

## Application of Various Techniques for Meat Preservation

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### Abstract

Since the pre-historic times, meat is consumed by humans as part of diet. Meat is an animal flesh that is considered as an excellent source of high biological value protein, zinc, iron, magnesium, selenium, phosphorus, and vitamins. In recent years, global meat production and consumption have increased. The production of meat in the world was estimated at 317.17 million tons in 2016. Meat is very much susceptible to spoilage due to chemical and enzymatic activities. The breakdown of fat, protein, and carbohydrates of meat result in the development of off-odors, off-flavor and slim formation, which make the meat objectionable for the human consumption. Several factors such as moisture, light, microbes, atmospheric oxygen, temperature, and endogenous enzymes influence the freshness and shelf life of meat. Microbes are ubiquitous in distribution and can reach the meat from different sources thus causing its spoilage. Therefore, various technologies are used to preserve the meat in order to inactivate/destroy the microbes, which are implicated in foodborne infections. Canned food stored in cool and dry place can last up to a year. Since preservation of meat by irradiation requires heavy investment, its commercial application is still in its infancy. It is emphasized that preservation of meat is imperative to prevent the occurrence of deteriorative changes brought by microbial, chemical and physical process. Further, well preserved meat can give protection against all hazards for a considerable time.

**Keywords:** Foodborne illness; Meat; Microbes; Preservation; Pressure processing; Spoilage; Technologies

### Introduction

Food, which contains essential nutrients, such as fats, proteins, carbohydrates, vitamins, and minerals, is the most indispensable part of human life. It is the basic necessity without which the survival of living beings is not feasible. Food is an edible substance of plant or animal origin, which is consumed to maintain life, provide energy and promote growth [1]. Among all the industries in the world, food industry is the most prominent and fastest growing enterprise. In India, meat production was estimated 7.0 million tons in 2015-2016. Various technologies are being developed in order to meet the ever increasing demand of food due to population growth. Since ancient times, humans have employed several methods for preserving the food, so that they can store it to eat later on [1]. The canning of vinegar was introduced in 1782 and the preservation of food by canning was patented by Nicolas Appert, a French Chemist. Later in 1837, Louis Pasteur, a French Scientist, used heat for the first time to destroy undesirable organisms in bear and wine. The use of sodium benzoate as a preservative in certain foods was given official sanction by USA in 1980. In the year 1990, the application of irradiation of the poultry was approved in the United States [2].

Meat primarily obtained from herbivorous animals, such as cattle, buffaloes, goats, sheep, camels, horses, is widely consumed by people of developed as well as developing nations [3]. Rich nutrient matrix meat is the first-choice source of animal protein for many people all over the world [4]. According to the American Heart Association, the daily consumption of meat should be limited to six ounces [1]. The transformation of animals into meat involves several operations, which

include handling and loading of animals on the farm, transporting animals to slaughterhouses, off-loading and holding of animals and 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 loss of meat, reduced meat quality and spoilage of meat. Therefore, the prevention of contamination during meat cutting and processing is very essential [5]. Storage time can be extended through hygienic slaughtering and clean handling of the carcass [6]. Due to nearly neutral pH, high moisture content and rich nutrients, it is highly prone to contamination by microorganisms, which makes the preservation of meat more difficult than most other foods. The principle of preservation is to create unfavorable conditions for the growth of microorganisms, which result spoilage of food. Due to spoilage, the texture, flavor and nutritive value of meat are altered and thereby, rendering it inedible for human use. Unless proper preservation methods are adopted, deterioration, microbial activity, enzymatic and chemical reactions along with physical changes is bound to occur. However, once meat is contaminated with microorganisms, their removal is difficult. Hence, preservation of meat is done by various preserving techniques such as chilling/refrigeration, freezing, curing, smoking, thermal processing, canning, dehydration, irradiation, chemicals and pressure processing [1,2,7-12]. This communication is an attempt to present an overview of various methods employed for the preservation of meat throughout the world.

### Preservation of Meat

Meat preservation became essential for transportation of meat for long distances without spoiling of texture, color and nutritional value after the development and rapid growth of super markets [13]. Traditional methods of meat preservation such as drying, smoking,

brining, fermentation, refrigeration and canning have been replaced by new preservation techniques such as chemical, bio-preservative and non-thermal techniques [12]. The aims of preservation methods are to inhibit the microbial spoilage and also to minimize the oxidation and enzymatic spoilage. Current meat preservation methods are broadly categorized into three methods (a) controlling temperature (b) controlling water activity (c) use of chemical or bio-preservatives [12]. A combination of these preservation techniques can be used to diminish the process of spoilage [14].

