PRESERVATION OF MEAT BY HEAT AND RADIATION – A REVIEW

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***Abstract* – Food preservation is the science and art of employing process which protect food from degradation by rodents, insects, microbes, enzymes or undesirable chemical alteration. A variety of processes can be used either alone or in combination including refrigeration, freezing, canning, drying and dehydration, salting, fermentation, radiation. Preservation technology has developed sufficiently to preserve the wide variety of foods for a considerable long time as near to the point of freshness as possible. Thermal processing and irradiation are two widely used techniques for preservation of meat and meat products in the present world. Thermal processing includes use of a suitable time temperature combination to obtain the desired preservation effect in the food. The process adopted may be pasteurization, commercial sterilization or sterilization. Most widely used method is canning or retorting which yields a commercially sterile product that can be stored safely at room temperature and is ready to be consumed. Irradiation technology uses ionizing radiations to preserve food. It has varying acceptability by the consumers. The radiations of interest for food industry include gamma rays, beta rays, X-rays and alpha particles as their quanta has sufficient energy to ionize particles in their path. The ionizing radiations produce ions and other chemically excited molecules that further react and produce free radicals and peroxides. The amount of dose for different applications is different. The doses can be low, medium or high depending on the desired effect.**

Keywords* – *Canning, Pasteurization, Sterilization, Retort, Radurization, Radappertization, Radicidation

I. INTRODUCTION

Meat itself is not a living organism but it is subject to endogenic enzymatic activity, proteolysis and spoilage.

As the meat is rich in proteins, lipids and water, it is a favourable substrate for the growth of micro-organisms.

Healthy animals, hygienically slaughtered after resting and fasting, provide a practically aseptic meat. However, following slaughter the evisceration and dressing operations inevitably produce microbial contamination in depth and especially on the surface. The micro-organism growth is a temperature-dependent process. To avoid it, it is absolutely essential to reduce the temperature of the meat, especially on the surface, immediately after dressing. Cooling must therefore be carried out in the slaughterhouse itself. Meat loses weight through surface evaporation. This process depends on differences in temperature and relative humidity between the meat and the environment [18]. Principle of preservation of all food preserving methods is the creation of unfavourable conditions for the growth or survival of microorganisms that can cause spoilage. Most common methods to preserve meat include drying, curing, cold, heat, chemicals and irradiation. For efficient preservation of meat it is essential that that the animals are carefully handled and managed in the farm as well as in the lairage, the abattoir operations must be carried out in an exemplary manner. [13]

II. PRESERVATION OF MEAT BY HEAT – THERMAL PRESERVATION

Thermal Processing is defined as the combination of temperature and time required to eliminate the desired number of micro-organisms from a food product. Heat treatment of processed meat products serves two main purposes

- Enhancement of desirable texture, flavour and colour, in order to make meat products more palatable and appetizing for consumption.
- Reduction of microbial content thus achieving the necessary preservation effects for an extended shelf life (storability) of the products and food safety effects by eliminating potential food poisoning agents.

The heating parameters to be applied in meat processing can vary considerably in temperature and time depending on the type of product. Heat treatment methods cause various physical-chemical alterations in meat, which result in the beneficial sensory and hygienic effects on the processed products. [16]

When bacteria in a suspension are exposed to heat, the number of survivors follow a logarithmic course against the length of heating time at a constant temperature. The D value or the decimal reduction time is the time taken at a constant temperature to reduce the surviving bacteria in a suspension to 10% of their original number. Total sterility can never be achieved and the effect of any thermal processing is measured against the activity of the spores of *clostridium botulinum*, the most heat resistant pathogenic bacteria of importance in canned food. In the modern canning operations for meat and meat products, the heat process must be equal to 12 times the D value of *clostridium botulinum* spores. [13]

III. HISTORY OF THERMAL PROCESSING

Preservation of meat by thermal processing dates from the beginning of the nineteenth century when Appert(1810), unaware 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. Canned Meat and Meat Products may be subjected to heat at two levels in the industry

A. Pasteurization

It is a moderate heating process at 60-90^{0}C, designed to inactivate some of the spoilage and most of the pathogenic bacteria. The shelf life of the product is extended but the product must be refrigerated.

