Recent developments and Challenges in Radiation Processing of Food

Dr. S. Gautam
Senior Scientist, FTD, Bhabha Atomic Research Centre,
Mumbai (Maharashtra) India.

ABSTRACT
Radiation processing of food involves controlled application of energy from ionizing radiations such as gamma rays, electrons and X-rays on food to achieve desired objectives. Gamma rays and X-rays are short wavelength radiations of the electromagnetic spectrum. Approved sources of gamma radiation for food processing are radioisotopes (Cobalt-60 and Caesium-137), electron beam (up to 10 MeV) and X-rays (up to 5 MeV). Later two is generated by machines using electricity. Gamma radiation can penetrate deep into food materials and bring about desired effects. Irradiation works by disrupting the biological processes that lead to decay. In their interaction with water and other molecules that make up food and living organisms, radiation energy is absorbed by the molecules they contact. The interaction of radiation and radiolysis products of water with DNA impair reproducing capacity of microorganism and insects as well as the ability of underground vegetables such as potato and onion to sprout.

I RADIATION PROCESS FOR FOOD

(a) Processing Facilities- Radiation processing of food is carried out in an irradiation chamber shielded by 1.5 - 1.8 m thick concrete walls. Food, either pre-packed or in-bulk, placed in suitable containers is sent into the irradiation chamber with the help of an automatic conveyor. The conveyor goes through a concrete wall labyrinth, which prevents radiation from reaching the work area and operator room. When the facility is not in use the radiation source is stored under 6 m deep water. The water shield does not allow radiation to escape into the irradiation chamber, thus permitting free access to personnel to carry out plant maintenance when required. For treating food, the source is brought to the irradiation position above the water level after activation of all safety devices and preventing human entry. The goods in carriers or tote boxes are mechanically sent inside and positioned around the source rack and are turned around their own axis, so that contents are irradiated on both the sides. The absorbed dose is determined by the residence time of the carrier or tote box in irradiation position. Absorbed dose is checked by placing dosimeters at various positions in a tote box or carrier.

(b) Food production and post-harvest losses in India- As per USDA database India ranked second in rice (approx. production 204 million MT), and wheat production (approx. 95 million MT) after China. India is the major producer of maize after USA, China, and Brazil, and also the leading producer of spices (approx. 1.5 million MT) (UN, FAO). Similarly it ranked second in fruits, and vegetables production after China. Yearly about 21 million MT of wheat i.e. approx. 22% of its total production rots in India. About 40% of India's fresh fruit and vegetables (equivalent to $8.3bn) perishes before reaching consumers (FAO).Cold storage facilities are available for just about 10% of India's perishable produce and are mostly used for potato. In developing countries 40% of losses occur at post-harvest and processing levels while in industrialized countries almost similar quantum of losses happen at retail and consumer levels.

(c) Food Safety- Microbial contaminations can occur at every level of food processing chain: at primary production stage (due to manure, soil, irrigation- water, worker etc.), processing stage (worker, conveyer belt, washing water), and retail or consumption stage (cross-contamination, cutting bed, improper storage). Bacteria like *Clostridium botulinum, E. coli O157:H7, L. monocytogenes, Salmonelle spp., Shigella spp., Staphylococcus spp., Vibrio cholerae, and Yersinia enterocolitica;* Viruses such as Norovirus, and HepatitisA, and protozoa like *Cryptosporidium* spp., and *Cyclospora* spp. have been reported to be associated with major fruits and vegetables associated outbreaks worldwide.Leafy greens like spinach are the most likely culprit in food borne illnesses as internalization of bacteria has been reported in such commodities. To address safety concern US FDA issued Final Rule on Approval of Irradiation of Spinach and Iceberg Lettuce (Food Chemical News, February 25, 2014). The proposition that *E-coli* testing of imported fresh fruits and vegetables should be mandatory was unanimously opined by the scientific panel on Contaminants or Biological Hazards of the Food Safety and Standards Authority of India (FSSAI) too, in its recent meeting discussing Biological Hazards, in New Delhi. U.S. Food and Drug Administration has recently also released a draft risk assessment on the levels of contaminants in spices. Approx. 12 percent of spices imported to the U.S. were found to be contaminated with insects and rodent excrement, and approx. 6.6 percent of spices were contaminated with *Salmonella*. Other pathogens found included

