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RIVIEW ARTICLE

# Application of Nuclear Technique is an Eco-friendly and Economically Viable Approach for the Processing and Preservation of Agricultural Produce

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**ABSTRACT** One of the important applications of nuclear technique is in the processing and preservation of food commodities. The advances in agricultural methods have ensured food production keeping pace with the rapidly growing requirements, unchecked processing and storage losses of food commodities, so equal emphasis has now to be devoted to food preservation. It is estimated that one quarter to one third of world food production is lost due to pests, insects, bacteria, fungi and enzymes which eat, degrade or destroy the crops. Apart from food losses, the problem of contamination has to be encountered which includes pathogens and parasites that lead to food borne diseases. The incidence of food borne disease is one of the most widespread health problems not only in developing countries but also in developed countries with relatively high standards of hygiene. The potential economic loss due to food borne disease and rejection of food contaminated with pathogenic microorganisms is apparently enormous. Therefore, a number of methods have been employed for food preservation. Popular means and ways include the use of chemical additives for the preservation of several food products. However, some of the chemicals like fumigants, ethylene di-bromide (EDB) and ethylene oxide are harmful to mankind and the environment. The use of ionizing and non-ionizing radiation offers very good potential in this context. It is essentially a technique of exposing agricultural produce to ionizing radiations such as X-rays, $\gamma$-rays, electron beams and non- ionizing radiation such as UV rays. These rays leave no radioactive residues, however help in reducing from the spoilage of post-harvest agricultural produce due to microorganisms as well as can slow down the speed at which enzymes change the food articles as a result prevents from ripening, and inhibits sprouting of potato, onion, and garlic so that enhance the shelf life. Moreover, irradiation of agricultural produce aims to prevent the spread of invasive pest species through trade in fresh vegetables, fruits, grains, pulses and spices, either within countries, or trade across international boundaries which could significantly affect agricultural production and the environment.

**Keywords:** Irradiation, Radioactive, Post-harvested, Preservation, Ecofriendly, Invasive

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## INTRODUCTION

Since time immemorial mankind has been cultivating. After human civilization, agriculture has been the way of life for their livelihood. Many impediments have come across their path. Farmers, through a long history of battle against insects stored product pests, have learnt to exploit natural resources to largely damage food grains in stores as well as during shipping and transportation. Several kinds of insects, diseases, weeds, rodents cause immense damage to crops both in field and in storage. The hot and humid climate of the country is quite favorable to the growth of numerous insects and microorganisms which destroy stored crops and cause spoilage of food. The seasonal nature of production and the long

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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 conventional way for this is generally, pickling, canning, smoking, sun drying followed by additional methods include freezing, refrigeration, cold storage, etc., for which not only expenditure increased but uses of electricity costlier more. For better protection traditional methods usually provide cheap and feasible ways of post-harvest handling of the crops, but they have many limitations. The war against pests is a long-drawn out and dangerous tendency. Excessive doses of pesticides leave harmful residues which find their way into the human body either directly from consumed agricultural produce or through the milk of animals that feed on plants. 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. In the changing scenario of world trade, switching over to radiation processing of food assumes great importance.

## NUCLEAR TECHNIQUES FOR FOOD PRESERVATION

Use of nuclear techniques by means of Ionizing radiation for the elimination from the decaying nuclei of radioactive isotopes of natural elements. There are two classes of radiation, namely corpuscular or particulate and electromagnetic radiation (IAEA, 1992). There are different radiation technologies used for food irradiation which include electron beam, X-rays, gamma rays.

## TYPES OF RADIATION SOURCES

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.

### Electrons

Electron irradiation uses a stream of electrons accelerated by an electric voltage or radio frequency wave to a velocity close to the speed of light. Electrons have mass and negative electric charge, and therefore electron beams at the energies allowed for food irradiation do not penetrate into the product beyond several centimeters, depending on product density. Therefore, electron beams are preferred for thin products.