B. Sterilization

In this a temperature of more than 100^{0}C is used to prepare “commercially sterile” food products that can be stored at room temperature for an extended period of time. This process aims to kill all spoilage microorganisms and destroy food poisoning bacteria and spores, but which alters the meat to a considerably greater degree in terms of texture, flavour and odour. The extent of changes increases with higher temperature and exposure time. [18]

IV. COMMON SPOILAGE OORGANISMS OF FRESH MEAT

Achromobacter, Pseudomonas and Flavobacterium, Micrococci, Cladosporium, Thamnidium [14]

V. CANNING OF MEAT

Canning is defined as hermatic sealing of foods in glass bottles or tin cans after giving the necessary heat treatment. It involves preparation of food, filling in cans with brine/syrup and then exhausting, sealing, processing and finally labelling and storage in cool and dry place. Canning provides a typical shelf life ranging from one to five years. The packaging prevents micro-organisms from entering and proliferating inside. The major reason for canning meat is to provide safe products that have desirable flavour, texture and appearance. However, the problems of meat canners are often more acute because meat products are low-acid foods. Successful production of commercially sterile canned meat products requires that all viable microorganisms be either destroyed or rendered dormant. The process must also inactivate raw material enzyme systems. Commercially sterile canned meat products generally reach an internal temperature of at least 225^{0}F, but this temperature may be as low as 215^{0} F, depending on salt and nitrite content.

There are three essential maxims of cannery safety

A. Container seal integrity

The vacuum in the can will tend to draw fluids (and the microbes they contain) through a faulty seal recontaminating the sterile contents.

B. Adequate thermal process lethality

The times of exposure to given high temperatures, required to effectively eliminate the most dangerous and heat-resistant pathogens, particularly *Clostridium botulinum*, are accurately known. Thermal processes are calibrated in terms of the product centre’s equivalent time at 121.1^{0}C.

C. Scrupulous post-process hygiene

While the can is still hot and wet, after the sterilisation process, it is most vulnerable to leakage through the seal. Cooling water is, therefore, measuredly chlorinated as are all surfaces with which the can comes into contact, and wet cans are never handled. [1]

VI. TYPES OF CANS

Five principal types of cans are used in the meat industry

A. Square and Pullman base-

These containers are used primarily for pasteurized meats. The principal meats packed are chopped products such as spiced luncheon meat, chopped ham, corned beef, and boneless hams.

B. Pear shaped

These containers are used to pack pasteurized hams and picnics. They are anodized and enamelled. Recently, plastic containers constructed of high-density polyethylene have been used commercially. Some containers are manufactured with a barrier material to lower the oxygen transmission and so increase product shelf life.

C. Round sanitary

Cylindrical or round sanitary cans are available in a variety of diameters and heights. They range in size from 208 X 108 to the No. 10 cans used for institutional canned meat products. The major products packed in sanitary cans are chilli, stews, hashes, and a variety of meat-base products.

D. Drawn aluminium

They are used principally for Vienna sausage, potted meats and meat spreads.

E. Oblong

Oblong cans are used for sterile canned luncheon meats, generally in the 12-oz size, although some 7-oz cans are also packed. Luncheon meat cans are available in either tinplate or aluminium. [13]

VII. CANNING OPERATION

A. Preparatory Process

- Receiving and storage of raw materials
- Preparation procedures – Thawing, Boning, cutting and trimming on the trimming table where the inedible parts such as bones, cartilages blood clots, skins and tendons together with the increased fat are removed.

B. Production processes-

1) Blanching

This is a heat treatment given to many foods prior to canning in hot water (100°C) for 1½-5 minutes. Blanching is significant to inactivate enzymes reaction.

2) Grinding

Meat cuts of variable size and shape and with a variable fat content are ground to form uniform particles of fat and lean. Proper mixing of these particles is extremely important to obtain a uniform blend.

3) Mixing with addition of suitable ingredients

Particles of fat and lean obtained by grinding are tumbled in a mixer to give a uniform distribution of fat and lean particles, and with suitable additions of required ingredients as salt, sodium nitrite, sugar, spices.

