Food preservation by irradiation

by J. van Kooij*

Food and its constant availability are among the basic human rights. Yet one person out of eight in the world today suffers from chronic undernourishment This problem is likely to get worse as the world's population is expected to double during the next thirty to forty years.

Since about over a quarter of our harvested food is lost due to various kinds of wastage and spoilage, food preservation is no less important than food production. It is sounder policy to conserve what is produced than to produce more to compensate for subsequent losses Besides the prevention of losses, demand is also growing in both the developed and the developing countries for food which is wholesome and which has a long shelf-life. There are obvious reasons for using radiation to preserve food and agricultural produce, and hence to alleviate the world's food shortage and to produce safe foods.

The emerging global energy crisis has led to a review of the efficiency of traditional methods of food preservation in terms of their energy consumption. In addition, some established technologies – e g. curing, chemical preservation and fumigation – are now being questioned with regard to their biological safety, economics, and possible reduction in market quality of products so treated.

Twenty-five years of development work on the preservation of food by irradiation has shown that this technology has the potential to reduce post-harvest losses and produce safe foods. It is energy-conserving when compared with conventional methods of preserving food to obtain a similar shelf-life; and food irradiation can replace or drastically reduce the use of food additives and fumigants which pose hazards for the consumers as well as for workers in food processing factories.

The technological feasibility of the more important applications of food irradiation has been well established. However, a general acceptance of the process by national government regulatory agencies and by consumers requires much attention Furthermore, the introduction of new technologies is difficult in many countries due to their poverty. Many developing countries often strive with limited technical know-how and with inadequate infrastructure, to adopt the food irradiation process efficiently

The process of food irradiation involves exposing the food to ionizing radiation so that a prescribed quantity is absorbed Radiation sources used for food irradiation are the following:

- Gamma-rays from the nuclides Co-60 or Cs-137;
- X-rays generated from machine sources operated at or below an energy level of 5 MeV;
- Electron beams generated from machine sources operated at or below an energy level of 10 MeV

The way in which the radiation dose absorbed is measured differs according to the source of radiation, and various dosimetry techniques exist [1].

Dose-range needed for effective treatment [2]

	kGy*
Inhibition of sprouting in potatoes and onions	0 03–0 1
Sterilization of insects and parasites	0 03–0.2
Killing of insects and parasites	0 05–5
Reducing by 10^6 the number of vegetative bacteria, moulds, and fungi	1–10
Reducing by 10^6 the number of dried or frozen vegetative bacteria, fungi, and spores	2–20
Reduction by 10^6 the number of viruses	10–40
Sterilization of food	20–45

* 1 kGy (Gray) = 100 000 rad (= 1 Joule/kg).

Because irradiation does not heat the treated material, the food keeps its freshness (fish, fruits, vegetables) and its physical state (frozen or dried commodities). The agents which cause spoilage (bacteria, insects, etc.) are eliminated from packaged food and, providing packaging materials are impermeable to bacteria and insects, recontamination does not take place. Irradiation of packaged food has a particular bearing when hygiene is difficult to maintain in areas where food is being handled or processed, e.g. under tropical conditions.

Through its ability to: inhibit the sprouting of root crops; prevent the reproduction of insects; kill insects and parasites; inactivate bacteria, spores, and moulds (food spoilers); delay ripening in fruits; and improve technological properties of food; irradiation can reduce post-harvest losses and produce wholesome food with a long shelf-life. A lot of data on the technology and microbiology of irradiated foods has been generated in the past. Readers are referred to the excellent review articles [3, 4, 5, 6]. In this article, attention is drawn to some highlights in food irradiation.

Improvement of food hygiene. The hygienic benefit of food irradiation can be as significant as, or even higher

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than, the economic advantages. This is because doses up to about 5 kGy kill off non-sporing pathogenic micro-organisms (e.g. Salmonella, Vibrio parahaemolyticus, Staphylococcus aureus, etc.), which are the main sources of the most important food-borne diseases. Microbial contamination, e.g. heat-resistant spores, of spices and mixed seasonings can be reduced by irradiation. These heat-resistant spores cause problems in the canning of meat products because their presence in insufficiently decontaminated spices makes it necessary to apply to the meat a heat treatment which renders the final product less acceptable from an organoleptic viewpoint.

