# Advantages and Disadvantages of the Use of Irradiation for Food Preservation

PAISAN LOAHARANU and MAINUDDIN AHMED

Food Preservation Section
Joint FAO/IAEA Division of Nuclear Techniques
in Food and Agriculture
International Atomic Energy Agency
P.O. Box 100, A-1400
Vienna, Austria

**Abstract** *Food irradiation is a physical method of processing food (e.g. freezing, canning). It has been thoroughly researched over the last four decades and is recognized as a safe and wholesome method. It has the potential both of disinfesting dried food to reduce storage losses and disinfesting fruits and vegetables to meet quarantine requirements for export trade. Low doses of irradiation inhibit spoilage losses due to sprouting of root and tuber crops. Food-borne diseases due to contamination by pathogenic microorganisms and parasites of meat, poultry, fish, fishery products and spices are on the increase. Irradiation of these solid foods can decontaminate them of pathogenic organisms and thus provide safe food to the consumer. Irradiation can successfully replace the fumigation treatment of cocoa beans and coffee beans and disinfest dried fish, dates, dried fruits, etc. One of the most important advantages of food irradiation processing is that it is a cold process which does not significantly alter physico-chemical characters of the treated product. It can be applied to food after its final packaging. Similar to other physical processes of food processing, (e.g. canning, freezing), irradiation is a capital intensive process. Thus, adequate product volume must be made available in order to maximize the use of the facility and minimize the unit cost of treatment. Lack of harmonization of regulations among the countries which have approved irradiated foods hampers the introduction of this technique for international trade. Action at the international level has to be taken in order to remedy this situation. One of the important limitations of food irradiation processing is its slow acceptance by consumers, due inter alia to a perceived association with radioactivity. The food industry tends to be reluctant to use the technology in view of uncertainties regarding consumer acceptance of treated foods. Several market testing and consumer acceptance studies have been carried out on food irradiation in recent years. These studies showed that, if the safety and the benefits of food irradiation were properly explained, the consumers were willing to accept irradiated foods. Considering its*

 0893/4282/91 $3.00 + .00

*potential role in the reduction of post-harvest losses, providing safe supply of food and overcoming quarantine barriers, food irradiation has received wider government approvals during the last decade. There is also a trend towards increased commercialization of irradiated food. Currently, there are 47 irradiation facilities in some 23 countries being used for treating foods for commercial purposes.*

**Keywords:** food irradiation, advantages, limitations, consumer acceptance, international status, trade.

## Introduction

Agriculture provides the economic backbone of developing countries. These countries have to produce a sufficient food supply for their population and export any excess to earn foreign exchange. However, post-harvest loss of food is still a great problem affecting the food supply and the economies of these countries. Food and agricultural products contribute significantly to the overall volume of international trade. The export of these products is hampered by strict quality regulations and quarantine restrictions imposed by the importing countries. Developed countries, on the other hand, are facing an increasing demand for safe and convenient food. Food-borne diseases are on the increase in both developed and developing countries. A need exists to address some of the above-mentioned problems in order to reduce post-harvest food losses, to meet quarantine restrictions and to improve the safety and hygienic quality of foods. Hence, food science and technology continually strive to develop and provide mankind with adequate food which is safe, wholesome and of better quality, meeting the demands of ready availability, variety and convenience.

Food irradiation is one of the recent food preservation technologies which can be used to address some of these problems. It is a physical process which has been thoroughly researched and is as well-understood as other methods of food processing, or more so. The potential of food irradiation processing to reduce post-harvest losses of foods, to meet quarantine requirements, to increase exports and to ensure the hygienic quality of foods has been increasingly recognized by many countries.

In spite of its potential benefits, progress of this technology into practical application has been slower than anticipated. The attitude of industry towards accepting this technology is very cautious due to a perceived notion that consumers will not accept irradiated food.

Food irradiation is not a panacea to solve all food-related problems. It has benefits and limitations, as do all food processing technologies. This paper examines a number of applications where food irradiation will play a significant and positive role, as well as identifying where it will have limitations. Recent developments in the field of food irradiation are also addressed.

## What is Food Irradiation?

Food irradiation is a process that exposes food to ionizing radiation which is a form of electromagnetic energy (i.e. radiowaves, microwaves, visible lights, ultra violet rays, X-rays, gamma-rays, etc.). Only gamma-rays emitted from Cobalt-60 and Cesium-137, and X-rays generated from a machine operated at or below 5 MeV and electrons from a machine at or below 10 MeV can be used for food irradiation (FAO, 1984). The use of radiation in the prescribed energy levels does not induce radioactivity in food. Thus, food treated by irradiation is not radioactive regardless of the radiation dose absorbed.

Food irradiation is carried out in a shielded room which does not permit radiation escaping during operation. Among the radionuclides, Cobalt-60 is normally used for food irradiation. It is a metal source doubly encapsulated in stainless steel. When the source is not in use, it is housed in a shielded container or in a pool of water which absorbs all radiation. It does not produce any waste as the decayed source is returned to the supplier either for replenishing or retention. The machine source (i.e. X-ray and electron machines) have nothing to do with radioactive waste as they are machines powered by electricity and not by nuclear sources.

