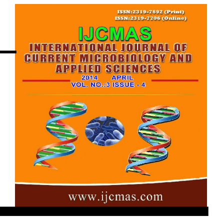
International Journal of Current Microbiology and Applied Sciences
ISSN: 2319-7706 **Volume 3 Number 4 (2014) pp. 549-555**
http://www.ijcmas.com



Review Article

Food Irradiation - Technology and Application

B.Kalyani* and K.Manjula

Department of Home Science, S.V.University, Tirupati, A.P., India-517502
**Corresponding author*

Keywords

Radiation, technology, food, packaging.

A B S T R A C T

The technology of food irradiation is gaining more and more attention around the world. In comparison with heat or chemical treatment, irradiation is more effective and appropriate technology to destroy food borne pathogens. Radiation technique makes the food safer to eat by destroying bacteria which is very much similar to the process of pasteurization. Radiation does not leave the food items radioactive for two seasons. First, the gamma rays from cobalt-60 used in food radiation are not energetic enough to make it radioactive. Second, as the food never comes into contact with the source directly, it is not possible for the food to become contaminated with radioactive material. In the changing scenario of world trade, switching over to radiation processing of food assumes great importance. Radiation will be moving fast to the status of a 'wonder technology' to satisfy the sanitary and phyto sanitary requirements of the importing countries. Food once irradiated, can be prone to re-contamination unless appropriately packed Therefore, if radiation treatment is intended to control microbiological spoilage or insect infestation, prepackaging becomes an integral part of the process.

Introduction

India has been practicing various methods of food preservation from time immemorial such as sun drying, pickling and fermentation. These methods were supplemented with more energy consuming techniques like refrigeration, freezing and canning; however had its merits and demerits. The quest was ever on for newer methods of food preservation with least change in sensory qualities. Preservation of food items is a pre-requisite for food security. The seasonal nature of production and the long and unmanageable distances between the production and consumption centers and the rising gap between demand and supply have posed great challenges to conventional techniques of food preservation and thereby to food security. The hot and humid climate of the country is quite favorable to the growth of numerous insects and micro organisms which destroy stored crops and cause spoilage of food. In the changing scenario of world trade, switching over to radiation processing of food assumes great importance. Radiation processing can be used for disinfestations of pests and disease-causing organisms from a range of products including fruits and vegetables.

Radiation as a Preservation Technique

Radiation is one of the latest methods in food preservation. Radiation technique makes the food safer to eat by destroying bacteria which is very much similar to the process of pasteurization. In effect, radiation disrupts the biological processes that lead to decay and the ability to sprout. Being a cold process, radiation can be used to pasteurize and sterilize foods without causing changes in freshness and texture of food unlike heat. Further, unlike chemical fumigants, radiation does not leave any harmful toxic residues in food and is more effective and can be used to treat packaged commodities too.

Countries including India guard against import of exotic insect pests by requiring a post harvest disinfestations treatment of commodities that can carry pests. India will not be able to resist the flow of radiated foods to the country as a prohibitive policy would be difficult to justify on technical grounds and could be challenged under the WTO agreement as a technical barrier to trade. Above all, radiation technology for food preservation will be moving fast to the status of a 'wonder technology' to satisfy the sanitary and phyto sanitary requirements of importing countries.

The Ministry of Food Processing Industries has a major role to play in ensuring food security by processing and preserving food items to be released in consuming areas and at lean periods. The ministry has a number of schemes to encourage entrepreneurs for setting up facilities for radiation processing of food in public as well as private sectors.

The Ministry extends assistance for setting up facilities for food processing by using radiation technology to promote commercial use of this technology in India. BARC will be the nodal agency for assistance and guidance on process technology while BARC/BRIT will provide information on availability, cost and possible alternatives of essential machinery including pollution control and disposal of radio isotopes. BARC can provide training to the staff on various aspects of operation and safety in India (saylor, and, Jordan, 2000).

Radiation Processing

Food irradiation is a technology that can be safely used to reduce food losses due to deterioration and to control contamination causing illness and death. Food irradiation uses radiant energy – electron beams, gamma rays or x-rays to rid food of harmful microorganisms, insects, fungi and other pests, and to retard spoilage. It does not make food radioactive. Irradiation kills pathogens and makes them incapable of reproduction.