### Gamma Rays

Gamma irradiation involves packets of light (photons) that originate from radioactive decay of atomic nuclei. Gamma rays are used for products that are too thick for treatment with electron beams. Every radioactive element gives rise to Gamma rays with specific energies characteristic of the source element, these rays have zero mass and no electrical charge. The ones used for food irradiation are able to penetrate through food products. The radioactive isotope radioisotope cobalt-60 is used as the source in all commercial scale gamma irradiation facilities. Gamma irradiation is the most widely used technology because the deeper penetration of the gamma rays enables administering treatment to entire industrial pallets or totes (reducing the need for material handling) and it is significantly less expensive than using an X-ray source. Cobalt-60 is bred from cobalt-59 using neutron irradiation in specifically designed nuclear reactors (Anon, 2005).

### X-Rays

Irradiation by X-ray is similar to irradiation by gamma rays. X-rays' ability to penetrate the target is similar to gamma irradiation. X-rays are generated by colliding accelerated electrons with a dense target material (this process is known as bremsstrahlung-conversion), and the X-rays produced have a spectrum characteristic of the dense target material. Heavy metals, such as tantalum and tungsten, are used because of their high atomic numbers and high melting temperatures. Tantalum is usually preferred versus tungsten for industrial, large-area, high-power targets because it is more workable than tungsten and has a higher threshold energy for induced reactions. Like electron beams, X-rays do not necessitate the use of radioactive materials and can be switched off when not needed.

## RADIATION PROCESSING

Up to the point where the food is processed by irradiation, the food is processed in the same way as all other food. Typically, when the food is being irradiated, pallets of food are exposed to a source of radiation for a specific time. Dosimeters are placed on the pallet (at various locations) of food to serve as a check and ensure that the correct dose was achieved. Most irradiated food is processed by gamma irradiation (Anon, 2005), however the usage of electron beam and X-ray is becoming more popular as well. Food irradiation is the process of exposing food to a carefully controlled amount of energy in the form of high-speed particles or rays. These occur widely in nature and are included among the energy reaching earth all the time from the sun. While the knowledge of how to produce them originated from research into nuclear energy many years ago, modern methods are available which are straightforward and safe. With gamma irradiation, special precautions are taken because gamma rays are continuously emitted by the radioactive material. In most designs, to nullify the effects of radiation, the radioisotope is lowered into a water-filled storage pool, which absorbs the radiation but does not become radioactive. This allows pallets of the products to be added and removed from the irradiation chamber and other maintenance to be done. Sometimes movable shields are used to reduce radiation levels in areas of the irradiation chamber instead of submerging the source. For x-ray, gamma ray and Electron beam irradiation, shielding is required when the foods are being irradiated. This is done to protect workers and the environment outside of the chamber from radiation exposure. Typically permanent or movable shields are used.[52] In some gamma irradiators the radioactive source is under water at all times, and the hermetically sealed product is lowered into the water. The water acts as the shield in this application. To treat the food, they are exposed to a radioactive source, for a set period of time to achieve a desired dose. Radiation may be emitted by a radioactive substance, or by X-ray and electron beam accelerators. Special precautions are taken to ensure the food stuff never comes in contact with the radioactive substances and that the personnel and the environment are protected from exposure to radiation. Food irradiation is sometimes referred to as “cold pasteurization” because ionizing the food does not heat the food to high temperatures during the process, and the effect is similar to heat pasteurization.

Ionising radiation can slow down cell-based processes such as early ripening in fruit, which would lead to premature decay. Likewise, it is effective against insects and moulds, which, if uncontrolled, can destroy grain stocks. Irradiation is thus an effective means of controlling all biological processes, which would render the food supply unpalatable or unsafe (Suresh *et al.*, 2005; and Miller, 2005).

## RADIATION DOSIMETRY

The dose of radiation received is commonly measured in grays. The radiation absorbed dose is the amount of energy absorbed per unit weight of the target material. Dose is used because, when the same substance is given the same dose, similar changes are observed in the target material. The SI unit for dose is grays. One gray corresponds to the absorption of one joule of energy in a mass of one kilogram (1 Gy = 1 J/kg.). The gray has superseded the older unit—the rad (1 Gy = 100 rad). The length of time the food is exposed to the ionising energy coupled with the strength of the source determines the irradiation dose, measured in grays (Gy) or kilograms (kGy), the food receives (1 kGy = 1,000 Gy). Dosimeters are used to measure dose, and are small components that, when exposed to ionizing radiation, change measurable physical attributes to a degree that can be correlated to the dose received (K. Mehta, 2006).