4) Filling of cans

The mix is then transferred to automatic piston-type filters and packed into the appropriate cans on the fill line with required weights. The head space volume or depth should be checked due to its critical factor in the attainment of an appropriate vacuum closure. Such process should be carefully controlled due to

- economic aspect
- Efficiency of exhausting procedure
- Rate of heat penetration.

5) Exhausting and sealing

Exhaustion or removal of air from the can before it is sealed, is necessary for the following reasons

- To prevent expansion of the contents during processing which may force the seam.
- To produce concave can ends so that any internal pressure may be readily detected and the can rejected.
- To lower the amount of oxygen in the can and prevent discolouration of the food surface.
- To reduce chemical action between the food and container and hydrogen swells.
- To prevent internal corrosion of the cans.

Exhausting can be Thermal exhausting using steam vacuum or mechanical exhausting using machine vacuum.

6) Washing

After the cans are closed, they pass through a detergent spray washer to remove grease and other material. The washing should consist of hot water

(66°C) then by suitable pre-rinse, detergent spray wash. Followed by a fresh warm water rinse (66°C).

7) Thermal processing

The cans must be processed (heat treated) immediately after closing (hermetic sealed) at suitable time and temperature. Food to be canned is threatened on the one hand by bacterial spoilage (if under processed) and on the other by danger of lower the nutritive quality by overheating. Vegetative bacteria are killed at 80^{0}C/30min. Spore formers at a temp.110C/30min. For destroying the spores, 121^{0}C/3min treatment is required.

The total time required to sterilize canned food depends on

- Size of can.
- Processing temperature
- Rate of heat penetration to the centre of the can.
- pH of the food
- The type and number of organisms present.

During processing, heat penetrates to the centre of the can by "conduction" and by "convection" currents. In solid meat packs, the heat diffuses by conduction and the process is therefore, slow. The convection current in loosely packed foodstuffs along with a medium, transfer heat faster.

8) Cooling Immediately after processing

The cans are cooled in water to a temperature of 36°C to 42°C to avoid thermophilic spoilage or can rust. If the cans are cooled much below 36°C, they may not dry thoroughly and rusting will result. If the cans are cased at temperatures much over 42°C, thermophilic spoilage may occur. Only potable water, as defined in International Standards of Drinking Water (WHO) should be used in food handling or as an ingredient.

9) Container drying

Cooled cans should be immediately dried as the externally dry seams and closures are almost free from microbial infection. One method that has been found to be quite efficient is the heated bed drier, which rolls cans over a surface heated by steam to 127-130°C covered by an absorbent cloth. Contaminating bacteria are rapidly killed at these temperatures.

10) Outside lacquering

Commercial lacquer or enamel is a coloured varnish containing vegetable or synthetic resin Lacquer may be applied to the outside of the can to prevent external corrosion.

11) Testing of post-processed container

Processed cans should be incubated at, for example, 30°C for 14 days and/or 37°C for 10-14 days. In addition, if the product is intended to be distributed in areas of the world with tropical climate or is to be maintained at elevated temperatures containers should also be incubated at higher temperatures (5 days at 55°C). Since thermophiles may die during such incubation period, it is advisable to examine containers periodically for the evidence of gas production before the end of incubation.

12) Labeling

The role of a label is to inform. The information can be grouped as follow: Product identification (corned beef, beef stew, luncheon) and grade (fancy, choice, standard). Brand name, a distinctive name protected by trademark Net contents by weight or volume. List of ingredients including additives as per the appropriate regulation. Nutritional information. Country of origin if the product was not processed in the country in which it will be offered for sale. Production date and the shelf life should be clarified. [11 & 4]

VIII. SOME CANNED MEAT PRODUCTS

Practically all processed meat products which require heat treatment during preparation are suitable for heat preservation. Meat products which do not receive any form of heat treatment before being consumed, such as dried meat, raw hams or dry sausages, are naturally not suitable for canning as they are preserved by low pH and/or low water activity.