Decontamination of food: Fumigation with ethylene oxide or propylene oxide is widely used for sterilizing or reducing microbial contamination in spices. However, the effectiveness of fumigation depends on the moisture content which should be at least 10% for proper success in spices. Fumigation does not kill moulds. Fumigation also poses health hazards to the workers in the food processing factory and, through the formation of chlorohydrins (LD_{50} equal to 0.07 g/kg test animal body weight), a possible direct toxic effect. Irradiation is a relatively simple process which can be applied without repacking. Fumigation on the other hand requires various steps. rehydration of the product by steam, preferably for 24 hours, exposure to the fumigant for about 16 hours; removal of the residual vapour of the fumigant by frequent flushing of the product by air (danger of recontamination); drying; and then regrinding as powdered products will have clumped together. The cost of this multi-step fumigation process appears to be twice that of irradiation.

Quarantine treatments are widely used for fruits and vegetables intended for international or interstate trade. Until pests can be eradicated from infested regions, products from these areas require to be treated by an approved method before they can be exported to pest-free areas Such treatments must be biologically safe, cause no reduction in market quality of the product, and be economic. At present approved quarantine treatment for citrus, papaya, other fruits and vegetables consists of fumigation with brominated organic fumigants, the biological safety of which is now being questioned.

Virtually all fruits being traded internationally can be irradiated at doses which will control the more important pests, such as the fruit fly. Irradiation would require a relatively short period of treatment. Since there are no fumigant residues, ventilation – necessary in the case of fumigation – is not required, and this reduces the interval between picking and shipment by as much as one day. Treatment of the finished packages reduces chances of re-infection, providing a further assurance of reliability of the quarantine treatment. Taking into account also the way radiation extends shelf-life (delay of ripening), the marketing period can be extended by 2 to 5 days

Irradiation can also be used as a quarantine treatment against the mango-seed weevil. An extensive research programme on this subject has been carried out in South Africa. The treatment consists of a hot water dip to arrest mould, and irradiation with a dose of 0.75 kGy for quarantining as well as to extend shelf-life

Irradiation of dried and cured fish A popular method for preserving fish in tropical countries is to dry it under the sun. Infestation by several species of flies. occurs during drying and gives rise to heavy losses during storage and marketing. Maggots may be found in dried fish only 3 days after drying. Applying insecticides directly to the fish, either during sun-drying or storage, had been used as the only fly disinfestation method before the problem of chemical residues was recognized. Besides insect infestation, moulds, bacteria, rancidity, and discolouration are the main causes of spoilage and deterioration in quality of dried fish.

The losses of unprotected dried products during storage and distribution can be as high as 50 to 70% in many parts of the world. Gamma radiation has proved to be an efficient method for disinfesting insects in dried and smoked fish. A dose of about 2 kGy is required to kill 99% of the larvae, although a dosage as low as 0.2 kGy renders them inactive and prevents the larvae of all fly species from developing into adults In certain cases the combined application of toxicologically unobjectionable preservatives (such as sorbate) and radiation may considerably extend the shelf-life of some commodities thereby enabling their wider distribution. This is the case with the cured fish popular in South-East Asian and Pacific countries.

Shelf-stable foods: High-quality meat, poultry, and fish products have been developed at Natick Laboratories in the USA by combination of conventional additives, mild heat-treatment, and irradiation in the frozen state. After irradiation with sterilizing doses, these foods can be stored without refrigeration for years. A particularly promising application is the radiation sterilization of bacon, where a shelf-stable product can be obtained without the use of nitrite. Although not carcinogenic themselves, curing salts such as nitrite and nitrate, when heated (fried) together with protein, can result in the formation of nitrosamines, some of which are recognized as notorious carcinogens. Combining irradiation and mild heating to treat protein foods can be of great future benefit especially in the developing countries, because the foods can be preserved from decay during storage in a way that is compatible with the infrastructure in many developing countries.

During the past decade several steps were taken by the Joint FAO/IAEA Division, or developed in close co-operation with the World Health Organization (WHO), the Organization for Economic Co-operation and Development and the Joint FAO/WHO Food Standards Programme, to promote international acceptance of irradiated food The Joint FAO/IAEA/WHO Expert Committees on the Wholesomeness of Irradiated Food

Shihoro Agricultural Co-operative Association's potato pallet irradiator, Japan. View of the irradiation chamber where potatoes and onions are irradiated in bulk.

(1969, 1976 and 1980) have evaluated the safety for human consumption of irradiated foods. The 1980 Expert Committee concluded that the irradiation of any food up to an average dose of 10 kGy causes no toxicological hazard and hence toxicological testing of foods so treated is no longer required [7]. Important applications in the low-dose field (e.g sprout inhibition, insect disinfestation, ripening delay in fruits) and medium-dose field (e.g. reduction of microbial contamination, reduction of non-sporing pathogenic micro-organisms, improvement of technological properties of food) all fall within this recommended limit.