## Specific Applications in which Irradiation Offers Advantages over Existing Technologies

The general applications of food irradiation are given in Table 1, and summarized specific applications are described below:

### *A Quarantine Treatment of Fruits and Vegetables*

Fumigation of food and food ingredients with various chemicals such as ethylene dibromide (EDB), methyl bromide (MB), ethylene oxide (ETO), etc., has been held suspect by health authorities in terms of both health and occupational safety. In the U.S., the use of EDB as a food fumigant was banned by the U.S. Environmental Protection Agency as of 1 September 1984 (EPA, 1983). Any food from other countries treated with EDB is also prohibited from sale in the U.S. The EDB ban has deprived the fruit and vegetable industry in the U.S. of a strong and broad spectrum fumigant that was commonly used for overcoming quarantine restrictions against fruit fly infestation of these products. Other chemical fumigants such as MB and phosphine do not offer as broad a spectrum for treating fruits and vegetables. Physical processes such as cold storage and heat treatment, which are capable of insect disinfestation of fruits and vegetables, also have limitations.

Irradiation appears to offer the most viable alternative for this purpose. The irradiation dose required for fruit fly disinfestation to satisfy quarantine regulations (0.15 kGy) does not change physico-chemical and organoleptic properties of most fruits and vegetables (IAEA, 1986). The final Food and Agriculture Organization/International Atomic Energy Agency (FAO/IAEA) Research Co-ordination Meeting (RCM) on Use of Irradiation as a Quarantine Treatment, held in Kuala Lumpur,

**Table 1**
General Application of Food Irradiation

| Purpose | Dose (kGy)* | Products |
|---|---|---|
| *Low Dose* (up to 1 kGy) | | |
| (a) Inhibition of sprouting | 0.05–0.15 | Potatoes, onions, garlic, ginger root, etc. |
| (b) Insect disinfestation and parasite disinfection | 0.15–0.50 | Cereals and pulses, fresh and dried fruits, dried fish and meat, fresh pork, etc. |
| (c) Delay of physiological process | 0.50–1.00 | Fresh fruits and vegetables |
| *Medium Dose* (1–10 kGy) | | |
| (a) Extension of food shelf-life | 1.50–3.00 | Fresh fish, strawberries, etc. |
| (b) Decontamination of spoilage and pathogenic micro-organisms | 2.00–5.00 | Fresh and frozen seafood, poultry and meat in raw or frozen state, etc. |
| (c) Improving technological properties of food | 2.00–7.00 | Grapes (increasing juice yield), dehydrated vegetables (reduced cooking time) etc. |
| *High Dose* (10–50 kGy) | | |
| (a) Commercial sterilization (in combination with mild heat) | 30–50 | Meat, poultry, seafood, prepared foods, sterilized hospital diets |
| (b) Decontamination of certain food additives and ingredients | 10–50 | Spices, enzyme preparations, natural gum, etc. |

* Gy: Gray – unit used to measure absorbed dose.
One Gy is the energy of 1 Joule absorbed by one kilogram of matter (1 Gy = 100 rad).
kGy: 1000 Gray.

Malaysia in August 1990 confirmed the earlier finding of 0.15 kGy as the minimum dose needed to provide quarantine security against fruit flies. Irradiation is the only technique which can disinfest mangoes of the seed weevil which dwells inside the seed before emergence as adults, which are quarantined by some importing countries. The RCM further concluded that a minimum dose of 0.3 kGy would ensure quarantine security against any stage of any arthropod pest. Also, irradiation is more broadly effective and is less phytotoxic than either heat or cold treatment.

## *A Method to Ensure Hygienic Quality of Foods*

The incidences of food-borne diseases continue to affect adversely the health and productivity of populations in most countries, especially the developing ones. Contamination of food – especially food of animal origin, with microorganisms, particularly pathogenic non-sporing bacteria, and infectious parasitic helminths and protozoa – is one of the most significant public health problems, and an important cause of human suffering all over the world. The economic impact of lost productivity and medical treatment is considerable. For example, the loss from trichinosis, toxoplasmosis, salmonellosis and campylobacteriosis in the U.S. in 1985 was estimated to be over US$ 1.5 billion (Morrison and Roberts, 1985). The cost of condemnation of pork infected with the tapeworm, *C. cellulosae*, in Mexico was estimated to be as high as US$ 43 million in 1982 (Acevedo, 1982).

Also, many dry ingredients, particularly spices and herbs, the majority of which are produced in developing countries as an important source of their foreign exchange earnings, may be highly contaminated with spoilage organisms, and occasionally with pathogens. Such contaminated ingredients can cause spoilage after incorporation into composite food products, as well as creating health hazards. The use of ethylene oxide fumigation for decontaminating these ingredients has been increasingly restricted in recent years. The European Community (EC) issued a Directive which prohibited the use of ethylene oxide on food starting 1 January 1991 (Dickman, 1991).

While thermal pasteurization of liquid foods is a well established and satisfactory means of terminal decontamination/disinfection of such commodities, it does not suit solid foods and dry ingredients. Alternative chemical sanitizing procedures have regulatory limitations and/or inherent public health problems due to toxic residues and environmental pollution.

Significant amounts of research data and commercial experience demonstrate that irradiation can play an important role in reducing some of the food-borne diseases. At the Task Force Meeting on the Use of Irradiation to Ensure Hygienic Quality of Food held in Vienna in July 1986 (WHO, 1987), it was concluded that, presently and for the foreseeable future no technology is available to produce raw foods of animal origin, particularly poultry and pork, in which the absence of certain pathogenic microorganisms and parasites such as *Salmonella*, *Campylobacter*, *Trichinella*, *Toxoplasma* etc. can be guaranteed. These pose significant threats to public health. Thus, the Task Force believed that, where such foods are important in the epidemiology of food-borne diseases, irradiation decontamination/disinfection must be seriously considered. Other new techniques, or improvement of current techniques, cannot be expected to achieve the same result except at very high cost.

