PRESERVATION OF MEAT: IRRADIATION

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Irradiation is well recognized cost effective method of preservation of meat and meat products. The safety of irradiated foods was demonstrated with experimentation. In 1980, the joint Expert Committee of Food and Agriculture Organization, International Atomic Energy Agency, and World Health Organization (FAO / IAEA / WHO) on the wholesomeness of Irradiated Food concluded that (i) Irradiation of any food commodity up to an overall average dose of 10 kGy (1 Mega rad, 1 M rad) causes no toxicological hazard, (ii) Toxicological testing of so irradiated food is not required and (iii) Irradiation up to 10 kGy causes no special microbiological and nutritional problems. This has encouraged the use of irradiation method in meat industry all over the world.

Irradiation is a cold process or cold pasteurization process. It destroys microbes without substantial increase in the temperature of the food. It does not cause significant physical and chemical changes in food. When food is irradiated to an absorbed dose of 10 kGy, the product temperature may rise only by 2.5 ºC. Hence the irradiation technology is considered non – thermal. Radiation at low energy level does not induce radioactivity in the food constituents. It will not produce any harmful toxic residues in food and can be used to treat pre - packed commodities. Irradiation achieves disinfestations of insects, enzyme inhibition and destruction of spoilage and pathogenic microbes and parasites of hazardous nature.

The following aspects are dealt with in this topic:

1. Sources of ionizing radiation
2. Mechanism of action of radiations
3. Irradiation processes
4. Irradiation in combination with other treatments
5. Quality of irradiated meat

1. SOURCES OF IONIZING RADIATION

Irradiation is the controlled application of energy from ionizing radiations. A joint FAO / IAEA / WHO Expert Committee of Irradiated Foods approved the use of only the following types of ionizing radiation for food irradiation.

i. Gamma rays from radionuclides Cobalt – 60 (Maximum energy 1.17 - 1.3 MeV) or Cesium - 137 (Maximum energy 0.67 MeV).
ii. X - rays generated by machines operated at or below an energy level of 5.0 – 7.5 MeV.
iii. Electrons produced commercially by machine sources at or below an energy level of 10 MeV

Units of radiation

Radiation energy is measured in terms of rads where 1 rad = 100 ergs of energy absorbed in 1 g of matter.

1 eV = 1.6 X 10^{-12} erg
1 erg = 10^{-7} Joule and
1 Joule = 10^{7} erg = 10 M erg

A new standard irradiation (SI) unit is known as Gray (Gy).

1 Gray = 100 rads
1 K rad = 1000 rads
1 M rad = 1000 000 rads
1 kGy = 100 000 rads

2. MECHANISM OF ACTION OF RADIATIONS

When ionizing radiations of approved energy levels pass through foods, there are collisions between ionizing radiations and food particles at the molecular levels. Ion pair is produced when the energy from these collision is sufficient to dislodge an electron from an atomic orbit. Molecular changes occur when collisions provide sufficient energy to break chemical bonds between atoms and form free radicals. Irradiation of food helps formation of ion pairs, free radicals, reaction of free radicals with other molecules and recombination of free radicals. These mechanisms alter microorganisms and food constituents effecting food preservation.

Resistance of microorganisms: The most radiation resistant microorganism in foods is *Clostridium botulinum.* Acid values below pH 4.5, aerobic conditions, extreme dryness in foods and / or, refrigeration below 4 ºC prevent growth and toxin formation by this organism. In foods where these conditions do not exist, the food is irradiated with the dosage sufficient to destroy this organism. Food with pH > 4.5, *Cl. botulinum* is not a problem but other spoilage organisms must be inactivated with lower radiation dosages.

Bacterial spores are more resistant to the germicidal action of ionizing radiations than are the vegetative cells.

Resistance of enzymes: Most food enzymes are more resistant to ionizing radiations than even the spores of *Cl. botulinum.* Inactivation of enzymes requires very high doses of the order of 200 kGy (20 M rad). Such a high dosage destroys food constituents and impairs safety of food. For these reasons, irradiation alone is not suitable for food stability. Hence combination of processes is preferred. Enzymes are more easily inactivated by heat (even blanching) and by certain chemicals.

3. IRRADIATION PROCESSES

Different materials absorb radiation energy to different degrees. The dose of energy absorbed is important in food preservation. A rad of radiation dosage represents the same amount of absorbed energy whether it comes from gamma rays or beta particles or a mixture of the two. Absorption of rads is determined by (a) Length of time the food is exposed to radiations and (b) Absorption properties of food and its container.

There are 3 general applications and dose categories when foods are treated with ionizing radiation. They are radurisation, radicidation and radappertisation and briefly described below.