The following groups of meat products are frequently manufactured as canned products

- Cooked hams or pork shoulders
- Sausages with brine of the frankfurter type
- Sausage mix of the bologna or liver sausage type

- Meat preparations such as corned beef, chopped pork
- Ready-to-eat dishes with meat ingredients such as beef in gravy, chicken with rice
- Soups with meat ingredients such as chicken soup, oxtail soup [16].

A. *Corned beef*

It is prepared from beef pickled in the salt, nitrite and sugar, boiled for 1 hour and then trimmed for soft fats, tendons, bones and cartilage. The texture and the fat content depend on the taste of the consumer country. The meat is machine cut and automatically packed in cans. A 453 g tin of corned beef requires 21 and half hour at 104.6^0C, a 2.7 kg tin 5hr at 105.5^0 and 6.3 kg tin at 108.3^0. Processing is followed by cooling, degreasing and lacquering. [13]

B. Canned hams

Hams are boned by hand and forced into a pressure mould to produce the desired shape. The hams are cooked without pressure at 93.5^0C for several hours. Cooking ham at a higher temperature for a shorter time in a pressure retort produces deleterious changes in the ham texture and causes heavy weight loss due to exudation of fat and gelatin. Large hams 1.4-7 kg, would be unpalatable if cooked at normal canning temperatures and should be subjected to 80^0C for upto 60 mins. This produces pasteurized ham which should be stored at 0^0C. [13]

C. Canned chicken/ rabbits

Freshly killed, dressed and healthy animals are selected. Large chickens are more flavourful than fryers. Dressed chicken are chilled for 6 to 12 hours before canning. Dressed rabbits are soaked for 1 hour in water containing salt, and then rinsed. The excess fat is removed. The chicken or rabbit are cut into suitable sizes for canning. Both can be canned with or without bones [2].

D. *Ground or chopped meat*

The meat can be bear, beef, lamb, pork, sausage, veal or venison. Fresh chilled meat is used. Chopped meat is shaped into patties or balls and is cooked until lightly browned. Ground meat may be sautéed without shaping. Excess fat is removed. Jars are filled with pieces. Boiling meat broth, tomato juice, or water are filled leaving 1 inch headspace. salt may be added if desired for taste. Processing is done in a pressure canner at the recommended pressure [2].

E. *Stripes, cubes or chunks of meat*

Quality chilled meat is used. Excess fat is removed. Soaking in brine is practiced for strong flavoured wild meats for 1 hour followed by rinsing and removal of large bones [2].

IX. RETORTS

In order to reach temperatures above 100°C (“sterilization”), the thermal treatment has to be performed under pressure in pressure cookers, also called autoclaves or retorts. In autoclaves (retorts) high temperatures are generated either by direct steam injection, by heating water up to temperatures over 100°C or by combined steam and water heating. The autoclave must be fitted with a thermometer, pressure gauge, pressure relief valve, vent to manually release pressure, safety relief valve where steam is released when reaching a certain pressure (e.g. 2.5 bar), water supply valve and a steam supply valve. The steam supply valve is applicable when the autoclave is run with steam as the sterilization medium or when steam is used for heating up the sterilization medium water [2]. These can be of three types

A. *Simple small autoclave*

These are usually vertical autoclaves with the lid on top. Through the opened lid the goods to be sterilized are loaded into the autoclave. The cans are normally placed in metal baskets. These types of autoclaves are best suited for smaller operations as they do not require complicated supply lines and are available at affordable prices.

B. *Larger autoclaves*

These are usually horizontal and loaded through a front lid. Horizontal autoclaves can be single or double vessel system. The double vessel systems have the advantage that the water is heated up in the upper vessel to the sterilization temperature and released into the lower (processing) vessel, when it is loaded and hermetically closed. Using the two–vessel system, the heat treatment can begin immediately without lengthy heating up of the processing vessel and the hot water can be recycled afterwards for immediate use in the following sterilization cycle. If steam is used instead of water as the sterilization medium, the injection of steam into a single vessel autoclave will instantly build up the autoclave temperature desired for the process.