At this stage, the most apparent health benefit from this use of food irradiation would be treatment of chilled or frozen poultry for destruction of *Salmonella* and *Campylobacter*, etc., treatment of pork to inactivate Trichinella larvae and the decontamination of spices and other food ingredients. As an example, the people of Thailand like to eat raw fermented pork sausage (nham) in spite of the inherent risk of *Salmonella*, etc., and *Trichinella* infection. Such organisms can be eliminated by irradiation. Marketing trials have shown that people are willing to buy safer irradiated nham even at a higher price (Prachasitthisak et al., 1989). The treatment of frozen shrimp and frog legs intended for export also offers considerable potential for reducing public health risks. A dose between 2 and 7 kGy is considered adequate for destroying pathogenic microorganisms and parasites mentioned above without causing an adverse effect on organoleptic properties of such frozen food. Commercial scale irradiation of frozen shrimp and/or frog legs has been carried out in Belgium, France and the Netherlands in the past several years.

### *A Broad Spectrum Process for Reducing Food Losses*

Irradiation is similar to other physical food preservation processes such as canning and refrigeration as a method for reducing losses of most food items. A very low dose (0.05–0.15 kGy) is effective in controlling sprouting of root crops such as potatoes, onions and garlic. The physiological process of sprouting is the most important cause of deterioration of these crops (Thomas, 1983, 1984). In countries where ambient temperatures are high, sprouting occurs much faster than in temperate or cold countries. In addition, chemical sprout inhibitors are not effective under tropical conditions. Irradiation with a dose of 0.1 kGy is effective for sprout inhibition of all root crops provided that the treatment is carried out when they are in the dormant state. Semi-commercial scale studies in Bangladesh have shown that irradiation can reduce the use of cold storage of potatoes and onions with forced ventilation (Matin, et al., 1991). Similar positive results have been achieved in other countries including Argentina, India and Pakistan. Irradiation is the only practical method to control sprouting of yams. Côte d'Ivoire is establishing a commercial irradiation facility in Abidjan to treat 45,000 tonnes of yams per annum to control losses due to sprouting.

Most spoilage microorganisms and all insects which cause damage to fresh commodities such as fish, meat, fruits, vegetables, etc., and their products, are sensitive to low dose irradiation. Thus, irradiating these foods with doses between 1 and 5 kGy results in insect disinfestation, and a several-fold reduction of spoilage microorganisms, thereby extending the shelf-life of the food (Nickerson et al., 1983; Moy, 1983; Urbain 1983). For example, in Bangladesh it is impossible to store dried fish for off-season consumption. Losses would reach over 50% in six months (Ahmed et al., 1989). Disinfestation with insecticides cannot be advocated due to undesirable residues.

Fruits and vegetables undergo senescence as part of their physiological maturation process. Low dose irradiation at 1 kGy or below can delay the physiological spoilage of certain fruits and vegetables such as papaya, mangoes, asparagus, mushrooms, etc., either by delaying ripening or by slowing down senescence. By combining irradiation with mild heat treatment such as a hot water dip (e.g., 50°C for 5 min.) both delayed ripening and fungal disease control of certain fruits such as mangoes and papaya can be attained.

### *To Satisfy Increasing Market Demand for Fresh Foods*

There has been an increasing consumer demand for wholesome, nutritious and convenient foods in recent years. Fresh fruits, vegetables, fish and poultry have registered significant growth in volume and value in supermarkets in western countries, especially in the U.S., since 1980. For example, fresh fruit and vegetables offered in some larger stores can involve on average as many as 250 different items. Similarly, for health and nutrition reasons, consumers in the U.S. are switching to eating more fish and poultry than red meat. As mentioned earlier, irradiation by itself or in combination with established processes such as refrigeration or heat treatment would facilitate the distribution and sale of fresh fruits, vegetables, fish and meat by increasing the shelf-life of these commodities. In the case of tropical fruits such as mangoes which are subject to quarantine regulations in several importing countries, irradiation would offer almost the only means to overcome all quarantine barriers, thereby increasing the international trade in these fruits. As mentioned earlier, irradiation would also promote marketing of fresh seafood and poultry by destroying spoilage and pathogenic microorganisms and/or parasites.

There is a growing concern over the use of fumigants for disinfestation of agricultural products. The scientists and technologists who attended the International Working Conference on Stored-Product Protection held in Bordeaux, France, from 8–15 September 1990 expressed their concern over the growing development of strains of stored product insects resistant to almost all groups of insecticides and insecticide residues in treated products. As an alternative to insecticide treatment the Conference advocated the use of physical methods to achieve disinfestation of stored products. The cocoa exporting countries (i.e. Ghana, Nigeria, Côte d'Ivoire, Malaysia) routinely treat the beans with fumigants prior to exportation. Once the irradiation process is accepted in the export trade, it can replace some chemical treatments. Similarly, disinfestation of dried fish and fishery products, coffee beans, dates, dried fruits and nuts etc., for the export trade can be achieved by irradiation.

## Current Limitations

### *Technical*

Food irradiation can reduce *specific* food loss problems and can complement other food processes, (e.g., refrigeration) in maintaining the quality and wholesomeness of food. It can neither replace good manufacturing practice nor is it applicable to all food. For example, dairy products such as milk and butter can develop an off-flavour when treated by irradiation. Many food products, (e.g., meat, fish, chicken, etc.) have threshold doses above which organoleptic changes occur. Some of the changes can be offset. If food such as meat is treated with high sterilizing doses in the frozen state little-or-no detectable change occurs.