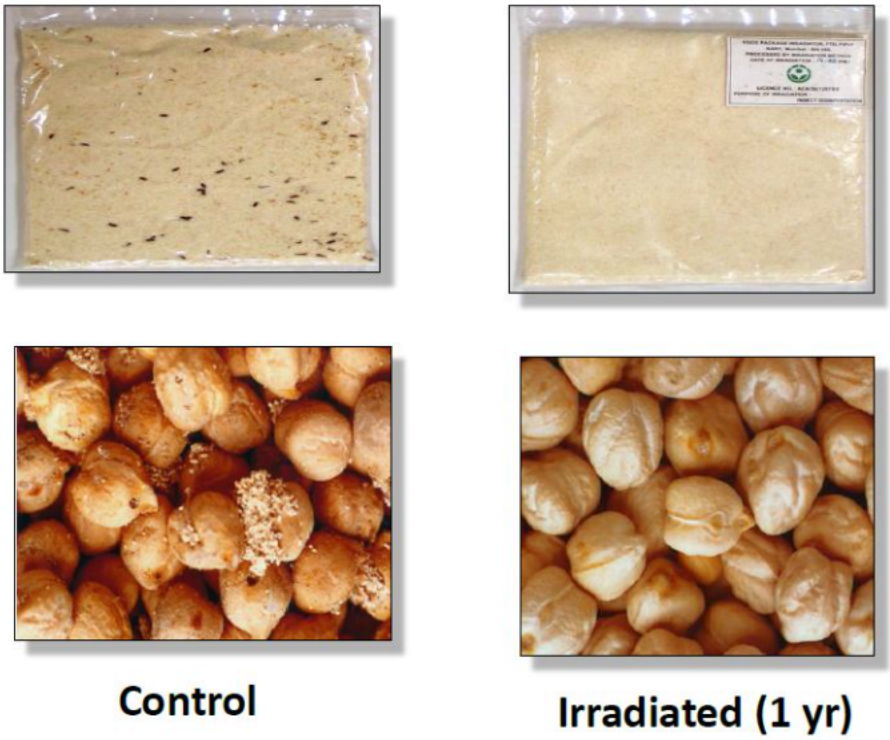

Fig 1 Insect Disinfestations of Cereals & Legumes

Clostridium perfringens, *Shigella* and *Staphylococcus aureus*

(d) Applications of radiation processing of foods- Major benefits achieved by radiation processing of food includes inhibition of sprouting of tubers and bulbs, disinfestations of insect pests in agricultural commodities, delay in ripening and senescence of fruits and vegetables, destruction of microbes responsible for spoilage, and elimination of pathogens and parasites of public health importance.

(e) Effect of radiation processing on food quality-Irradiation produces very little chemical changes in food. Physical properties of food were also not found to be affected by the radiation treatment. The majority of changes due to radiation processing of food are similar to those by other preservation methods like heat. The radiolytic products and free radicals produced in irradiated food are identical to those present in foods subjected to treatment such as cooking and canning. None of the changes known to occur have been found to be harmful. Highly sensitive scientific tests carried out during the past 50 years have failed to detect any new chemical product in radiation processed foods. The safety and wholesomeness of the technology was endorsed in 1981 by international bodies like World Health Organization, Food & Agricultural Organization, International Atomic Energy Agency, and in 1983 by the Codex Alimentarius Commission. Food Safety and Standards Authority of India (FSSAI) has also endorsed this technology. The irradiation process involves passing of food through a radiation field allowing the food to absorb desired radiation energy but the food itself never comes in contact with the radioactive material and hence the irradiation process does not make food radioactive. There is no evidence to suggest that free radicals or radiolytic products affect the safety of radiation processed food.

II ECONOMICS OF FOOD RADIATION PROCESSING

(a) Cost of Setting up Facilities - Estimated cost for setting of a commercial radiation processing facility comes in the range of Rs. 10-12 crores excluding land cost. However, the processing cost is quite cheaper. Radiation treatment cost ranges from Rs.0.25 to 0.50/ kg for a low dose applications such as sprout inhibition of potato and onion and insect disinfestations in cereals and pulses; and Rs.1-3/kg for high dose applications such as treatment of spices for microbial decontamination. The costs could be even further brought down in a multipurpose facility treating a variety of products around the year. In many cases, extended shelf-life offsets the extra cost.