The 10 kGy dose does not cover potential applications in the field of radiation sterilization of foods (shelf-stable foods). The use of high-dose radiation for the sterilization of meats, poultry, and fish is gaining much interest now because it needs less energy than other treatments, e.g. the combination of heat, and frozen storage. However, to assess the safety of high-dose irradiation (20–45 kGy), further information is needed on its nutritional, microbiological, and toxicological implications. Only national public health authorities can clear irradiated foods or the food irradiation process. In their decisions, national authorities are usually guided by the recommendations or evaluations of international agencies, especially WHO. At present the relevant authorities in 22 countries have given unconditional or provisional clearance to 39 items of food and groups of related food products. Greatly relaxed criteria for approval of the domestic sale of irradiated foods were recently [8] recommended by the Irradiated Food Committee of the Bureau of Foods and accepted for further action by the Food and Drug Administration of the USA

To promote the world-wide introduction of food irradiation, it is necessary to develop national legislation and regulatory procedures that will enhance confidence among trading nations that foods, irradiated in one country and offered for sale in another, have been subjected to commonly acceptable standards of wholesomeness, hygienic practice, and irradiation treatment control. To aid harmonization of national laws the Codex Alimentarius Commission has adopted a recommended international general standard for irradiated foods [9], which will be distributed to Member States of the FAO/WHO Food Standards Programme for acceptance. This standard was based on the clearance of eight foods which was recommended by the 1976 Expert Committee on the Wholesomeness of Irradiated Foods, but has to be revised in light of the recommendations of the 1980 Expert Committee. The revision, in collaboration with WHO and FAO, is one objective of the food irradiation programme of the Joint FAO/IAEA Division

In 1979, the IAEA published *Model regulations for the control of and trade in irradiated food* [10] providing valuable guidelines for Governments of RCA* countries to harmonize their national laws in accordance with the Codex Standard and the Code of Practice for the operation of radiation facilities used for the treatment of foods. Incorporation of the regulations in existing national food laws would greatly facilitate international trade and ensure a similar and effective control over the irradiation of foods.

Establishing the wholesomeness and harmonizing national regulations for the legal control of the irradiation process and international trade of irradiated foods are not enough to introduce the technique as an industrial method. For that, experiments are needed to show that food irradiation is economic.

Studies are being carried out under a co-ordinated research programme on how a country 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 kinds of spoilage (e.g. staple foods, dried fish, fishery products, and vegetables). In these studies special attention will be given to. acceptance of irradiated foods by national governmental regulatory agencies and consumers; establishing good manufacturing practices so that retailers and consumers obtain high-quality foods as, otherwise, objectionable quality may be associated with the irradiation, recognizing that large-scale applications of food irradiation require a commercially organized agricultural system; involving national authorities and the food industry in research and development projects; economics of the siting and design of irradiation facilities, either for seasonal, year-round or multipurpose use.

Many developing countries have only limited technical know-how. Scientists and technicians concerned with research, development, and management of food irradiation in developing countries need more practical training that better fits them to solve their own specific problems. A main objective of the International Facility for Food Irradiation Technology (IFFIT) is to offer training to scientists from developing countries in the technological, economic, and commercial aspects of food irradiation [11]. International co-ordination of research and development in food irradiation and assessing the feasibility of applying radiation techniques to foods are also objectives of IFFIT. Several countries in South-East Asia and the Pacific participate now in the Asian Regional Co-operative Project on Food Irradiation (RPFI) The main objective of this project is to harmonize and further irradiation studies at pilot-scale level of four selected foods e.g. fishery products, mangoes, onions, and spices, which are likely to find practical application in the near future [12]

The history of the development of food preservation technologies clearly illustrates that the introduction of new techniques has always been a time-consuming affair. It should also be realized that none of the conventional food processing techniques now applied on a large scale, e.g. heating, freezing, drying, had to undergo extensive investigations for wholesomeness; nor were they subject to legislation, public health acceptance, and consumer education before their commercial introduction.

Nevertheless, world-wide interest in food irradiation technology continues although, in the coming years, continued efforts and support from international organizations, govenrments, and the food industry will be needed for the introduction of food irradiation on a truly commercial scale.

* Regional co-operative agreement for research, development and training related to nuclear science and technology

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