There are several processes that are collectively referred to as “Food Irradiation”. The object of each process is to kill or impair the breeding capacity of unwanted living organisms or to affect the product morphology in a beneficial way that will extend shelf-life. Each process has an optimal dose of ionizing energy (radiation) dependent on the desired effect. The dose of radiation is measured in grays (Gy). A “gray” is a unit of energy equivalent to 1 joule per kilogram. This unit of measure is based on the metric system. Thus, 1 kilogray (kGy) is equal to

1,000 grays (Gy). All three forms of ionizing energy have the same effect, gray for gray. Some of the major processes are:

Pasteurization (Pathogen Reduction)

Irradiation is used to effectively eliminate disease causing organisms including bacteria and parasites. (e.g. Irradiating ground beef to make it safe from *E. coli* O157:H7. Irradiating live oysters to make them safe from *vibrio*.)

Sterilization – Irradiation is used at a very high dose to eliminate all organisms so that refrigeration is not required (shelf stable). (e.g. Certain foods are sterilized for NASA astronauts.)

Sanitation – Irradiation is widely used to reduce organisms for spices, herbs and other dried vegetable substances. (e.g. Irradiating spice blends that are added to meat for hot dogs and other "Ready to Eat" products that may not be cooked again.) the population of spoilage causing organisms, including bacteria and mold. On certain fruits and tubers, irradiation delays ripening and/or sprouting. (e.g. Irradiating berries to reduce mold. Irradiating fresh fruits to extend their market reach. Irradiating potatoes, onions and garlic to impair cell division and hence allow them to go through the "off" season without sprouting.)

Disinfestation – Irradiation is used to stop reproduction of both storage and quarantine insect pests.(e.g. Irradiating foreign produced mangoes to eliminate the seed weevil, which is a quarantined pest, for import to the US. Irradiating papaya is to eliminate fruit flies, which are quarantined pests, for import from Hawaii or foreign countries into the US mainland.) All three forms of irradiation are referred to as a "cold process". Although all of the radiation energy is converted to heat during treatment, the process typically increases the product temperature by about 1 degree Celsius(Benebion.).

Types of Radiation sources

Three principal types of radiation source can be used in food irradiation according to the

Codex Alimentarius General Standard (Food and agriculture organization, world health organization, 1984) :

(a) Gamma radiation from radionuclides such as 60Co or 137Cs 8;

(b) Machine sources of electron beams with energies up to 10 MeV;

(c) Machine sources of bremsstrahlung (X rays) with electron energies up to 5 MeV.

Because of their greater penetrating capability, γ rays and X rays may be used for processing of relatively thick or dense products. For situations where only a shallow penetration is needed and where rapid conveyor speeds can be used, high power electron beams may provide a higher output at lower cost per unit of product when large amounts of product are involved.

Gamma rays

The γ rays used in food processing are obtained from large 60Co radionuclide sources. This type of radiation is essentially monoenergetic (60Co emits simultaneously two photons per disintegration with energies of 1.17 and 1.33 MeV). Using analytical techniques such as the point kernel or Monte Carlo methods, it is possible to compute the dose distribution in irradiated food products even when very complicated source geometries such as extended plaque sources are used. The resulting depth–dose distribution in the food products usually resembles an approximately exponential curve. Irradiation from two sides (two sided irradiation), obtained either by turning the process load or by irradiation from two sides of a plaque source, is often used to increase the dose uniformity in the process load (Olivieira, et al., 2000; saylor, m.c., jordan, 2000).

Electrons

Electrons emitted by accelerators have fairly narrow spectral energy limits (usually less than ±10% of the nominal energy). The energy of the electrons reaching the product is further controlled by the bending magnets of the beam handling system, if applicable. The range of an electron in a medium is finite (unlike that for photons) and is closely related to its energy (Hayashi, 1998).

Bremsstrahlung (X rays)

Bremsstrahlung irradiator design principles are essentially the same as those for electron irradiators .An extended source of X rays is achieved by distributing the primary electron beam over a target (X ray converter) of sufficient size. In contrast to the radionuclide sources, which emit nearly monoenergetic photons, bremsstrahlung (X ray) sources emit photons with a broad energy spectrum (Aikawa, Y, 2000; Cleland, M.R., Pageau, G.M., 1987).

The effectiveness of processing of food by ionizing radiation depends on proper delivery of absorbed dose and its reliable measurement. For food destined for international trade, it is of the utmost importance that the dosimetry techniques used for dose determination are carried out accurately and that the process is monitored.