Fig 2 Insect Disinfestations & Microbial Hygienization of Spices

Processing also brings benefits to consumers in terms of availability, storage life, distribution, and improved hygiene of food. Irradiation can have a stabilizing effect on market price of commodities by reducing storage losses resulting in increased availability of produce.

(b) Current Status- In countries, such as France, The Netherlands, South Africa, United States, Thailand and China, radiation processed foods such as strawberries, mango, banana, shrimp, frog legs, chicken, spices, and fermented pork sausages are sold on regular basis on the market shelf. More than 23 countries are irradiating food for processing industries and institutional catering. These radiation processed food items are labeled with radura logo to indicate the treatment and its purpose. Recent development in the area of food irradiation in India include harmonization of food irradiation rules with international regulation through adaptation of class wise clearance of irradiated food items by the Atomic Energy (Radiation processing and Allied Food Products) Rules, 2012 by the Food Safety and Standards Authority of India (FSSAI). Twelve food irradiation plants have been commissioned till date in the private sector. Two plants set by Government of India (Radiation Processing Plant, Vashi, Navi Mumbai; and KRUSHAK, Lasalgaon, Nashik) are also operational. Volume of food irradiated in India has been steadily increasing. A total of approx. 31,000 tons of produce have been irradiated by Radiation Processing Plant, Vashi, Navi Mumbai till 2014. Irradiated mango is being exported to USA since 2007.

III RECENT R&D FINDINGS INDICATING ADDITIONAL APPLICATIONS OF RADIATION PROCESSING

Shelf-life extension of 10 days was achieved for button mushroom (*Agaricusbisporus*) by gamma irradiation (2 kGy) and low temperature (10°C) storage. Sugarcane juice was preserved for 35 days by addition of permitted preservatives, gamma irradiation (5kGy) and storage at 10°C. Safety of leafy vegetables can be ensured by radiation processing with extended shelf life of more than two weeks. A combination process including radiation treatment can ensure safety and also extend the shelf life of sweet corn kernels up to one month. Dried water chestnut can be preserved by radiation processing for more than one year. Safety of herbals and tea can also be ensured by radiation treatment.

IV SPECIAL PURPOSE FOODS

Several new ready to eat (RTE) food products have also been developed for different target groups such as persons affected by natural calamities, defence personnel, or immune-compromised patients. Many food items were developed by India using radiation processing during IAEA CRP(D6.20.09) on "The Development of Irradiated Foods for Immuno-Compromised Patients and other Potential Target Groups". Also radiation doses, treatment and storage conditions were standardized for these products. The products include Naso-Gastric Liquid Feed formulation (NGLF), Low Cost Enteral Food (LCEF), Intermediate Moisture (IM) Papaya Cubes, Irradiated honey, Stuffed Baked Food (SBF, Local name: Litti), MethiParatha, PuranPoli, Vegetable pulav, and RTE meat products (Chickentikka, Chicken pahadikabab, Chikenparatha, Chikenpulav, and Baked chiken dumpling). The products were found to retain wholesomeness and quality attributes. Two of these products (NGLF, and LCEF) were developed in association with Tata Memorial Hospital mainly for immune-compromised patients. Rest other products are for use during natural calamities, and defence personnel placed at remote places. These products are equally good for routine consumption by an individual.

Fig 3 Phytosanitary Treatment for Export

V SAFETY OF FOOD IRRADIATION FACILITY & CHALLANGES

Gamma irradiator does not undergo meltdown, as Cobalt-60 is not a fissile material and no neutrons are produced unlike in a nuclear reactor. Also no environmental contamination due to leakage of radioactivity can occur because the radioisotope is doubly encapsulated in stainless steel tubes.Laws and regulations enacted by Atomic Energy Regulatory Board govern operations of irradiators. The plants must be approved by the Government of India before construction, and are subject to regular inspection, safety audits, and other reviews

Shelf-stable Litti (1 yr of storage at room temperature)

Fig 4: Radiation Processing of Foods and Applications.

to ensure that they are safely and properly operated. Cobalt-60 and Caesium-137 which are used as the source of radiation energy decay over many years to nonradioactive Nickel and Barium, respectively. When the radioactivity falls to a very low level the source pencils are returned to the supplier who has the provision of storing them.

