the amount that can be used in curing.

Sugar (sucrose) serves several important purposes in cured meat. First of all, it adds flavour, and secondly, it counteracts the harshness of salt. Also sugar provides a surface colour characteristic of aged ham if caramelized sugar is used. Both brown and white sugars can be used. The sugars most frequently used are sucrose, cane sugar, dextrose, and invert sugar. The amount of sugar used is self-limiting due to its sweetening power.

There are several methods of curing:

1. Dry curing: In this dry ingredients are rubbed to meat, e.g. curing of bacon.
2. Pickle curing: Meat cuts are immersed in the solution of ingredients (called pickle), e.g. curing of pork shoulder.
3. Injection curing: Concentrated ingredient solution is injected by needles or pumped into meat via artery, e.g. curing of pork ham.
4. Direct addition method: To a finely ground meat curing agents are added directly, e.g. luncheon meat.

V. Smoking:

Three traditionally recognized reasons for smoking meat are for preservation, appearance, and flavour. Smoked meat is less likely to spoil than unsmoked meat. Smoking improves the flavour and appearance, aids in reducing mold growth, as well as retards rancid flavours. Smoke contains a number of wood degradation products like aldehydes, ketones, organic acids, phenols, etc. which exert bacteriostatic effect besides imparting characteristic smoky flavour. Preservation is also due to surface dehydration, lowering of surface pH and antioxidant property of smoke constituents. The most known undesirable effect of smoking is the risk of residues of benzopyrene in smoked products which can be carcinogenic if the intake is in high doses over long periods. With normal eating habits, a carcinogenic risk is normally not associated with moderately smoked food such as smoked meat products.

Smoke is produced in the specially constructed smoke house where saw dust or hardwood and sometimes both are subjected to combustion. Depending on the product, smoke is applied at different temperatures. There are two principal smoking techniques: cold smoking and hot smoking. The principle of both methods is that the smoke infiltrates the outside layers of the product in order to develop flavour, colour and a certain preservation effect.

Cold Smoking: The combination of cold smoking and drying/ripening can be applied to fermented sausages and salted or cured entire meat pieces, in particular many raw ham products. In long-term ripened and dried hams, apart from providing colour and flavour, cold smoking has an important preservative effect as it prevents the growth of moulds on the meat surfaces. The optimal temperature in cold smoking is 15°C to 18°C (up to 26°C). Sawdust should be burned slowly with light smoke only and the meat hung not too close to the source of the smoke. Cold smoking is a long process which may take several days. It is not applied continuously, but in intervals of a few hours per day.

Hot Smoking: Hot smoking is carried out at temperatures of 60°C to 80°C. The thermal destruction of the wood used for the smoking is normally not sufficient to produce these temperatures in the smoking chamber.

Hence, additional heat has to be applied in the smoking chamber. The relatively high temperatures in hot smoking assure a rapid colour and flavour development. The treatment period is kept relatively short in order to avoid excessive impact of the smoke (too strong smoke colour and flavour). Hot smoking is used for a range of raw-cooked sausages, bacon and cooked ham products.

These days many liquid smoke preparations are commercially available in the developed countries. Application of liquid smoke on the product surface before cooking imparts it a smoky flavour which is very much liked by the consumers. Liquid smoke is generally prepared from hard wood wherein polycyclic hydrocarbons are removed by filtration. The starting point for the production of liquid smoke is natural smoke, generated by burning/smouldering wood under controlled temperatures with the input of an air supply. There are basically two different methods used for the subsequent processing of liquid smoke:

- direct condensation of natural wood smoke to liquid smoke
- penetration of the smoke into a carrier substance and using this "smoked" carrier substance as an ingredient for meat products.

VI. Thermal processing:

Preservation of meat by thermal processing dates from the beginning of the nineteenth century when Appert (1810), whilst not aware of the nature of the processes involved, found that meat would remain edible if it were heated in a sealed container and the seal maintained until the meat was to be eaten. This method of preservation has developed into the canning industry (although glass containers as well as metal cans may be employed). Canned meat and meat products may be subjected to heat at two levels: pasteurization, which is designed to stop microbial growth with minimum damage; and sterilization, in which all or most bacteria are killed, but which alters the meat to a considerably greater degree.

Pasteurization refers to moderate heating in the temperature range of 58^{o}C to 75^{o}C, whereby most of the microorganisms present are killed. Many muscle enzymes are inactivated in the temperature range used in pasteurization, especially the more complex ones such as hexokinase: others such as creatine kinase are not inactivated until a temperature of 60°C is reached: but an enzyme such as adenylic kinase can stand a temperature of 100°C at pH 1 and, clearly, would still be operative. Fortunately, changes effected by the latter are of minor importance. Nevertheless, it is obvious that in semi-preserved meats, wherein the temperature is not raised much above 60°C, there may still be residual enzymic activity. This could be undesirable even though the microbial status of the product was satisfactory. This heat treatment significantly extends the shelf life of meat, although such products also need to be stored under refrigeration. From the point of view of minimizing damage to texture, it is preferable to administer the dose of heat required for stabilizing the microbial status of the product by a short period at high temperature, rather than by longer period at lower temperature.