The preservation of food has several objectives [1].

1. To control foodborne infections and intoxications
2. To ensure the safety of food from microbes
3. To prevent the spoilage of food
4. To extend the shelf life of food
5. To enhance the keeping quality of food
6. To reduce financial losses

### Chilling/refrigeration

This is the most widely used method of preservation for short term storage of meat as chilling/refrigeration slows or limit the spoilage rate at temperature below the optimal range can inhibit the microbial growth [7], enzymatic as well as chemical reactions [1,7]. Storage of fresh meat is done at a refrigeration temperature of 2 to 5°C. Chilling is critical for meat hygiene, safety, shelf life, appearance and nutritional quality [7,12]. Carcasses are first hanged in chilled coolers (15°C) to remove their body heat, and are then passed on to holding coolers (5°C). It is essential to maintain proper spacing between carcasses so as to allow throughout air circulation. It is employed by two methods: (a) immersion chilling, in which the product is immersed in chilled (4°C) water and (b) air chilling, in which the carcasses are misted with water in a room with circulating chilled air [15].

Refrigeration of meat begins with the chilling of animal carcass and continues throughout the entire channels of holding, cutting, transportation, retail, display and even in the customer household before the ultimate use. The relative humidity is generally kept at 90% in order to avoid excessive shrinkage due to loss of moisture.

The refrigerated storage life of meat is influenced by species of origin, initial microbial load, packaging and temperature as well as humidity condition during storage. Pork and poultry starts with comparatively high microbial load. Irrespective of species of origin, maximum care should be taken during handling of meat in order to check further microbial contamination. Refrigerated temperature favors the growth of psychrophilic organisms causing spoilage of meat in due course of time.

Generally, fresh meat remains in good condition for a period of 5-7 days if kept at refrigerated temperature of  $4 \pm 1^\circ\text{C}$ . Cold-shortening and toughening may result from ultra-rapid chilling of pre-rigor meat [16]. It is emphasized that the processed meat should be stored under refrigerated condition till they are finally consumed. The well preserved meat has enhanced shelf life as compared to fresh meat.

### Freezing

Freezing is an ideal 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 [4]. It stops the microbial load and retards the action of enzymes.

The most significant advantage of freezing is the retention of most of the nutritive value of meat during storage, with a very little loss of nutrients occurring in the drip during thawing process. It is important to wrap fresh meat in suitable packaging film before freezing otherwise meat undergoes freeze burn. This abnormal condition occurs due to progressive surface dehydration resulting in the concentration of meat pigments on the surface.

The quality of frozen meat is also influenced by its freezing rate. In slow freezing, there is formation of large ice crystals, which may cause physical damage to muscular tissue, giving it distorted appearance in the frozen state. In fast freezing, numerous small ice crystals are formed uniformly throughout the meat tissue. The freezing rate is increased with decreases in temperature, almost 98% of water freezes at  $-20^\circ\text{C}$  and complete crystal formation occurs at  $65^\circ\text{C}$  [17]. Thus, problem of muscle fiber shrinkage and distorted appearance is not there in meat tissue. The drip losses during thawing are considerably low as water freezes within the muscle fiber itself. Numerous small ice crystals on the surface of the fast frozen meat are also important as they give a desirable light color as compared to slow frozen meat. Microbial growth stops at  $-12^\circ\text{C}$  and total inhibition of the cellular metabolism in animal tissues occurs below  $-18^\circ\text{C}$  [18]. However, enzymatic reactions, oxidative rancidity and ice crystallization will still play an important part in spoilage [12]. During freezing, about 60% of the viable microbial population dies but the remaining population gradually increases during frozen storage [19].

### Curing

Sodium chloride, sodium nitrate, sodium nitrite and sugar are main curing ingredients. Various methods of curing are practiced in India, such as dry cure, pickle cure, injection cure, direct cure etc. Preservation of meat by heavy salting is an old age practice. Sodium chloride has a long history of use in food preservation in sufficiently high concentrations [20]. It was applied as a thumb rule because refrigeration facilities were not available during olden days. Later, curing by common salt and sodium nitrate resulted in comparatively improved products. Sodium Chloride inhibits microbial growth by increasing osmotic pressure as well as decreasing the water activity in the micro-environment [20]. Some bacteria can be inhibited by concentrations as low as 2% [21]. A concentration of 20% of sodium chloride is high enough to inhibit many food spoilage yeasts including *Debaryomyces hansenii*, *Yarrowia lipolytica*, *Kloeckera apiculata*, *Kluyveromyces marxianus*, *Pichia anomala*, *Pichia membranaefaciens*, *Saccharomyces cerevisiae*, *Yarrowia lipolytica*, *Zygosaccharomyces bailii*, and *Zygosaccharomyces rouxii* [22]. However, some microorganisms from the genera *Bacillus* and *Micrococcus* have shown ability to tolerate high concentrations of salt [21]. Sugars have the capabilities to bind with moisture and reduce water activity in foods [20]. Dextrose, sucrose, brown sugar, corn syrup, lactose, honey, molasses, maltodextrins, 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 [23]. In Canada and the United States, sugars are generally recognized as safe [24,25]. 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 [2]. Further, nitrite salts are effective in controlling color, lipid oxidation and odor in addition to controlling the anaerobic bacteria [26-29]. The current limit for nitrite in food is 156 ppm in US, and 200 ppm in Canada for meat products [24,30]. On the other hand, the use of nitrite as food additive may form carcinogenic nitrosamines with