C. *Rotary autoclaves*

In this the basket containing the cans rotates during sterilization. This technique is useful for cans with liquid or semi-liquid content as it achieves a mixing effect of the liquid/semi-liquid goods resulting in accelerated heat penetration. The sterilization process can be kept shorter and better sensory quality of the goods is ensured.

At the final stage of the sterilization process the products must be cooled down as quickly as possible. This operation is done in the autoclave by introducing cold water. The contact of cold water with steam causes the latter to condense with a rapid pressure drop in the retort. However, the overpressure built up during thermal treatment within the cans, jars or pouches remains for a certain period. During this phase, when the outside pressure is low but the pressure inside the containers is still high due to high temperatures there, the pressure difference may induce permanent deformation of the containers. Therefore, high pressure difference between the autoclave and the thermal pressure in the containers must be avoided. This is generally achieved by a blast of compressed air into the autoclave at the initial phase of the cooling. Sufficient hydrostatic pressure of the introduced cooling water can also build up counter pressure so that in specific cases, in particular where strong resistant metallic cans are used, the water pressure can be sufficient and compressed air may not be needed. For the stabilization of metallic cans, stabilization rims can be moulded in lids, bottom and bodies [16].

X. TYPES OF CONTAINERS FOR THERMALLY TREATED PRESERVES

Containers for heat-preserved food must be hermetically sealed and airtight to avoid recontamination from environmental microflora. Most of the thermally preserved products are in metal containers (cans). Others are packed in glass jars or plastic or aluminum/plastic laminated pouches.

To prevent interaction between a meat product and the metal, cans are generally coated on the inside with an organic material. The terms enamel and lacquer are used interchangeably with organic coating. These coatings are solutions of resins in organic solvents. Two general kinds of organic coatings are used in the food industry

- Acid-resistant
- Sulfur-resistant

Meat products are generally packed in cans that have been lined with a sulphur-resistant material. This is necessary because during the retorting operation, sulphur released from meat proteins will stain tinplate an unsightly black. Because solid meat products are frequently difficult to remove from cans, coatings containing a release agent are used to facilitate product removal. [1]

A. *Metal containers*

They are cans or “tins” produced from tinplate. They are usually cylindrical. However, other shapes such as rectangular or pear-shaped cans also exist. Tinplate consists of steel plate which is electrolytically coated with tin on both sides. The steel body is usually 0.22 to 0.28mm in thickness. The tin layer is very thin (from 0.38 to 3.08 µm). In addition, the interior of the cans is lined with a synthetic compound to prevent any chemical reaction of the tinplate with the enclosed food.

Aluminium is frequently used for smaller and easy-to-open cans,. Aluminium cans are usually deep-drawn two-piece cans, i.e. the body and the bottom end are formed out of one piece and only the top end is seamed on after the filling operation. The advantages of aluminium cans compared to tin cans are their better deep-drawing capability, low weight, resistance to corrosion, good thermal conductivity and easy recyclability. They are less rigid but more expensive than steel plate cans.

B. *Glass jars*

Glass jars are sometimes used for meat products but are not common due to their fragility. They consist of a glass body and a metal lid. The seaming panel of the metal lid has a lining of synthetic material. Glass lids on jars are fitted by means of a rubber ring.

C. *Retortable pouches*

These are the containers made either of laminates of synthetic materials only or laminates of aluminium foil with synthetic materials, are of growing importance in thermal food preservation. Thermo-stabilized laminated food pouches, have a seal layer which is usually PP (polypropylene) or

PP-PE (polyethylene) polymer, and the outside layers are usually made of polyester (PETP) or nylon. Retortable pouches/laminated containers have good thermal conductivity which can considerably reduce the required heat treatment time and hence is beneficial for the sensory product quality. [16]

1) Advantages of retort pouches –

- It has superior taste due to reduced retort time.
- The shelf life is extended.
- Reduced storage space is required.
- Transportation cost is less.
- It is easier and safer to use.
- It can be tear open.
- The disposal is easier.
- We have microwave convenience.