Sterilization refers to severe heating at temperatures above 100^{o}C, whereby all spoilage microorganisms or other microbial cells in meat are killed. The aim of sterilization of meat products is the destruction of all contaminating bacteria including their spores. Heat treatment of such products must be intensive enough to inactivate/kill the most heat resistant microorganisms, which are the spores of *Bacillus* and *Clostridium*. In practice, the meat products filled in sealed containers are exposed to temperatures above 100°C in pressure cookers. Temperatures above 100°C, usually ranging from 110-121°C depending on the type of product, must be reached inside the product. Products are kept for a defined period of time at temperature levels required for the sterilization, depending on type of product and size of container. If spores are not completely inactivated in canned foods, vegetative microorganisms will grow from the spores as soon as conditions are favourable again. In case of heat treated processed meat, favourable conditions will exist when the heat treatment is completed and the products are stored under ambient temperatures. The surviving microorganisms can either spoil preserved meat products or produce toxins which cause food poisoning of consumers. Majority of canned meats are 'commercially' sterilized, i.e. they are processed to the point at which most micro-organisms and their spores have been killed: this permits more or less indefinite storage life in the can, at any ambient temperature, provided it is kept sealed; but the product is markedly different from fresh meat, and may alter chemically and physically in the course of time. Since the most lethal food-poisoning organism, *C. botulinum*, has a lower limit of growth at pH 4.5, all foods such as meat which support its growth are given heat treatment sufficient to destroy it. Its F_0 value [the time, in minutes, needed to achieve sterility at a temperature of 250°F (121°C)] is 2.8; and at 100°C the toxin is destroyed in 10 min.

Since most proteins are denatured by heat, sterilized canned meats suffer considerable changes in the process. There is an increase in free –SH groups and the proteins may coagulate and precipitate. The texture of canned meat after sterilization is thus more like the cooked than the fresh commodity. If heat treatment is excessive, marked deterioration in aesthetic appeal and eating quality occurs. Moreover, since meat (especially pork) contains appreciable quantities of thiamine (vitamin B_1) and other B-complex vitamins and these are destroyed by heat, the nutritive value of the canned product will be lower than that of fresh meat. It must be remembered, however, that meat is not primarily eaten for its vitamin content, and that these vitamins would, in any case, be largely destroyed in cooking. The loss of such labile nutrients will be exaggerated if the cans are subsequently stored for long periods at high ambient temperatures. The colour of canned meats will also tend to resemble that of the cooked commodity, since the high temperatures will change the red pigment (myoglobin) to brown myohaemochromogen. If the interior of the cans is not lacquered, there may be discoloration due to the reaction of H_2S (produced from the meat proteins) with the plate metals. In order to comply with above aspects, a compromise has to be reached in order to keep the heat sterilization intensive enough for the microbiological safety of the products and as moderate as possible for product quality reasons.

VII. Irradiation:

Radiations are capable of ionising molecules in their path. These radiations can destroy microorganisms by fragmenting their DNA molecules and causing ionisation of inherent water within microorganisms. Ionising radiation has been a method of direct microbial inhibition for preserving meat since around 1940. Since microbial destruction of foods takes place without significantly raising temperature of food, irradiation is also referred as cold sterilisation. A maximum dosage of 10 kGy represents a low amount of energy (equivalent to that needed to raise the temperature of 1 g water by 2.4°C), which is why the technology is considered nonthermal, thus preserving the freshness and nutritional quality of the meat and meat products when compared with thermal methods (Aymerich et al., 2008). A dose of 50-100 krad (radurisation) can enhance the shelf-life of fresh meat cuts and poultry products by 19 days. This will eliminate most non-spore forming bacteria and give a significant reduction in the number of spoilage micro-organisms, thus extending the shelf life. Unfortunately, enzymes are not denatured and the ultimate spoilage pattern is changed, requiring a reappraisal of spoilage criteria. A dose of 4-5 Mrad (radappertisation) can sterilize pork, poultry and fish. This level of treatment is the most severe and will destroy all spoilage and pathogenic micro-organisms. *C. botulinum* spores require 4.5 Mrad for a 12 D process (this requires that the process reduces a hypothetical *C. botulinum* population by 12 decimal logarithmic cycles). Unfortunately, there are no indicator micro-organisms that will survive such a process. Furthermore, it would stimulate off-flavours and odours and possibly cause textural damage as well. It has been claimed that such changes can be reduced by blanching, by including antioxidants or by irradiating at -80 to -180°C. Among the non-ionising radiations, ultraviolet radiations of 2650Å are most bacteriocidal in nature, but due to poor penetration power, these are used only for surface sterilization of meat.