prolonged exposure. However, there is no epidemiological evidence to support the relationship between nitrate consumption and a specific cancer or cancer risk [31].

### Smoking

Meat smoking is also known as an aid in the preservation for a long time to the meat product. It is now well known that smoke contains a large number of wood degradation products such as aldehydes, ketones, organic acids, phenols and many more. Preservation of meat by smoke is also due to surface dehydration, lowering the surface pH and antioxidant property of smoke constituents. Curing and smoking of meat are closely related. These days, curing is usually followed by smoking.

Smoke is produced in specially constructed smoke house where sawdust or hard wood and sometimes both are subjected to combustion at the temperature of about 300°C [1]. Smoke generation is accompanied by formation of numerous organic compounds and their condensation products. Aldehydes and phenols condense, which constitute 50% of smoke components and contribute to the most of the color of the smoked meat products. Phenols act mainly as the chief bactericidal compounds.

Currently, many liquid smoke preparations are commercially available in the developed countries. Liquid smoke is generally prepared from hard wood wherein polycyclic-hydrocarbons are removed by filtration. Application of liquid smoke on the product surface before cooking imparts it a smoky flavor, which is very much liked by the consumer [1].

### Thermal processing

Thermal processing as a preservative method is employed to kill the spoilage causing microorganisms. Pasteurization refers to moderate heating in the temperature range of 58-75°C, which is also the cooking temperature range of most of the processed meats. This heat treatment extends the shelf life of meat significantly. It is imperative that such products also need to be stored under refrigerated conditions.

Sterilization refers to the severe heating of meat at the temperatures above 100°C whereby all spoilage causing microbes in meat are killed or their microbial cells are damaged beyond repair. This heat treatment renders the meat product commercial sterilization as the bacterial spores may still survive. However, exposure of meat to high temperatures imparts sulphhydryl flavors in cans and also modifies texture.

Various meat products differ in water content, fat and consistency. These are the deciding factors of thermal processing schedule. For example moist heat is more effective in killing microorganisms and spores as compared to dry heat. Therefore, a meat product with high moisture content requires comparatively less heat for sterilization [1].

### Canning

It is the process of preservation achieved by thermal sterilization of a product held in hermetically sealed containers. Canning preserves the sensory attribute such as appearance, flavor and texture of the meat products to a large extent. Besides, canned meat products have a shelf life of at least two years at ambient temperature. Canning involves several steps, which include preparation of meat, precooking, filling, exhausting, seaming, thermal processing, cooling, and storage [1].

### Dehydration

Removal of water from meat concentrate, the water soluble nutrients making them unavailable to the microorganisms. The extent of unavailability of water to microbial cell is expressed as water activity. Dehydration lowers the water activity considerably to prevent the growth of spoilage causing microbes. Sun drying of meat chunks as a means of preservation was practiced in ancient days but rehydration of such meat chunks used to be limited. The mechanical drying process involves the passage of hot air with controlled humidity but here also there is difficulty in rehydration.

Freeze drying of meat is a satisfactory process of dehydration, preservation due to better reconstitution properties, nutritive quality and acceptability of the meat products. Freeze drying involves the removal of water from a food by sublimation from the frozen state to vapor state by keeping it under vacuum and giving a low heat treatment. Freeze drying of meat is carried out in three steps, namely pre-freezing, primary drying and secondary drying [1].

Meat is first frozen at -40°C, and then it is dried under vacuum for 9-12 hours at low temperature in plate heat exchangers at 1-1.5 mm pressure of Hg. Ice crystals get sublimated to water vapors and there is no rise of temperature. In the 1<sup>st</sup> phase of drying, free and immobilized water of meat, which is freezable and constitutes about 90-95% of total moisture, is removed. Secondary drying is done at high temperature to remove remaining 4-8% bound water. Freeze dried products are packed under vacuum and have very good storage stability. The process has been largely used for the preparation of dehydrate meat soup mixtures [1].