At the doses recommended for treating food at present, irradiation of certain foods will not eliminate all micro-organisms or their toxins. Low dose irradiation will not destroy bacterial spores. Treatment of meat, poultry and fish by irradiation, as with heat pasteurization and controlled atmosphere storage, requires appropriate temperature control during storage to prevent germination and toxin production by *Clostridium botulinum*. Toxins such as mold-produced mycotoxins or staphylococcus bacterial toxin cannot be inactivated by irradiation. Therefore, foods prone to contamination by these organisms must be handled in strict adherence to good manufacturing practices (GMPs) required for each food (e.g., chilling, low moisture content, proper storage and packaging, etc.) prior to and after processing by any substerilizing method, including irradiation, to prevent toxin production. Viruses also cannot be destroyed by low-dose irradiation applicable for extending shelf-life of most food products. The well-developed radiation sterilization process is used to eliminate microbial spores (and certain viruses, if present).

In this respect, low-dose irradiation does not differ from some other food processes such as heat pasteurization, which destroys spoilage and pathogenic bacteria but is not capable of inactivating bacterial spores, mycotoxins or staphylococcus enterotoxin.

## *Infrastructure and Economics of Food Irradiation*

Successful implementation of a new technology depends upon a proper infrastructure available within a given country. In general, food irradiation processing requires the same types of infrastructure as other physical processes such as canning, freezing, drying, etc. For example, a factory using any of these processes must be located at a central point where sufficient amounts of food are produced and transported to the plant for treatment and storage before sending it to the market.

Understandably, any food treatment adds cost (and value) to the product. Like other physical food processes, irradiation has high capital costs and requires a critical minimum capacity and product volume(s) for economic operation (Urbain, 1982). But unlike other physical processes, irradiation has a low operating cost, especially with regard to energy requirements. In technologically advanced countries the infrastructure required for setting up processing plants already exists, as demonstrated by the many canning and freezing plants. Similar infrastructure also exists in many developing countries which process food by canning or freezing on a large scale, many of these foods being for export.

## *Consumer concerns*

As food irradiation is perceived to be associated with nuclear technology, any introduction of irradiated food can be erroneously connected with radioactive materials. Thus, it comes as no surprise that there appears to be a widely-held opinion among some national authorities that consumers would be apprehensive about foods treated by irradiation because of the perceived association with radioactivity. Most consumers do not know why foods should be irradiated while the same foods (but unirradiated) are available in the market. Although consumers are becoming more aware of the danger of chemicals in the food chain, they are not as well aware of pathogenic microorganisms which can be present in foods of animal origin such as meat and poultry. Concern has been raised that irradiation may result in the development of radiation resistant strains of microorganisms. There is no evidence for such concern; on the contrary the microorganisms that survive the irradiation process are injured and therefore, more vulnerable to conditions that are unfavourable to microbial growth (e.g., cold temperature) and are more likely to be killed by cooking. Thus, an introduction of food irradiation on a commercial scale requires an education campaign on not only how and why foods are normally treated before they reach the market but also how and why irradiation could provide consumers with a wider choice or a safer food supply. Consumers might also be interested in how to identify irradiated foods other than through labelling.

Several surveys on consumer attitudes towards irradiated foods were conducted among different target groups in the past 10 years. The results of the surveys varied widely based on the types of questionnaires and the technical background of interviewees. A recent household survey in the U.S. was conducted to evaluate consumer willingness to accept irradiated fresh food products (Malone Jr., 1990). Only 36% of the food purchasers interviewed indicated a willingness to purchase irradiated products.

Three-fourth of consumers in the survey had not heard of irradiation and 37% of those not willing to purchase irradiated products indicated insufficient information about the process as a reason. The survey further revealed that the consumers willing to purchase irradiated food were also willing to pay a significantly higher amount for an increased level of food safety. This survey again confirms that a low level of awareness of food irradiation exists among consumers.

Therefore, consumer education is critical to the success of food irradiation. The majority of consumers appear to put their trust in the Government to decide for them the safety of food irradiation. National authorities, food industry trade associations and consumer interest organizations therefore have an important role to play in presenting the facts and benefits of irradiated food to the consumer.

It should be noted that consumers can decide whether they will accept irradiated food or not, at the point of purchase. Thus, results of opinion polls are not as valuable as results of market tests. A number of market tests of irradiated foods have been carried out in the past five years with interesting results (Food Irradiation Newsletter, 1990). Most of these tests were carried out with full labelling and information that the foods were treated by irradiation to achieve certain objectives. The following market tests illustrate the level of acceptance of irradiated food: Three tons of irradiated Puerto Rican mangoes sold well in a Miami market over a five week period in 1986 (Giddings, 1986). Irradiated mangoes were clearly labelled and displayed alongside non-irradiated mangoes which were inferior and did not sell as well. Similarly, Hawaiian papayas were irradiated and sold in Anaheim and Irvine markets in California. The purchase ratio in favour of irradiated papaya was 11:1 compared to unirradiated but hot water dipped papayas (Bruhn and Noell, 1987). Two metric tonnes in 1987 and five metric tonnes in 1988 of irradiated strawberries were put on sale by a supermarket chain in Lyon, France. The fruit was clearly labelled with the "Radura" logo plus the expression "ionization." Consumers paid a higher price for the irradiated strawberries because of their superior quality (Moog, 1988).

From these tests, it can be concluded that consumers not only will accept irradiated foods once they understand the safety and benefits of the treatment, but the majority of them would be prepared to buy them repeatedly. These results appear to be the opposite of what groups opposed to food irradiation have tried to project as public attitudes. These groups are fully aware of the successful results of these market tests and have threatened picketing and public boycotts of stores which carry out such tests.