Radurisation: Low doses up to 1 kGy are employed in this process. These low doses substantially reduce the pathogenic and spoilage microorganisms and enhance the keeping quality of meat and meat products. Radurisation is used along with refrigeration to maintain quality. The shelf life of fresh meats in refrigeration at 2 - 4°C is normally 3 days. The shelf life of radurised fresh meats is 5 weeks at the same temperature. Radurisation is helpful if fresh meat is to be transported in chilled condition to the destimation. Radurisation reduces the levels of potential pathogens such as *Salmonella spp* and spoilage organisms such as *Pseudomonas spp.* Also it causes insect disinfestations and parasite inactivation. However, radurisation may induce oxidation of myoglobin to metmyoglobin and drip from cut surfaces. This may cause off flavors in meat. Addition of sodium tripolyphosphate, use of oxygen permeable and moisture impermeable plastic wrapping with dosage of about 1 kGy prolongs the storage life of meats up to 3 weeks. The dosage up to 1 kGy does not induce lipid oxidation.

Radicidation: This process involves the application of medium radiation doses of 1 – 10 kGy necessary to reduce the number of viable non - sporing pathogenic and spoilage bacteria. Meat and poultry are frequently contaminated with pathogens such as Salmonella, Campylobacter and Listeria, which are inactivated by this dosage of irradiation. .

Radappertisation (Cold sterilization): Radappertisation is an alternative to commercial preservation by thermal sterilization, freezing and drying. The doses used are high in the range of 10 - 45 kGy. It is similar to thermal processing of canned meat products (Fig. 1). Reduction in numbers of microorganisms will be to the point of commercial sterility.

Very few microorganisms survive following the radappertisation process. The product is shelf - stable (long term storage without refrigeration). Products subjected to radappertisation should be packed properly to prevent microbial recontamination and the deleterious effects from light, oxygen and moisture. Both metal containers and flexible packages are used under vacuum to prevent rancidity of lipids.

In India, irradiation process has been approved for treatment of meat, fish and poultry and their products. Changes occurr in microbial counts, physico – chemical and rancidity parameters immediately after irradiation of goat meat mince with a dosage of 4 kGy. Microbial counts are substantially lower in irradiated meat compared to non – irradiated meat. Enterococci, *Escherichia coli* and *Staphylococcus aureus* are not detected in irradiated meat (Table 1). Water holding capacity and pH of goat meat are lower in irradiated meat. Changes in emulsion stability and Hunter color values of meat due to irradiation are marginal. Irradiated goat meat has slightly higher free fatty acid value and substantially lower thiobarbituric acid value (Table 2).

Radiolytic products: The radiolytic products from all meats (including poultry and fish) are the same. They include several chemicals such as alkanes, alkenes, alkynes, aromatic hydrocarbons, alcohols, aldehydes, esters and sulphur compounds. Degree of formation of radiolytic components increases with dosage as well as with increased product temperature.

4. IRRADIATION IN COMBINATION WITH OTHER TREATMENTS

As mentioned in many instances irradiation alone may not be successful in providing safe meat. Combination of different treatments show better results for maintaining the quality of irradiated meat products. The combination treatments have synergistic antimicrobial effect. Incorporation of ascorbic acid and spice powders in to meat products may offset the ill effects of irradiation by minimizing the production of off odors / flavors. Addition of alpha tocopherol / antioxidant in to ground meat and proper packaging retards or limits lipid oxidation in the irradiated meat. The role of nitrite in meat curing is color fixation and imparting flavor to the product. Nitrite also inhibits the growth of *Cl. botulinum*. The nitrite in cured meats forms nitrosamines that are carcinogenic (cancer causing). Radiation destroys *Cl. botulinum.* Hence, nitrite requirement in meat curing can be reduced by 50%, if the meat is subjected to radiation.

Irradiation in combination with vacuum packaging, edible coating film containing natural antimicrobial compounds or modified atmosphere packaging reduced bacterial growth. Irradiation and refrigeration of meat and meat products increased both safety and shelf life of products. High dosage of radiations required for inactivation of enzymes in meat or poultry products is detrimental. The dosage can be reduced by vacuum packaging in subfreezing temperatures to prepare sterile shelf stable products with excellent sensory properties. Such products have been used extensively by military organizations during space flights and hospitals.

5. QUALITY OF IRRADIATED MEAT

Meat color is the primary quality attribute of fresh meat that affects consumer acceptance. Heme pigments, especially myoglobin, are responsible for meat color. Irradiation influences the release of iron from heme pigments and also converts oxygen to ozone. Ozone is a strong oxidizing agent and it oxidizes myoglobin. This causes bleaching discoloration. Pre – slaughter feeding of antioxidants to livestock or addition of antioxidants directly to the meat product helps maintain meat color during irradiation.

Irradiated fats cause autoxidation in the late post – irradiation period leading to off odors / flavors due to increased rancidity. Peroxide value of irradiated meat may remain unchanged if meat is blanched and vacuum packed in cans or flexible pouches before irradiation.