## CLASSIFICATION OF RADIATION DOSE AND APPLICATION

For purposes of legislation doses are divided into low (up to 1 kGy), medium (1 kGy to 10 kGy), and high-dose applications (above 10 kGy).

Bulbs and tubers, such as potatoes and onions to prevent sprouting. Doses of less than 1 kGy have been recommended. Potatoes are irradiated in Japan and sweet potatoes in Hawaii. Low doses (<3 kGy) eliminate 90-95% of spoilage organisms, resulting in an improvement in shelf-life. Cereals, grains and certain fruits, such as papaya and mango as a quarantine measure, to kill insects. Doses of 1 kGy are recommended. In 2003 about 9 million tonnes of ground beef and papaya were irradiated in Hawaii (Olson, 2004). 0.03-0.15 kGy Inhibit sprouting of bulbs and tubers, Delay fruit ripening 0.03-0.15 kGy, Stop insect/parasite infestations to help clear quarantine 0.07-1.00 kGy and eliminate all vegetative bacterial pathogens. Shrimp in ice have a shelf life of 7 days; treating with 1.5 kGy adds another ten days. 1 kGy eliminates both *E.coli* and V*ibrio* spp. in oysters without detracting from their raw quality. 20% of oyster consumers said they would be prepared to consume irradiated oysters now that their safety has been significantly enhanced. Certain fruits and vegetables in order to reduce the numbers of microorganisms, particularly those that cause spoilage. Doses of up to 2 kGy have been recommended. Irradiation of onions, garlic, mung beans and tamarind is commercially viable in Thailand. Irradiation is also useful in combating rice weevil (*Sirohilus oryzae)* and lesser grain borer (*Rhyzopertha dominica*). It is particularly effective against internal feeders. Some seafood, in particular warm water shrimp/prawns and other shellfish, to improve their microbiological safety. Doses up to 3 kGy have been recommended. Delay spoilage of meat 1.50-3.00 kGy, Reduce risk of pathogens in meat, 3.00-7.00 kGy, Increase sanitation of spices 10.00 kGy (Annex III of Directive 1999/2/EC). High Dose irradiation to produce sterile foods, such as ready meals, for special medical diets, emergency or space diets. These foods are irradiated by doses of 45 kGy to render the foods commercially sterile.

## NUTRITIONAL QUALITY OF IRRADIATED FOODS

Irradiation is very effective against living organisms which contain DNA and/or RNA but does not cause any significant loss of macronutrients. Proteins, fats and carbohydrates undergo little change in nutritional value during irradiation even with doses over 10 kGy, though there may be sensory changes. Similarly, the essential amino acids, essential fatty acids, minerals and trace elements are also unaffected. There can be a decrease in certain vitamins (particularly thiamin) but these are of the same order of magnitude as occurs in other manufacturing processes such as drying or canning (thermal sterilization). It is calculated that the loss of thiamin in the American diet, due to irradiation of chops and roast pork at 1 kGy would be 1.5%. (Wilkinson and Gould, 1996). More details are given in WHO (1994) and FAO/IAEA/WHO (1999). On the other hand, the niacin content of bread from irradiated flour was 17% more than the non-irradiated control flour (Diehl, 1991). Also, an increase in the niacin content (24%) and riboflavin content (15%) in pork chops after irradiation was reported in another study (Fox *et al*., 1989).

## STANDARDS AND REGULATIONS

The Codex Alimentarius represents the global standard for irradiation of food, in particular under the WTO-agreement. Member states are free to convert those standards into national regulations at their discretion, therefore regulations about irradiation differ from country to country. The United Nations Food and Agricultural Organization (FAO) has passed a motion to commit member states to implement irradiation technology for their national phytosanitary programs; the General assembly of the International Atomic Energy Agency (IAEA) has urged wider use of the irradiation technology. Standards that describe calibration and operation for radiation dosimetry, as well as procedures to relate the measured dose to the effects achieved and to report and document such results, are maintained by the American Society for Testing and Materials (ASTM international) and are also available as ISO/ASTM standards. 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. It extends assistance for setting up facilities for food processing. To promote commercial use of this technology BARC will be the nodal agency for assistance and guidance. It will provide information on availability, cost and possible alternatives of essential machinery including pollution control and disposal of radioisotopes. It can provide training to the staff on various aspects of operation and safety in India (Saylor and Jordan, 2000).