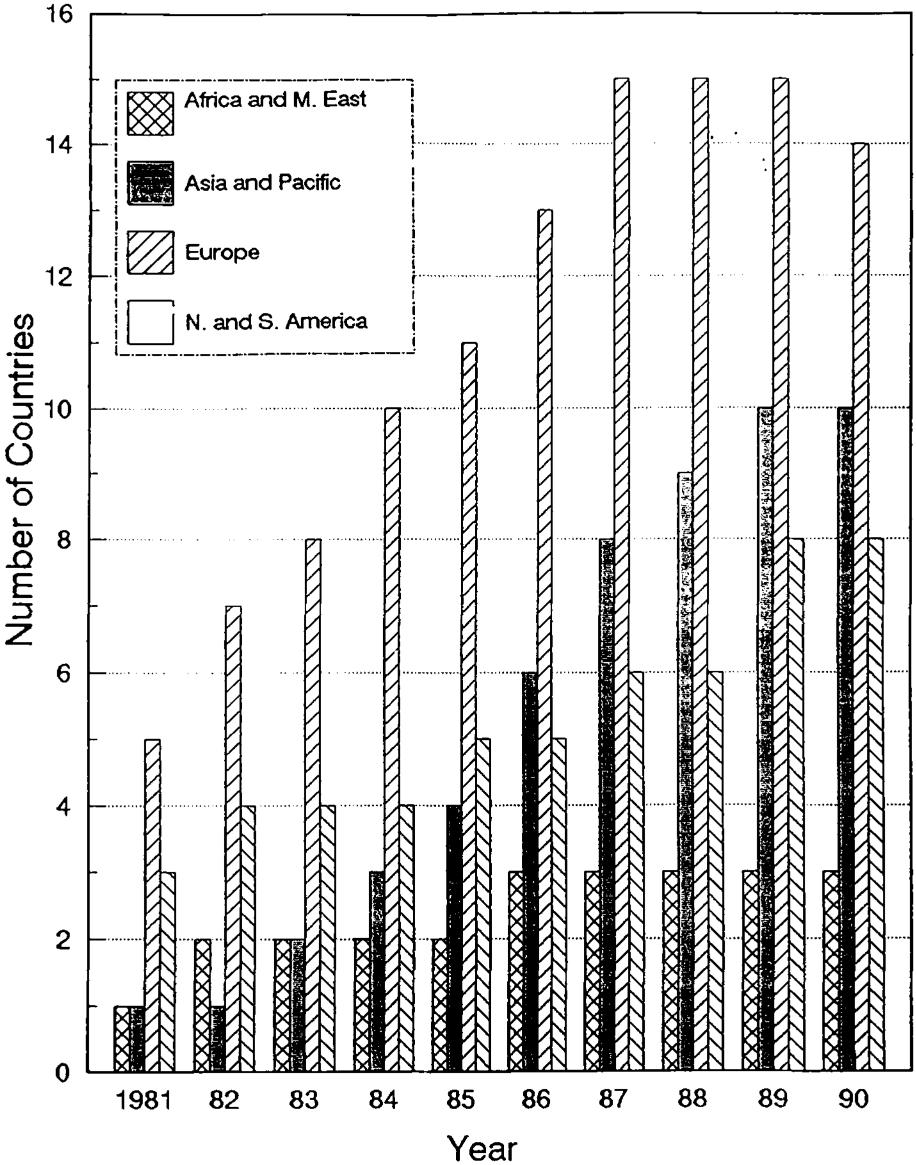


**Figure 1** Trends in unconditional approval of one or more irradiated food items in different regions

## *Harmonization of National Regulations*

Although 37 countries at present have provisions in their regulations allowing the use of food irradiation on specific commodities (Fig. 1), either on an unconditional or a restricted basis, or even on the process itself, such provisions vary from country to country. Such variations make it difficult to implement trade in irradiated food among nations. The Food Preservation Section of the Joint FAO/IAEA Division, Vienna has attempted to compile regulations on food irradiation and publish these in the Food Irradiation Newsletter (FIN) at specific intervals. The last compilation, appearing in Supplement to FIN 14 (1) 1990, showed that 37 countries have approved the use of irradiation for more than 40 commodities (Food Irradiation Newsletter, 1990). It should be noted that an increasing number of countries including Chile, Israel, Thailand, the United States and Yugoslavia have approved irradiation as a food process up to a certain maximum dose.

Information on the safety of irradiated food, and on the efficacy of the process which is now available offers national authorities the means to adapt the existing legislation, where necessary, or to develop appropriate legislation in countries without any form of legislation on food irradiation. It should be stressed that the Codex General Standard for Irradiated Foods serves as a model for individual countries. Incorporating its provisions into national legislation would protect consumers and facilitate international trade. Evidence of concrete regulatory progress has occurred during the past few years in a number of countries (Argentina, Bangladesh, Canada, Denmark, France, Hungary, The Netherlands, Norway, South Africa) where food irradiation is likely to be approved as a process up to a specified dose.