2) Disadvantages of retort pouches –

- Large capital investment is required by the processor.
- Filling is slower and more complex.
- Critical parameters to be monitored are residual air, pouch thickness, steam-air mixture etc.
- A special racking system is needed.
- It can be easily punctured and thus, require over wrapping.
- It is required to check the leakage and container integrity. [14]

XI. CHANGES IN THE MEAT DUE TO THE CANNING PROCESS

The sterilized canned meats suffer a considerable change in the process. There is an increase in free –SH groups. The proteins may coagulate and precipitate. The texture of canned meat after sterilization is more like cooked meat rather than fresh meat. If the heat treatment is excessive, marked deterioration in aesthetic appeal and eating quality occurs. Since meat contains appreciable quantities of thiamine and ascorbic acid, which are heat sensitive vitamins, the nutritive value of the canned product will be lower than that of fresh meat. The loss of such labile nutrients will be exaggerated if the cans are subsequently stored for long periods at high ambient temperatures. The high temperature also affects the color of canned meat as the red pigment, myoglobin is changed to brown myohaemochromogen. If the interior of the can is not lacquered, there may be discoloration due to reaction of H_2S (produced from the meat proteins) with the plate metals. [17]

XII. IRRADIATION OF MEAT

Food irradiation is the process of exposing foodstuffs to a source of energy capable of stripping electrons from individual atoms in the targeted material. The concept of application of ionizing radiations to preserve food dates back to 1940. [13]. The radiations of interest for food industry include gamma rays, beta rays, X-rays and alpha particles as their quanta has sufficient energy to ionize particles in their path. The ionizing radiations destroy microorganisms in food without raising the temperature thus, the process is also known as “cold sterilization”. [17]. Ionizing radiations used in food industry can be emitted by a radioactive substance also called as radionuclide or generated by high-energy accelerators including X-ray converters. [13]. The machine type radiations are produced by an electron accelerator that generates a high energy electron beam or high energy X rays. Isotopic radiations can be produced by using isotopes such as Cobalt-60 (^{60}Co) or Cesium-137 (^{137}Cs) as a source of gamma rays. [17]. Although the two sources of ionizing radiations produce similar reactions in food but they may not be equally suitable for all food applications because of their different penetrating powers. High energy electrons are less penetrating than gamma rays, the extent of penetration is influenced by the energy and density of the product[13]. As the energetic particles or waves pass through the target material they collide with particle. Around the sites of these collisions chemical bonds are broken. This treatment is used to preserve food, reduce the risk of food borne illness, prevent the spread of invasive pest, delay or eliminate sprouting or ripening, increase juice yield, and improve rehydration [12].

Measuring the amount of radiation absorbed by the food is described as dosimetry and is expressed as a unit called rad. A rad is a unit equivalent to the absorption of 100 ergs/g of matter. A kilorad is equal to 1000 rads, and a megarad(Mrad) is equal to one million rads. A newer unit of an absorbed dose is the gray (1 G = 100 rads = 11 joule/kg; 1 kGy = 10^5 rads.) [13]

The amount of dose for different applications is different. On the basis of the dose of radiation the application is generally divided into three main categories

1) Low dose applications (up to 1 kGy):

Insect disinfestation including quarantine treatment, pest control and sprout inhibition and elimination of food borne parasites 0.07-1.00 kGy.

2) *Medium dose applications* (1 kGy to 10 kGy)

- Radicidation – similar to pasteurization causes reduction of pathogenic microbes in fresh and frozen meat, other than viruses : 2.5-10 kGy
- Radurization – is a lower level pasteurization that is used to reduce specific spoilage microorganisms with a common dose level of 0.75-2.5 kGy

3) *High dose applications* (above 10 kGy)

The doses are approved for non commercial applications, such as sterilizing frozen meat for NASA astronauts (doses of 44 kGy).