Food packed in crates or boxes is placed on conveyor belts and moved into the heart of the irradiator, where it is exposed to the radiation source. Electron beam irradiators can cleanse packaged food at the end of food-processing production lines. High-energy waves pass through the food, exciting the electrons in both the food and any pests or pathogens. When the electrons absorb enough energy, they break away from their atoms, leaving positively charged centers behind. Irradiation disrupts the molecular structure; kills or reduces the number of bacteria and yeasts; delays the formation of mold; and sterilizes or kills parasites, insects, eggs and larvae. Levels of absorbed radiation are currently measured in kilo grays (kGy).

Food Irradiation Applications

The scientific community has defined three levels of food irradiation:

Applications at low dose levels (10 Gy–1 kGy)

Sprouting of potatoes, onions, garlic, shallots, yams, etc. can be inhibited by irradiation in the dose range 20–150 Gy. Radiation affects the biological properties of such products in such a way that sprouting is appreciably inhibited or completely prevented. Physiological processes such as ripening of fruits can be delayed in the dose range 0.1–1 kGy. These processes are a consequence of enzymatic changes in the plant tissues. Insect disinfestations by radiation in the dose range 0.2–1 kGy is aimed at preventing losses caused by insect pests in stored grains, pulses, cereals, flour, coffee beans, spices, dried fruits, dried nuts, dried fishery products and other dried food products.

A minimum absorbed dose of about 150 Gy can ensure quarantine security against various species of tephretid fruit flies in fresh fruits and vegetables, and a minimum dose of 300 Gy could prevent insects of other species from establishing in non-infested areas. In most cases irradiation either kills or inhibits further development of different life-cycle stages of insect pests. The inactivation of some pathogenic parasites of public health significance such as tapeworm and trichina in meat can be achieved at doses in the range 0.3–1 kGy.

(i) Inhibition of sprouting 0.05 - 0.15 Potatoes, onions, garlic, root ginger, yam etc.
(ii) Insect disinfestations and parasite disinfection 0.15 - 0.5 Cereals and pulses, fresh and dried fruits, dried fish and meat, fresh pork, etc.
(iii) Delay of physiological processes (e.g. ripening) 0.25 - 1.0 Fresh fruits and vegetables.

Applications at medium dose levels (1–10 kGy)

Radiation enhances the keeping quality of certain foods through a substantial reduction in the number of spoilage causing micro-organisms. Fresh meat and seafood, as well as vegetables and fruits, may be exposed to such treatments with doses ranging from about 1 to 10 kGy, depending on the product. This process of extending the shelf life is sometimes called 'radurization'.

Pasteurization of solid foods such as meat, poultry and sea foods by irradiation is a practical method for elimination of pathogenic organisms and micro-organisms except for viruses. It is achieved by the reduction of the number of specific viable non-spore-forming pathogenic micro-organisms such that none is detectable in the treated product by any standard method, for which doses range between 2 and 8 kGy.

The product will usually continue to be refrigerated after the radiation treatment. This process of improving the hygienic quality of food by inactivation of food-borne pathogenic bacteria and parasites is sometimes called 'radicidation'. This medium dose application is very similar to heat pasteurization, and is hence also called radiopasteurization.

(i) Extension of shelf-life 1.0 - 3.0 kGy fresh fish, strawberries, mushrooms etc.
(ii) Elimination of spoilage and pathogenic microorganisms 1.0 - 7.0 kGy Fresh and frozen seafood, raw or frozen poultry and meat, etc.
(iii) Improving technological properties of food 2.0 - 7.0 kGy Grapes (increasing juice yield), dehydrated vegetables (reduced cooking time), etc.

Applications at high dose levels (10–100 kGy)

Irradiation at doses of 10–30 kGy is an effective alternative to the chemical fumigant ethylene oxide for microbial decontamination of dried spices, herbs and other dried vegetable seasonings. This is achieved by reducing the total microbial load present in such products including pathogenic organisms.

Radiation sterilization in the dose range 25–70 kGy extends the shelf life of precooked or enzyme inactivated food products in hermetically sealed containers almost indefinitely. This is valid independent of the conditions under which the product is subsequently stored as long as the package integrity is not affected. This effect is achieved by the reduction of the number and/or activity of all organisms of food spoilage or public health significance, including their spores, to such an extent that none are detectable in the treated product by any recognized method. This process is analogous to thermal canning in achieving shelf-stability (long term storage without refrigeration) and is sometimes called 'radappertization'.