Thus, harmonization of the national regulations among nations is an important prerequisite for international trade in irradiated food. Such efforts are being undertaken by the International Consultative Group on Food Irradiation (ICGFI). The ICGFI organized an Inter-American Meeting on Harmonization of Regulations Related to Trade in Irradiated Foods in Orlando, Florida from 27 November to 1 December, 1989 in order to harmonize food irradiation regulations among the regional states with the aim of facilitating trade in irradiated food within the region and beyond (Anon., 1989). The role of the ICGFI will be discussed later. The regulation in the U.S. which allows the use of food irradiation for insect disinfestation and/or delay of maturation of food of plant origin up to 1 kGy, and for decontaminating spices up to 30 kGy could provide a strong incentive for international trade in these commodities. On 1 May 1990, the U.S. Food and Drug Administration (USFDA) approved irradiation to a maximum dose of 3 kGy to control food-borne pathogens in fresh or frozen uncooked poultry products (USFDA, 1990). The Commission of the European Community (CEC) has identified food irradiation as one of the main areas where harmonization of legislation is required to enable the free movement of foods throughout the Member States of the EC. The Commission has prepared a draft directive for consideration by the Council of Ministers. The Council will consider it before the end of 1991. The new *U.K. Food Safety Act* which would permit the use of any process including food irradiation to enhance food safety, received approval of the British Government in June 1990. Specific regulation on food irradiation therefore was introduced and entered into force on 1 January 1991. Eight groups of foods such as fruits, vegetables, cereals, bulbs and tubers, spices and condiments, fresh and frozen shellfish and fresh meat and poultry have been approved, which is compatible with the proposed draft directive of the EEC.

**Table 2**
Countries with Commercial Irradiation Facilities Available for Food Processing (December 1989)

| | Location (starting date for food irradiation) | Products |
|---|---|---|
| Argentina | Buenos Aires (1986) | Spices, spinach, cocoa powder |
| Belgium | Fleurus (1981) | Spices, dehydrated vegetables, deep frozen foods, including seafood |
| Brazil | São Paulo (1985) | Spices, dehydrated vegetables |
| Canada | Laval (1989) | Spices |
| Chile | Santiago (1983) | Spices, dehydrated vegetables, onions, potatoes, chicken |
| China | Chengdu (1978)<br>Shanghai (1986)<br>Zhengzhou (1986)<br>Nanjing (1987)<br>Jinan (1987)<br>Lanzhou (1988)<br>Beijing (1988)<br>Tienjin (1988)<br>Daqing (1988)<br>Changsha (1989)<br>Changshu (1989)<br>Shijianzhuang (19899) | Potatoes, garlic, apples, spices, onions, Chinese sausage, Chinese wine |
| Cuba | Havana (1987) | Potatoes, onions, beans |
| Denmark | Risø (1986) | Spices |
| Finland | Ilomantsi (1986) | Spices |
| France | Lyon (1982) | Spices |
| | Paris (1986) | Spices, poultry |
| | Nice (1986) | Spices, vegetable seasonings |
| | Vannes (1987) | Poultry (frozen deboned chicken) |
| | Marseille (1989) | Spices, vegetable seasonings |
| German Dem. Rep. | Zwenkau (1983) | Onions, garlic |
| | Queis (1986) | Onions |
| | Schönebeck (1986) | Enzyme preparation |
| Hungary | Budapest (1982) | Spices, onions, wine cork |
| Indonesia | Pasar Jumat (1988) | Spices |
| Israel | Yavne (1986) | Spices |
| Japan | Hokkaido (1973) | Potatoes |
| Korea, Rep. | Seoul (1986) | Garlic powder |
| Mexico | Mexico City (1980) | Spices, dehydrated vegetables |
| Netherlands | Wageningen (1978) | Spices |
| | Ede (1983) | Spices, frozen products, poultry, dehydrated vegetables, rice, egg powder, packaging material |
| Norway | Kjeller (1982) | Spices |

**Table 2** Contd.

| | Location (starting date for food irradiation) | Products |
|---|---|---|
| South Africa | Pretoria (1968) | Potatoes, onions |
| Pretoria (1971) | Fruits | |
| | Pretoria (1980) | Spices, meat, fish, chicken |
| | Tzaneen (1981) | Fruits, spices, onions, potatoes |
| | Kempton Park (1981) | Processed products |
| | Mulnerton (1986) | Fruits, spices potatoes, onions, vegetables |
| Thailand | Bangkok (1971) | Onions, fermented |
| | Patumthani (1989 ) | pork sausages |
| USSR | Bogucharovo (1960) | Potatoes, onions, cereals, fresh and dried fruits and vegetables, meat and meat products, poultry |
| | Odessa (1983) | Grain |
| USA | Rockaway, NY (1984) | Spices |
| | Whippany, NJ (1984) | Spices |
| | Irvine, CA (1984) | Spices |
| Yugoslavia | Zagreb (1985) | Black pepper |
| | Belgrade (1986) | Spices |

## Commercialization

Research and development studies on food irradiation have been carried out intensively for the last 45 years. While its practical application is low so far, considering its benefits, there is continued progress in industrialization of the process. There are over 160 commercial irradiation facilities treating mainly medical supplies and other non-food products, and about 50 of these facilities in 24 countries are used for treating some foods. Another 20 demonstration/commercial facilities are under construction and it is expected that, within the next few years, the number of countries irradiating food commercially will reach 30.

As previously mentioned, it is estimated that the total production of irradiated food worldwide amounts to about 500,000 tonnes per annum. Additional irradiation facilities which will treat foods in addition to medical products are being built in Bangladesh, China, Côte d'Ivoire, France, Poland, U.S. and Vietnam. Countries which are planning to construct commercial irradiation facilities include Indonesia, India, Algeria, Brazil, Hungary and Syria. It is expected that the number of irradiation facilities and the volume of irradiated foods will increase significantly when international trade has been initiated.