## QUARANTINE SECURITY

In 2003, the Codex Alimentarius removed any upper dose limit for food irradiation as well as clearances for specific foods, declaring that all are safe to irradiate. Countries such as Pakistan and Brazil have adopted the Codex without any reservation or restriction. Other countries, including New Zealand, Australia, Thailand, India, and Mexico, have permitted the irradiation of fresh fruits for fruit fly quarantine purposes, amongst others. Cereals, grains and certain fruits, such as papaya and mango as a quarantine measure, to kill insects. Doses of 1 kGy are recommended.

## NUCLEAR SAFETY AND SECURITY

Interlocks and safeguards are mandated to minimize this risk. There have been radiation-related accidents, deaths, and injuries at such facilities, many of them caused by operators overriding the safety related interlocks (IAEA). In a radiation processing facility, radiation specific concerns are supervised by special authorities, while "Ordinary" occupational safety regulations are handled much like other businesses. The safety of irradiation facilities is regulated by the United Nations International Atomic Energy Agency and monitored by the different national Nuclear Regulatory Commissions. The regulators enforce a safety culture that mandates that all incidents that occur are documented and thoroughly analyzed to determine the cause and improvement potential. Such incidents are studied by personnel at multiple facilities, and improvements are mandated to retrofit existing facilities and future design. WHO is taking the lead in advising international agencies and national ministries of health on implementing integrated strategies, including food irradiation, for preventing the international spread of pathogens in food and animal feed, for controlling food borne illnesses and for enhancing the availability of safe and nutritious foods.

## IRRADIATED FOOD SUPPLY

In 2003 about 9 million tonnes of ground beef and papaya were irradiated in Hawaii (Olson, 2004). In total, 103000 tonnes of food products were irradiated on the mainland United States in 2010. The three types of foods irradiated the most were spices (77.7%), fruits and vegetables (14.6%) and meat and poultry (7.77%). 17,953 tonnes of irradiated fruits and vegetables were exported to the mainland United States. Mexico, the United States' state of Hawaii, Thailand, Vietnam and India export irradiated produce to the mainland US Mexico, followed by the United States' state of Hawaii, is the largest exporter of irradiated produce to the mainland US ("Food Irradiation in Asia, the European Union, and the United States", 2015). In total, 6,876 tonnes of food products were irradiated in European Union countries in 2013; mainly in four member state countries: Belgium (49.4%), the Netherlands (24.4%), Spain (12.7%) and France (10.0%) (European Commission, 2015).

## CONCLUSION

Irradiation like other preventive measures for storing, processing of agricultural commodities is one of effective ways of food preservation to inactivate microorganisms and destroy insect pests to push the world-wide introduction of food irradiation, it's a necessity to develop national legislation and regulatory procedures that will enhance confidence among trading nations that foods, irradiated in one country, offered purchasable in another, are subjected to commonly acceptable standards of wholesomeness, hygienic practice. Studies are being conducted under a co-ordinated research programme on how a pastoral can increase the international market share for its cash crops (e.g., cocoa beans, dates, fruits, spices), and on improving food supplies at the national level by reducing post-harvest losses and preventing various varieties of spoilage (e.g., staple foods, dined fish, fishery products, and vegetables). Effective irradiation treatment on food is expounded to an efficient 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. Above all, use of nuclear technology for food storage is moving fast to satisfy the sanitary and phytosanitary requirements of importing countries. Moreover across the world the consumers are gaining knowledge about the advantages of food irradiation to avoid the food spoilage and infections from pest and pathogens. It's the right time and right choice for accepting such important technique for the sustainable development during this changing climate.

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