(i) Industrial sterilization (in combination with mild heat) 30 - 50 Meat, poultry, seafood, prepared foods, sterilized hospital diets.
(ii)Decontamination of certain food additives 10 - 50 Spices, enzyme preparations, natural gum, etc and ingredients (Technical reports series No. 409 2002)

Packaging

Food once irradiated, can be prone to re-contamination unless appropriately packed. Therefore, if radiation treatment is intended to control microbiological spoilage or insect infestation, prepackaging becomes an integral part of the process. Technical functions of packaging are well known. These include prevention of moisture uptake or loss, maintenance of an atmosphere other than air, protection from mechanical damage or simply keeping the food clean.

Since packaging materials are also exposed to radiation during the treatment, these materials must also satisfy additional requirements such as resistance to radiation with respect to its functional properties. In addition, it should not transmit toxic substances into food nor impart any off odor to the products. Of the several packaging materials currently available such as cellulose, glass, metals and organic polymers, plastics offer unique advantages over the use of conventional rigid containers from the point of view of flexibility, low cost, light weight and low weight to volume ratio. Increasingly, packaging materials for use in aseptic processing lines in the food, pharmaceutical and cosmetic industry are now being sterilized by ionizing radiation.

The packaging requirements of a particular food are significantly influenced by the desired objective of the radiation treatment.

Packaging materials used for irradiated food are broadly classified into two categories depending on the type of radiation treatments.

• Processes requiring doses less than 10 kGy, such as extension of shelf-life of food.
• Processes requiring doses from 10-60 kGy, for storing such items as meat and poultry for long periods without refrigeration.

Irradiation of food is one of the most effective ways of food preservation to inactivate microorganisms and destroy insect pests. Effective irradiation treatment on food is associated with an effective packaging material, which performs all the technical functions of packaging along with resistance to radiations. Though several packaging materials like glass, cellulose, metals and organic polymers are available for this purpose, plastics offer unique advantages over the conventionally used rigid containers in terms of flexibility, low cost, light weight, and low weight to volume ratio. Multi-laminate packaging structure of polymers like nylon, EVOH, PVC, cellophane, PE and Polyester are used as a prominent barrier material in packaging of irradiated food (Agarwal, S.R. and Sreenivasan, A., 1972).

Irradiation of food is one of the most effective ways of food preservation to inactivate microorganisms and destroy insect pests. Effective irradiation treatment on food is associated with an effective packaging material, which performs all the technical functions of packaging along with resistance to radiations

References

Agarwal, S.R. and Sreenivasan, A., 1972. Packaging of irradiated flesh food: A review. J.Food Technol., 8, 27-37.

Aikawa, Y, 2000, A new facility for X-ray irradiation and its application, Radiat. Phys.Chem. 57, 609–612.

Benebion. S.A.FOOD Technology Service Inc.GRAY*STAR, Inc. Food Irradiation Processing Alliance, FIPA is an affiliate of the International Irradiation Association.

Cleland, M.R., Pageau, G.M., Comparison of X-ray and gamma-ray sources for industrial radiation processes, Nucl. Instrum. Methods, Sect. B 24/25 (1987) 967–972.

Food and agriculture organization, world health organization, Codex General Standard for Irradiated Foods and Recommended International Code of Practice for the Operation of Radiation Facilities used for the Treatment of Food, Codex Alimentarius, Vol. 15, FAO/WHO, Rome (1984).

Hayashi, T., Decontamination of dry food ingredients and seeds with 'soft-electrons' (low-energy electrons), Food Sci. Technol. Int. Tokyo 4 (1998) 114–120.

Olivieira, C., Salgado, J., Botelho, M.L., Ferreira, L.M., Dose determinations by Monte Carlo calculations, Radiat. Phys. Chem. 57 (2000) 667–670.

Santha Balakrishnan, Features Radiation processing of food,*Press information Bureau, Government of india, 37,11/27/13.*

saylor, m.c., jordan, T.M., Application of mathematical modelling technologies to industrial radiation processing, Radiat. Phys. Chem. 57 (2000) 697–700.

Technical reports series NO. 409, Dosimetry for food irradiation, international atomic energy agency vienna, 2002.