## Role of International Organizations

In 1961, FAO, IAEA and the World Health Organization (WHO) formed a Joint Expert Committee on Irradiated Food (JECFI). The JECFI was convened in 1964, 1969, 1976 and 1980 to review the wholesomeness aspects of irradiated foods. The Committee reviewed data produced internationally over the years and concluded in its 1980 meeting that the irradiation of any food commodity up to an overall average dose of 10 kGy presents no toxicological hazard; hence toxicological testing of food so treated is no longer required (WHO, 1981). The Committee considered that the irradiation of food up to an overall dose of 10 kGy introduces no special nutritional or microbiological problems. Although the Joint Expert Committee had carefully considered microbiological aspects, FAO and WHO desired additional reassurances that nothing had been overlooked in this area. At their request, the Board of the International Committee on Food Microbiology and Hygiene of the International Union of Microbiological Societies reconsidered the evidence concerning microbiological safety of the food irradiation process in 1982. The Board found no cause for concern and concluded that "food irradiation was an important addition to the methods of control of food-borne pathogens and did not present any additional hazards to health" (FAO, 1983). The Joint Expert Committee's conclusions were fully adopted by the Codex Alimentarius Commission in its General Standard for Irradiated Foods and Recommended International Code of Practice for the Operation of Radiation Facilities (FAO, 1984). Later in 1988 WHO published a book entitled *Food Irradiation—A Technique for Preserving and Improving the Safety of Food* in order to facilitate the acceptance of this technology through reassurance of its safety, wholesomeness and beneficial aspects. The national expert bodies of major countries such as the U.S., Canada, U.K. and the European Economic Community Scientific Committee have also endorsed the safety and wholesomeness of irradiated foods.

In 1984, more than 20 countries formed the ICGFI under the auspices of the FAO, WHO and IAEA to focus on aspects of international trade, economics, legislation, regulation and public information. At present 36 countries are members of ICGFI, two thirds from the developing countries. The first phase of ICGFI ended in 1989. It has been extended for another five years. The ICGFI is assisting governments and the three sponsoring United Nations agencies (i.e. FAO, IAEA and WHO) in considering the safe, effective applications of food irradiation technology in ways which will enhance the world food supply, reduce post-harvest/slaughter food losses, reduce the risk from food-borne diseases and provide an alternative to some chemicals in agricultural and fishery products.

The activities of ICGFI include, among others: (1) raising the level of knowledge of irradiation technology and its benefits, limitations, safety assessments and costs by preparing background information and inventories; (2) facilitating improved regulatory control and acceptance of food irradiation by preparing and publishing material on national legislation, licensed facilities for treating foods on a commercial or pilot scale, product clearance, etc.; (3) providing information and advice on specific applications such as use of radiation to enhance hygienic quality of foods, quarantine treatment of agricultural commodities, etc., and assisting national authorities and industries in conducting feasibility studies as well as organizing training courses; (4) facilitating technology transfer and training through organizing training courses and workshops for regulators, inspectors, managers and operators; (5)

maintaining wholesomeness data on irradiated products; and (6) facilitating international trade in irradiated foods by organizing regional seminars, developing technological guidelines for specific applications, and assisting the Codex Alimentarius Commission in developing appropriate labelling standards.

FAO and IAEA, through their Joint FAO/IAEA Division, have been assisting their Member States in transferring this technology to local industry. Such technology transfer differs depending on the needs of various geographical regions.

In addition to the efforts of FAO and IAEA, global research and training in food irradiation was further supported by the International Facility for Food Irradiation Technology (IFFIT), based in the Netherlands and sponsored by the FAO, IAEA and the Netherlands Ministry of Agriculture and Fisheries. IFFIT was in operation from 1979 to 1990 to provide training and techno-economic feasibility studies to scientists from Member States of FAO and IAEA. Several interregional and regional training courses on food irradiation have been organized by IFFIT and attended by some 500 scientists/technologists from more than 50 countries. Some 50 scientists have also conducted long-term research on techno-economic feasibility of food irradiation at IFFIT.

Upon termination of IFFIT at the end of 1990, the FAO/IAEA and the ICGFI Network for Training on Food Irradiation will continue to provide training facilities to scientists and technologists from developing countries.

## Conclusions

After over four decades of research, development and evaluation of the wholesomeness and safety of irradiated foods, food irradiation has been established as a valuable additional physical food processing technique. However, it is not a panacea that will eliminate all food-related problems. As in all other methods of food processing, food irradiation has benefits and limitations. It can play an important role in reducing post-harvest food losses. It has the advantage over the food fumigation treatments that it uniformly treats the products, it is less time consuming and it leaves no residues on treated products. Irradiation can replace fumigation treatment of some fruits and vegetables in order to meet quarantine requirements in international trade. It has been increasingly recognized that food irradiation can play a significant role in improving the hygienic quality of foods. These are some of the potential applications where food irradiation offers tangible benefits and deserves consideration for application.

Food irradiation is a capital intensive process like most modern food processing techniques. It requires the same infrastructures for successful application as do other industrial processes like canning, freezing, pasteurizing, etc. Therefore economic feasibility studies are required in order to establish need and the profitability of this process in each case. The most important impediment in the commercial application of food irradiation processing could be the slow acceptance of this process by the industries as well as the consumers due to its perceived association with nuclear technologies plus a relative lack of accurate information. The notions of the environmental groups which believe that any nuclear-related technology may be harmful or cause environmental pollution can influence the general public. So far, the marketplace has shown that if this process is properly explained, consumers' attitudes toward food irradiation can be positive. Consumers are largely interested in the quality of the products they are buying. If food irradiation provides a better, safer product and the consumers are convinced that the treated product is safe, wholesome and nutritionally adequate, they will buy it. The cautious approach of industries to the establishment of commercial irradiation facilities will be positively changed once they feel that consumers accept irradiated food.