Proteins are built of amino acids. There are about 20 amino acids in food proteins of which 9 are essential. These 9 amino acids must be provided in the diet since they are not synthesized by the human body. The nutritional quality of protein directly refers to its ability to provide 9 essential amino acids in the quantity required. Damage caused to proteins by irradiation includes deamination, decarboxylation, reduction of sulphur linkages and oxidation of sulfhydryl groups. Irradiation also causes breakage of peptide bonds and changes in valency states of the coordinated metal ions. Irradiation reduces water binding capacity of muscle proteins resulting in increased drip loss. The solubility of collagen is increased by irradiation, which improves tenderness quality of meat. Irradiation decreases viscosity of liquid egg white (albumin) suggesting the denaturation of albumin proteins in to smaller units. However, digestibility, biological value, net protein utilization and amino acid composition are same as untreated meat. This was depicted by experiments on rats. Changes in proteins due to irradiation of meat also influence the emulsion characteristics of proteins, which in turn affect sensory quality attributes of meat emulsion products.

The vitamins, thiamine, riboflavin and pyridine, are reduced on irradiation while niacin is not affected. Pantothenic acid and folacin vitamins are reasonably resistant to radiation. Carotene is sensitive to radiation but can be protected by ascorbic acid.

CONCLUSION

Irradiation is a cold process or cold pasteurization process as it can destroy microbes without substantial increase in the temperature of food. Irradiation is cost effective method of preservation. Radiation at low energy level does not induce radioactivity in the food constituents. It does not produce any harmful toxic residues in food and can be used to treat pre - packed commodities. Irradiation achieves disinfestation of insects, enzyme inhibition, destruction of microbes responsible for spoilage and elimination of pathogens and parasites of hazardous nature.

The radiation sensitivity of microbes is affected by the extrinsic environment including atmosphere, temperature and intrinsic characteristics such as pH and chemical composition of the product. Radurisation, radicidation and radappertisation are different irradiation processes depending on radiation dosages used to irradiate foods.

Bacterial spores are more resistant to the germicidal action of ionizing radiations than are the vegetative cells. Food enzymes are more resistant to ionizing radiations than even the spores of bacteria. Very high radiation dosage required for inactivation of enzymes destroys food constituents and impairs safety of food. For these reasons, irradiation alone is not suitable for food stability. Hence combination of processes is employed. Enzymes are more easily inactivated by heat (even blanching) and by certain chemicals. Low temperature, modified atmospheres, mild thermal treatment, vacuum packing in combination with irradiation can ensure minimum changes in physico – chemical, biochemical and sensory quality attributes and provide better quality meat products.

Cook meat to internal temperature of 75 ºC
(Inactivation of enzymes)

↓

Vacuum packed
(Multilayered pouch)

↓

Freeze to – 40 ºC

↓

Irradiate with dosage of 45 kGy
(Temperature – 30 ºC to - 40 ºC)

Fig. 1. Radappertisation process to obtain sterile shelf stable meat product

Source: Narasimha Rao 2011

Table 1. Effect of irradiation on microbial quality (Counts in log cfu / g) of goat meat

Organisms / Toxin	**Non - irradiated**	**Irradiated** (Dosage: 4 kGy)
Total aerobic counts	4.9	2.6
Psychrotrophs	5.0	2.5
Enterococci	3.9	Not detected
Escherichia coli	2.1	Not detected
Total staphylococci	3.7	2.1
Staphylococcus aureus	1.9	Not detected
Yeast and mould	2.6	1.5

Source: Modi *et al*. 2008

Observations

- Microbial counts are substantially lower in irradiated goat meat than in non - irradiated meat.
- Enterococci, *Escherichia coli* and *Staphylococcus aureus* are not detected in irradiated meat.

Table 2. Effect of irradiation on physico - chemical and rancidity quality of goat meat

Parameter	**Non - irradiated**	**Irradiated** (Dosage: 4 kGy)
Physico - chemical		
pH	6.0	5.7
Water holding capacity (% Bound water)	55.5	51.7
Emulsion stability (ml juice / 100 g emulsion)	26.0	27.5
Hunter color, L	30.0	33.5
Hunter color, a	12.0	12.5
Hunter color, b	7.3	8.5
Rancidity		
Free fatty acid (% Oleic acid)	0.5	0.6
Thiobarbituric acid value (mg malonaldehyde / kg sample)	0.42	0.27

Source: Modi *et al.* 2008

Observations

- Water holding capacity and pH of goat are lower in irradiated meat.
- Changes in emulsion stability and Hunter color values of meat due to irradiation are marginal.
- Irradiated goat meat has slightly higher free fatty value and substantially lower thiobarbituric acid value.