- Radappertization – commercial Sterilization of packaged meat, poultry, and their products that are shelf stable without refrigeration 30-40 kGy. [5 &18]

The World Health Organisation (WHO) in 1980 declared that '…no health hazard results from consuming any food irradiated up to a dose of one megarad (1 Mrad) or 10 kGy'. Thus, radurisation (the application of ionising radiation at a dose level which substantially reduces the microbial population) increases the shelf life of poultry, comminuted meat and meat dishes significantly. Low dose irradiation, or radicidation, eliminates parasites such as *Trichinae* and cysticerci in pork and, very importantly, salmonella organisms in poultry and red meat. Therefore, irradiation has an important rôle to play in public health protection. High dose irradiation, or radappertisation ('cold sterilisation'), uses doses in excess of 1 Mrad and is analogous to retorting as understood in the canning industry. However, it can adversely affect quality in producing 'free radicals' in high protein foods such as meat. To prevent this, special precautions are necessary, e.g. irradiation is conducted at very low temperatures and the product is usually vacuum packed [12].

XIII. EFFECTS OF IRRADIATION IN FOOD

The ionizing radiations produce ions and other chemically excited molecules in the food. The activated molecules further react and produce free radicals, polymers and in the presence of oxygen, peroxides. Meat has a substantial aqueous phase and thus destruction of organic molecules also occur indirectly through their reactions with the H atoms and OH radicals of irradiated water molecules. The damage to the organic compounds by irradiation is proportional to their molecular weight. Thus, the very large DNA molecules which as essential to microbial survival are particularly vulnerable [15]. Even though an extremely small percentage of chemical bonds are broken when a food is irradiated, the effect can be dramatic. For example, breaking bonds in the deoxyribose nucleic acid (DNA) results in the loss of a cell's ability to replicate. A relatively small change in the DNA of a bacterial cell can destroy the cell. The cellular destruction caused by disruption of the genetic material in a living cell is the principal effect of radiation on food, enabling destruction of insects, inactivation of parasites. [7]

Proteins are the chief organic components of meat. Random coiled structures in meat proteins are less resistant to the changes produced in them due to ionizing radiations as compared to helical arrangements. Most of the water in proteins is bound thus the secondary reactions are limited. Moreover, many substances are present in meat which can act as free radical acceptors. There is little damage to the amino acids, but soluble amino acids are deaminated. The main chemical changes in proteins are denaturation, polymerization and degradation to aggregates of lower molecular weight. [15]

Color changes in irradiated fresh meat occur because of the susceptibility of the myoglobin molecule, especially the iron, to alterations in the chemical environment and to energy input. The potential for iron electrons to exist in various states makes the environment adjacent to the iron atom particularly vulnerable to the presence of electron-donating compounds and high energy inputs (irradiation). Generation of stable red pigments or brown pigments which become red over time appears to be due to binding of irradiation-generated reactive oxygen species or gasses which become ligands bound by iron under altered reducing conditions. Rapid generation of large amounts of metmyoglobin when irradiation is conducted in an oxygen-containing environment appears to be an acceleration of the normal process by which myoglobin undergoes oxidation. Generation of green pigments appears to be due to breakdown of the porphyrin integrity and/or formation of sulfmyoglobin. Maintenance of ideal meat color during irradiation can be enhanced by various combinations of pre-slaughter feeding of antioxidants to livestock, optimizing the condition of the meat prior to irradiation, addition of antioxidants, gas atmosphere (MAP), packaging, and temperature control [3].

Ionizing radiations brings changes in lipids similar to that of oxidative rancidity. In the absence of oxygen, fatty acids are decarboxylated. If they are unsaturated, they get polymerised. In the presence of oxygen, hydroperoxides and carbonyls are formed. The quantity of carbonyls produced increases with increasing dose. Ionizing radiations may break C-C linkages forming various aliphatic hydrocarbons.

Carbohydrates of meat tend to get oxidised in the fifth position, yielding gluconic acids and aldehydes.
Vitamin C and thiamine are greatly affected and the destruction of thiamine is the greatest nutrient loss in irradiated meat. [15]

Organoleptic changes at doses of about 5kGy or above, odour and flavour changes may be produced in food. These are mainly caused by the formation of volatile sulphur containing substances – hydrogen sulphide, carbonyls, amines, etc. hydrogen sulphide odour is lost on subsequent storage and different odours develop. Beef is particularly susceptible to the development of these unpleasant odours and flavors, pork is much less affected. If the meat is irradiated in frozen state the unaccepatable organoleptic changes produced are minimum due to virtual removal of aqueous phase and prevention of secondary chemical changes[13].