### Irradiation

Irradiation is also known as “cold sterilization”. It is the emission and propagation of energy in the material media. Electromagnetic radiations are in the form of continuous waves. These are capable of ionizing molecules in their path. These radiations can destroy the microorganisms by fragmenting their DNA molecules and causing ionization of water within microorganisms. It is pertinent to mention that microbial destruction of foods take place without significantly rising the temperature of the food [1].

Gamma radiations produce desired effect only during food irradiation and have no effect after removal of source. These are widely used in food preservation. Among the known ionizing radiations, UV radiations are mostly bactericidal in nature but do not have good preventing power, so these are used only for surface sterilization of meat.

### Chemicals

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 [32]. Traditional methods for preservation of meat by salting and pickling 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 humans [7]. Freeze storage cannot prevent oxidative spoilage and microbial/enzymatic spoilage [2]. Thus, chemical preservation methods are quite beneficial in combination with refrigeration in order to optimize stability, product quality while

maintain freshness and nutritional value [7]. Antimicrobial preservatives are substances which are used to extend the shelf life of meat by reducing microbial proliferation during slaughtering, transportation, processing and storage [33]. Growth of bacteria and spoilage of meat is depending on the species of bacteria, nutrients availability, pH, temperature, moisture and gaseous atmosphere [34]. Antimicrobial compounds added during processing should not be used as a substitute for poor processing conditions or to cover up an already spoiled product [35]. They offer a good protection for meat in combination with refrigeration [7]. Common antimicrobial compounds include: chlorides, nitrites, sulfides and organic acids [27,35,36]. Freeze storage cannot prevent oxidative spoilage and microbial/enzymatic spoilage [2]. Thus, chemical preservation methods are quite beneficial in combination with refrigeration in order to optimize stability, product quality while maintain freshness and nutritional value [7]. Several organic acids have been generally recognized as safe. Benzoic acid, citric acid, propionic acid, sorbic acid and their salts are effective mold inhibitors. Acetic acid and lactic acid prevent the bacterial growth whereas sorbate and acetate are capable of arresting the growth of yeasts in food. Ascorbic acid (vitamin C), sodium ascorbate and D-isoascorbate (erythorbate) have been used as meat preservatives. Their antioxidant properties can oxidize reactive oxygen species producing water. Ascorbic acid has been shown to enhance antimicrobial activity of sulfites and nitrites [37,38]. The enhanced activities include both the antioxidant properties and the sequestering of iron [39]. Benzoic acid and sodium benzoate are also used as preservatives in the meat industry. The un-dissociated molecule of benzoic acid is responsible for its antibacterial activity [40-42]. The benzoic acid is generally used to inhibit yeasts and fungi rather than bacteria [36,42]. It has been reported that yeasts such as *Saccharomyces* and *Zygosaccharomyces* have intrinsic ability to resist benzoic acid under the tolerable toxicological limits. The combination of benzoic acid treatment and nitrogen starvation conditions is suggested to enforce effective food preservation from yeast spoilage.

### Hydrostatic pressure processing

High pressure directly affects cellular physiology of the micro-organisms. High pressure of a few hundred MPa can decrease the viability of bacterial cells, and a pressure of a few tens MPa can decrease the growth rate. New high-pressure technology for food sterilization is being developed based on these facts. The inactivation is due to widespread damages of micro-organisms through modification of morphology and of several vulnerable components such as cell membranes, ribosomes, and enzymes, including those involved in the replication and transcriptions of DNA [43]. Microbial inactivation through high pressure application has been well reviewed by Cheftel [8]. The extent of inactivation depends on several parameters such as the type of micro-organisms, the pressure level, the process temperature and time, and the pH and composition of the food or the dispersion medium. In general, Gram-negative bacteria such as *Yersinia enterocolitica* and *Salmonella* spp. were found to be more sensitive than Gram-positive bacteria such as *Listeria monocytogenes* and *Staphylococcus aureus*. Some strains of *Escherichia coli* O157:H7 were found to be relatively resistant to pressure. Some investigators reported the effect of substrate on pressure resistance of *S. aureus*, *S. enteridis* and one of the resistant *E. coli* O157:H7 strains [9]. There was greater survival of *E. coli* and *S. enteridis* in ultra-high-temperature treated (UHT) milk compared to poultry meat, whereas there was greater recovery of *S. aureus* in poultry meat than in the milk. The simultaneous applications of pressure with mild heating (up to 60°C)

significantly increased the death of *E. coli* O157:H7 in poultry meat and UHT milk compared to either treatment alone.