It is quite challenging but utmost needed to expand and strengthen the collaborations, with Food Corporation of India, Ministry of Food Processing, National Disaster Management Authority, Defence authorities, hospitals, and commercial as well as institutional food suppliers. This will ensure the eventual adoption and integration of irradiated foods into the supply chains and will help promote commercialization and widespread use of the technology. It is also required to develop appropriate outreach and education materials for target audiences including family members, medical professionals, private investors, community groups, NGO's, regulatory agencies, financial and legal industries. Private entrepreneurs should be encouraged to establish more food irradiation facilities to ensure the large scale availability of the irradiated food in the market so that consumers get an option.

REFERENCES

[1] Alothman M, Bhat R, and Karim AA. 2009. Effects of radiation processing on phytochemicals and antioxidants in plant produce. Trends in Food Sci Tech 20:201-12.

[2] Basfar AA, Mohamed KA, and Al-Saqer OA. 2012. De-contamination of pesticide residues in food by ionizing radiation. Rad PhyChem 81:473–8.

[3] Bidawid S, Farber JM, and Sattar SA. 2000. Inactivation of hepatitis Avirus (HAV) in fruits and vegetables by gamma irradiation. Int J Food Microbiol 57:91–7.

[4] Diehl JF. 2002. Food irradiation-past, present and future. Rad PhyChem 63:211-5.

[5] Fan X. 2005. Antioxidant capacity of fresh-cut vegetables exposed to ionizing radiation. J Sci Food Agricul 85:995-1000.

[6] Fan X, Niemira BA,and Prakash A. 2008. Irradiation of fresh fruits and vegetables. Food Technol 62:36-43.

[7] FAO/IAEA/WHO. 1999. High-dose irradiation: Wholesomeness of food irradiated with doses above 10 kGy. Report of a Joint FAO IAEA WHO Study Group. Rome: Food and Agriculture Organization of the United Nations.

[8] Foley DM, Dufour A, Rodriguez L, Caporaso F, andPrakash A. 2002. Reduction of *Escherichia coli* O157:H7 in shredded iceberg lettuce by chlorination and gamma irradiation. Rad PhyChem 63: 391–6.

[9] Hajare S, Gautam S, Nair A, and Sharma A. 2014.Formulation of a naso-gastric liquid feed (NGLF) and shelf life extension using gamma radiation. JFood Prot, 77(8):1308-16.

[10] Gautam S, Sharma A, and Thomas P. 1998. Gamma irradiation effect on shelf-life, texture, polyphenol oxidase and microflora of mushroom (*Agaricusbisporus*).Int J Food Sci Nut 49:5-10.

[11] Kumar S, Gautam S, and Sharma A. 2015. Hurdle technology including chlorination, blanching, packaging and irradiation to ensure safety and extend shelf life of shelled sweet corn kernels. Journal of Food Processing and Preservation, DOI: 10.1111/jfpp.12481.

[12] Mishra BB, Gautam S, and Chander R, and Sharma A.2015. Characterization of nutritional, organoleptic and functional properties of intermediate moisture shelf stable ready-to-eat *Carica papaya* cubes. Food Bioscience: 69 – 79.

[13] Mishra BB, Gautam S, and Sharma A. 2004.Shelf-life extension of fresh ginger (*Zingiberofficinale*) by gamma irradiation. J Food Sci 69:274-79.

[14] Saxena S, Maurya DK, Gautam S, and Sharma A. 2014.Effect of radiation hygienization of honey on its health protective properties. Food Bioscience, 8: 14 – 21.

[15] Sharma A. 2008. Radiation Technology Enabled Market Access to Indian Mango. BARC News Letter, Issue 296: 2-8.

[16] SommerR, andDuizer E. 2004. Calicivirus inactivation by nonionizing (253.7-nanometer-wavelength [UV]) and ionizing (Gamma) radiation.Appl Environ Microbiol 70:5089–93.