The advantages of ionising radiation for food preservation include its highly efficient inactivation of bacteria, the fact that the product is essentially chemically unaltered and the appreciable thickness of material, which can be treated after packing in containers. Colour changes in irradiated meat can occur because of the inherent susceptibility of the myoglobin molecule to energy input and alterations in the chemical environment; haem iron being particularly susceptible. Maintenance of ideal meat colour during the process of irradiation could be enhanced by various combinations of pre-slaughter feeding of antioxidants to livestock, condition of the meat prior to irradiation (pH, ratio of oxymyoglobin and metmyoglobin), addition of antioxidants directly to the product, gas atmosphere (MAP) or lack thereof, packaging and temperature control (Brewer, 2004). Radiation treatment resulted in essentially no loss of thiamine (one of the least stable vitamins); therefore suggesting that such radiation has no detrimental effects on these nutrients.

A direct hit by a wave or particle beam on the cell nucleus may cause total chromosomal disorder, or mutation in micro-organisms or food tissue, but this effect is now considered to be less important in food preservation. Of greater importance is the production of free radicals, the most significant of which is the ionisation of water in the presence of oxygen to give the peroxide ion. The oxidative effect of the peroxide ion no doubt plays a major part in the inhibition of microbial spoilage, demonstrated by the fact that catalase positive micro-organisms are least affected. Unfortunately, the peroxide ion also causes many undesirable changes in the composition of the food e.g. deamination of amino acids, denaturation of protein and both deamination and dephosphorylation of nucleoproteins. While carbohydrates are relatively stable, cellulose may be depolymerised, resulting in softening of texture. Fats are particularly vulnerable to oxidation as are fat-based pigments susceptible to bleaching. Up to 50 per cent of the vitamin C may be lost while vitamin A and E losses depend on whether they are associated in protein or fat (the latter resulting in higher losses). The ionisation effect also causes concern when considering the possible hazards to the consumer. As many reactions are occurring in the food, it is thought possible that toxic chemicals, e.g. carcinogens, might be produced; therefore, considerable research effort is directed at testing irradiated foods.

VIII. Dehydration:

Removal of water from meat concentrates the water soluble nutrients making them unavailable to the microorganisms. The extent of water available to microbial cells is expressed as water activity (a_w). The term water activity (a_w) refers to water which is not bound to food molecules and can support the growth of microorganisms. Thus, microbiological safety of food is directly influenced by the water activity (a_w). It represents the ratio of the water vapour pressure of the food to the water vapour pressure of pure water under the same conditions. Water activity in meat products is equivalent to the relative humidity of air in equilibrium with the product. Dehydration lowers water activity considerably to prevent the growth of spoilage microorganisms, as each microorganism has minimum, optimum and maximum water activities. Micro-organisms generally grow best between a_w values of 0.980-0.995 and growth ceases at a_w <0.900. Yeasts and molds can grow at a low a_w of 0.6. However, growth of pathogens is prevented at a_w of 0.85.

The basic traditional drying method is called sun drying, characterized by direct solar radiation and natural air circulation on the product. The sun drying method is known to have certain disadvantages, such as exposure to contamination from sources such as dirt, wind, rain, insects, rodents and birds. Quality deficiencies, such as changes in colour, off-flavours, foreign contaminating substances such as dirt and sand and even high surface microbial contamination may occur. Heavy microbial contamination can affect the meat after rehydration, when sufficient moisture for renewed bacterial growth is available, as this will lead to product deterioration and even possible food poisoning. Mechanical drying involves the passage of hot air with controlled humidity. When hot air is blown over a wet food, water vapour diffuses through a boundary film of air surrounding the food & is carried away by the moving air. On rehydration the product absorbs water more slowly & does not regain the firm texture of the fresh material. In contrast, there are better reconstitution properties, nutritive value and acceptability in case of freeze dried meat. In freeze drying, the water content is first converted to ice & then changed into vapour without passing back through the water phase. If the water vapour pressure of food is held below 4.58 Torr (610.5 Pa) & the water is frozen, the solid ice sublimes directly to vapour without melting when food is heated. In freeze drying, meat is first frozen at -40°C. Then it is dried under vacuum for 9-12 hours at low temperature in plate heat exchanger at 1-1.5mm pressure of mercury. Ice crystals formed during freezing get sublimed to water vapour and there is no increase in temperature. Freeze-drying of meat yields a product of excellent stability, which on rehydration closely resembles fresh meat.

Continuous evaporation and weight losses during drying cause changes in the shape of the meat through shrinkage of the muscle and connective tissue. The meat pieces become smaller, thinner and to some degree wrinkled. The consistency also changes from soft to firm to hard. In addition to these physical changes, there are also certain specific biochemical reactions with a strong impact on the organoleptic characteristics of the product. Drying of meat pieces can cause aggregation & denaturation of proteins and loss of water-holding capacity, which leads to toughening of muscle tissue. Undesirable alterations may occur in dried meat when there is a high percentage of fatty tissue in the raw meat. Open porous structure of dried food allows access of oxygen which causes aroma loss due to oxidation of volatile components & lipids during storage. The rather high temperatures during meat drying and storage cause intensive oxidation (rancidity) of the fat and an unpleasant rancid flavour which strongly influences the palatability of the product.