In practical meaning, high-pressure processing is preferable as an additional final processing step to produce safety products. High-pressure processing can eliminate manufacturing contamination of *Salmonella*, *Listeria monocytogenes*, and other food-borne pathogens in finished, packaged products without any adverse effects on color, flavor, texture, and moisture, and increase refrigerated shelf life.

The tenderization of meat or acceleration of meat conditioning could be induced by high-pressure treatment and the improvement of thermal gel formability of pressurized actomyosin, especially at low salt concentration, opens up the possibility for exploitation of new types of meat products. The shelf life of cooked meat products prepared by conventional methods could be extended by exposing them to high pressure.

### Hydrodynamic pressure processing

Tenderness is the major criterion driving consumer's decisions to purchase meat. A means of controlling and assuring a meat product's safety and tenderness level is essential. Unfortunately, tenderness has proven to be the most difficult quality factor for meat producers and meat packers to manage. Thus, a commercial method to ensure a consistently tender meat product is of primary importance for enhanced consumer acceptance of meat. Techniques applied individually or in combination include mechanical, chemical, temperature conditioning, aging, electrical stimulation, high pressure heat treatments, and alternative carcass positioning. A number of these techniques require additional holding periods, space, and labor. Furthermore, several of these methods have been criticized for their lack of consistency in tenderizing meat. The concept of tenderizing meat using shock waves from underwater detonation of explosives, called hydrodynamic pressure processing (HDP), was first patented by Godfrey [44]. Hydrodynamics refers to the motion of fluids and the forces acting on solid bodies immersed in these fluids. The HDP process should not be confused with research using high hydrostatic pressure (HHP), which was introduced by Japanese scientists and dates back to the end of the 19th century. The HDP-treated meat displayed no outward signs of change, but on cooking, it was found to be significantly tender than non-treated control samples.

HDP involves underwater detonation of a high-energy explosive in a containment vessel to generate a shock wave pressure front at velocities exceeding the speed of sound. The shock wave passes through the liquid medium and vacuum-packaged meat (placed at the bottom of the container). Shock waves generated and transmitted through water move equidistant from an explosive source depending on the shape of the explosive [45]. The shock wave, with targeted pressure fronts of 70 MPa to 100 MPa in the HDP process, occurs in fractions of milliseconds. Hugoniot (adiabatic) compression of water (or of aqueous solutions) causes a temperature increase of only 2 to 3°C per 100 MPa, depending on the initial temperature and the rate of pressure increase [45]. Pressure release causes a decrease in temperature of the same order of magnitude. Because the dynamics of the shock wave pressure front in the HDP process occur in fractions of milliseconds and at pressures less than 100 MPa, there is virtually no increase in the temperature of the meat or water.

The shelf life of HDP-treated meat products is increased by reducing the non-pathogenic (normal) microbial flora in the sample. Microbial populations of HDP-treated meat does not increase significantly for

approximately 14-15 days of storage at 5°C whereas there is increase in microbial population of untreated meat products.

## Conclusion

Meat is an important component of a healthy and balanced diet due to its nutritional richness. The composition of meat provides an ideal environment for the growth and propagation of spoilage microbes and common foodborne pathogens. Microbial growth and metabolism depends upon the condition of the carcasses at the time of slaughter, the type of packaging and storage conditions. Microbial spoilage results in a sour taste, off-flavors, discoloration, gas production, pH change, slime formation, structural components degradation, off odors and change in appearance. Preservation ensures that the quality, nutritive value and edibility of meat remain intact. It may be noted that modern meat food processors do not rely on any single preservative technique. For controlling enzymatic, oxidative and microbial spoilage, low temperature storage and chemical techniques are the most common in the industry today. It is essential to store the meat at lower than 4°C immediately after slaughtering and during transport and storage, as it is critical for meat hygiene, safety, shelf life, appearance and eating quality. Therefore, it is imperative to employ a combination of preservative factor in a balanced manner to derive maximum benefit. A combination of chemical additives such as tertiary butyl hydroxyl quinone and ascorbic acid can be most effective for controlling spoilage of meat and meat products. The application of pressure-processed meat or meat products will be launched in the market in the near future because of the development of true commercial-scale high-pressure machines and reduced running costs. As meat is quickly spoiled due to microbes, it is advised that meat should be properly preserved so that it remains in good condition for future use. Further work on the development of low cost effective preservation technique without affecting organoleptic and nutritive qualities of food, which can be easily practiced by poor resource nations of the world, will be rewarding.

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## Conflict of Interest

None

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