The Irradiation dose should not exceed 10 MeV as it can lead to induced radioactivity in certain elements of meat. The advantages of the use of ionizing radiations for meat preservation include their highly efficient inactivation of bacteria, low total chemical change, the appreciable thickness of material that can be treated after packaging in containers, even those made of metal. Meat preserved by irradiation are superior in quality to thermally processed meats [15]. Ionizing radiation cannot make food radioactive. The radiolytic products that form when food is irradiated are generally the same as those that are formed when food is cooked. Despite concerns expressed by those who decry the use of radiation, no unique radiolytic products of toxicological significance have been found in irradiated foods.

World Health Organization (WHO) review of the safety and nutritional adequacy of irradiated foods concluded that food irradiation

- will not lead to toxicological changes in the composition of food that would have an adverse effect on human health.
- will not increase microbiological risk; and
- will not lead to nutrient losses that would have an adverse effect on the nutritional status of people (WHO, 1994).

Furthermore, a meeting of the Food and Agriculture Organization of the United Nations, International Atomic Energy Agency, and the World Health Organization (WHO) concluded on the basis of knowledge derived from over 50 years of research that irradiated foods are safe and wholesome at any radiation dose (WHO, 1997). [7]

XIV. LABELLING OF IRRADIATED FOODS

FDA requires that irradiated foods bear the international symbol for irradiation. Radura along with the statement "Treated with radiation" or "Treated by irradiation" on the food label. Bulk foods are required to be individually labeled or to have a label next to the sale container. FDA does not require that individual ingredients in multi-ingredient foods (e.g., spices) be labeled.

It is important to remember that irradiation is not a replacement for proper food-handling practices by producers, processors and consumers. Irradiated foods need to be stored, handled and cooked in the same way as non-irradiated foods, because they could still become contaminated with disease-causing organisms after irradiation if the rules of basic food safety are not followed.

Processors may add information explaining why irradiation is used; for example, treated with irradiation to inhibit spoilage or treated with irradiation instead of chemicals to control insect infestation [9].

XV. CONCLUSIONS

Thermal processing and Irradiation are two of the several techniques available for preservation of meat and meat products. Thermal processing involves use of high temperatures for killing of microorganisms and inactivation of enzymes to obtain the desired preservation effect. According to the end product requirement heat treatment can be mild or drastic. Most of the meat and meat products are commercially sterilized in an autoclave and the process is known as canning. The processed product can be packed in metal cans, glass containers or retort pouches. The main changes in sterilized canned meats include an increase in free –SH groups, coagulation and precipitation of proteins and alteration in the texture. Irradiation is the process of exposing foods to ionizing radiations. The radiations of interest for food industry include gamma rays, beta rays, X-rays and alpha particles as their quanta has sufficient energy to ionize particles in their path. The amount of dose for different applications is different. The doses can be low, medium or high depending on the desired effect. The ionizing radiations produce ions and other chemically excited molecules that further react and produce free radicals and peroxides. The main chemical changes in proteins are denaturation, polymerization and degradation to aggregates of lower molecular weight. Color changes in meat occur because of the susceptibility of the myoglobin molecule. Ionizing radiations brings changes in lipids similar to that of oxidative rancidity. Carbohydrates of meat tend to get oxidised. Organoleptic changes are mainly caused by the formation of volatile sulphur containing substances – hydrogen sulphide, carbonyls, amines, etc. hydrogen sulphide odour is lost on subsequent storage and different odours develop. Ionizing radiation cannot make food radioactive. The World Health Organisation (WHO) in 1980 declared that '…no health hazard results from consuming any food irradiated up to a dose of one megarad (1 Mrad). FDA requires that irradiated foods bear the international symbol for irradiation. Radura along with the statement "Treated with radiation" or "Treated by irradiation" on the food label.

ACKNOWLEDGEMENT

I would like to extend a sincere thanks to and gratitude to my family and friends for their constant support and encouragement.

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