## References


Acevedo, H. 1982. Economic impact of porcine cysticercosis. In *Cysticercosis, Present State of Knowledge and Perspectives*, edited by A. Flisser, et al. New York: Academic Press.

Ahmed, M., A. Karim, M.A. Quaiyum, A.D. Bhuiya, M.A. Matin, A.K. Siddiqui, and M.M. Hossain. 1989. Economic feasibility studies on dried and cured fishery products, onions and potatoes. In *Radiation Preservation of Fish and Fishery Products*. Tech. Report Series No. 303. Vienna: International Atomic Energy Agency.

Anonymous. 1989. Inter-American Meeting on Harmonization of Regulations Related to Trade in Irradiated Food, 27 November – 1 December, 1989, Orlando, Florida, U.S.

Bruhn, C.M., and J.W. Noell. 1987. Consumer in-store response for irradiated papayas. *Food Technology* 41(9): 83–85.

Dickman, S. 1991. Compromise eludes EC. *Nature* 349: 273.

Environmental Protection Agency (EPA). 1983. EPA Acts to ban EDB Pesticides. *Environmental News*. U.S. Environmental Protection Agency, September 30, 1983.

Food and Agriculture Organization (FAO). 1983. *The Microbiological Safety of Irradiated Food*. Codex Alimentarius Commission, Report CX/FH 83/9. Rome: FAO.

——. 1984. *Codex General Standard for Irradiated Foods and Recommended International Code of Practice for the Operation of Radiation Facilities Used for the Treatment of Foods*. Codex Alimentarius Commission, CAC/Vol. XV. Rome: FAO.

Food Irradiation Newsletter. 1990. Compilation of information on market trials (1984–89), *Food Irradiation Newsletter* 14(1): 53–56.

Giddings, G.G. 1986. Summary of the Puerto Rico mango consumer test market initiated and coordinated by Isomedix, Inc. *Food Irradiation Newsletter* 10(2): 56–57.

International Atomic Energy Agency (IAEA). 1986. *Report of a Task Force Meeting on Irradiation as a Quarantine Treatment*, Chiang Mai, Thailand, 17–28 February 1986. Vienna: International Atomic Energy Agency.

Malone Jr., J.W. 1990. Consumer willingness to purchase and to pay more for potential benefits of irradiated fresh food products. *Agribusiness* 6(2): 163–177.

Matin, M.A., A.D. Bhuiya, M. Ahmed, A. Karim, S. Rahman, J. Khatoon, M.M. Hossain, S. Islam, M. Islam, M.R. Amin, M.A. Hossain, and A.K. Siddiqui. 1991. Studies on commercialization, storage and transportation of irradiated dried fish and onions. In *Asian Regional Co-operative Project on Food Irradiation:*

*Technology Transfer*. Panel Proc. Series (under publication). Vienna: International Atomic Energy Agency.

Moog, P. 1988. How to win consumer acceptance in the marketing of irradiated food. In *Factors Affecting Practical Application of Food Irradiation,* IAEA-TEC-DOC-544. Vienna: International Atomic Energy Agency.

Morrison, R.M., and T. Roberts. 1985. *Food Irradiation: New Perspectives on a Controversial Technology*. Washington, DC: Office of Technology Assessment.

Moy, J.H. 1983. Radurization and radicidation: fruits and vegetables. In *Preservation of Foods by Ionizing Radiation. Vol. III,* edited by E.S. Josephson and M.S. Peterson. Boca Raton, FL: CRC Press.

Nickerson, J.T.R., J.J. Licciardello, and L.J. Ronsivalli. 1983. *Radurization and radicidation: fish and shellfish.*

Prachasitthisak, Y., U. Pringsulka, and S. Chareon. 1989. Consumer acceptance of irradiated nham (fermented pork sausage). *Food Irradiation Newsletter* 13(1): 65–67.

Thomas, P. 1983. Radiation Preservation of Foods of Plant Origin. Part 1. Potatoes and other tuber crops. *CRC Crit. Rev. Foods Sci. Nutri.* 19(4): 327–380.

——. 1984. Radiation Preservation of Foods of Plant Origin. Part 2. Onions and other bulk crops. *CRC Crit. Rev. Food Sci. Nutri.* 21(2): 95–136.

United States Food and Drug Administration (USFDA). 1990. *US Department of Health and Human Services, Food and Drug Administration, Federal Register,* 21 CFR Part 179, May 2, 1990.

Urbain, W.M. 1982. Considerations on economics and energy requirements of food irradiation applications in developing countries: Anticipated benefits of irradiation. In *Food Irradiation for Developing Countries in Asia and the Pacific,* IAEA-TECDOC-271. Vienna: International Atomic Energy Agency.

——. 1983. Radurization and radicidation: meat and poultry. In *Preservation of Foods by Ionizing Radiation. Vol. III,* edited by E.S. Josephson and M.S. Peterson. Boca Raton, FL: CRC Press.

World Health Organization (WHO). 1981. Wholesomeness of Irradiated Food. Report of a Joint FAO/IAEA/WHO Expert Committee. WHO Technical Report Series 659. Geneva: WHO.

——. 1987. *Report of a Task Force Meeting on the Use of Irradiation to Ensure Hygienic Quality of Food,* Vienna, 14–18 July 1986. WHO/EHE/FOS/87.2. Geneva: WHO.