# Food irradiation in developing countries: A practical alternative

*Health and economic benefits are major reasons why more countries are looking closely at the technology's commercial uses*

by Paisan Loaharanu

Among existing technologies for food preservation, irradiation of food is recognized as a safe and effective method for a range of specific applications. Through its use, food losses and food-borne diseases can be reduced, and wider trade of many food items can be facilitated.

A worldwide standard on food irradiation was adopted in 1983 by the Codex Alimentarius Commission of the Joint Food Standard Programme of the Food and Agriculture Organization (FAO) of the United Nations and the World Health Organization (WHO). Such a standard provides an assurance to governments and consumers of the safety and effectiveness of the technology. As a result, 38 countries have approved the use of irradiation for treating one or more food items, and the number is increasing. Currently 27 countries — half of which are from the developing world — are using the technology for treating food for commercial purposes. *(See table.)*

In light of such developments, the IAEA has developed an action plan directed at the practical utilization of food irradiation in developing countries. The plan was developed in response to an initiative from the Ambassador of India in 1992. It now includes a detailed project proposal for the introduction of commercial-scale food irradiation in developing countries through appropriate technical co-operation channels, and in collaboration with other United Nations organizations, including the FAO, WHO, and International Trade Centre. The proposal was approved by the IAEA Board of Governors and subsequently endorsed by the IAEA General Conference in September 1993.

It included the outcomes of several economic feasibility studies. Four countries — Chile, China, Mexico, and Morocco — were invited to collaborate with the IAEA to conduct the studies, and all but Chile's has been completed.

Based on its study, the Chinese government decided to allocate approximately US $1.1 million toward the design and construction of a commercial food irradiator in Beijing for treating mainly rice, garlic, and a few other food items for the domestic market. The IAEA was requested to provide a cobalt-60 source, expert services, quality control equipment, and fellowship training of their personnel.

Mexico's feasibility study reported that several commercial food irradiators may be considered both for the domestic market and for export. The first such commercial plant was recommended to be built in the central region of Mexico for treating spices, dried food, fruits and vegetables, and medical products; a potentially high profit was foreseen.

In Morocco, on the other hand, the study found that the infrastructure required for introducing commercial-scale food irradiation appeared to be premature. An IAEA expert mission recommended strengthening research and development efforts prior to embarking on commercial-scale application.

This article looks at some of the major reasons why more countries, particularly those from the developing world, are interested in commercial applications of food irradiation technology.

## Health and economic considerations

***Post-harvest food losses.*** Despite the availability of many food processing technologies, developing countries are still experiencing high post-harvest losses of food. Up to 50% of perishable food — such as fish and seafood, fruits and vegetables, meat and poultry — is lost during production through various

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spoilage agents before reaching the consumer. Post-harvest losses in countries of the Asian region, for example, are estimated at 30% for grains, 20% to 40% for fruits and vegetables, and up to 50% for fish. In Africa, a conservative estimate shows that a minimum of 20% of total food production is lost after harvest. Losses of perishable items such as fruits, vegetables, and fish, for example, are even higher than 50%. The US National Academy of Sciences has estimated that the minimum post-harvest food losses in developing countries amounted to more than 100 million tonnes at a value surpassing US $10 billion in 1985.

Many of the losses are attributed to insect infestation. To combat the problem for cereals, pulses, and other stored products, developing countries often fumigate them with chemicals such as ethylene dibromide, methyl bromide, or ethylene oxide which have to be imported from advanced countries. Their use has created problems relating to health, environment, and worker safety. For these reasons, ethylene dibromide has been prohibited for fumigating food since the mid-1980s. Recently, methyl bromide — the most widely used chemical for fumigating food against insect infestation — has been reported to have strong ozone-depleting properties. Under terms of the Montreal Protocol — which was adopted in 1989 by most nations to protect the environment — chemical substances which damage the ozone layer will have to be phased out by the year 2000.

***Food-borne diseases.*** Food-borne diseases continue to affect adversely the health and productivity of populations in most countries, especially in developing ones. Contamination of food — especially of animal origin — with microorganisms, particularly pathogenic non-spore-forming bacteria, as well as infection with parasitic helminths and protozoa, are important public health problems and causes of human suffering and malnutrition. According to WHO, infectious and parasitic diseases represented the most frequent cause of death (35%) worldwide in 1990, with the majority of deaths occurring in developing countries. These diseases include malaria, diarrhoea, tuberculosis, measles, pertussis, and schistosomiasis. Diarrhoeal disease caused about 25% of deaths in developing countries. It is estimated that in possibly up to 70% of cases food is the vehicle for transmission of diarrhoeal diseases.

Moreover, during the past 2 years, 15 countries in Latin America have reported some 400 000 cases of cholera and more than 4000 deaths. The most important cause of transmission of the disease was the consumption of contaminated water and food.

In a number of countries, consumers have had the choice of buying foods processed by irradiation. *(Credit: CEA)*

Elsewhere, 7 million people in the north-eastern provinces of Thailand, 3 million in the Republic of Korea, and millions more in China are infected by liver fluke parasites from consumption of raw freshwater fish. The economic losses caused by these diseases in these countries are estimated to be hundreds of millions of US dollars annually.

***Food trade.*** Besides having to compete among themselves for food export markets, developing countries also have to satisfy the increasingly strict standards of quality and quarantine in major importing countries. They are accustomed to exporting raw agricultural and food commodities, such as spices and condiments, fruits and vegetables, cereals and pulses, as well as beverage crops such as coffee beans and cocoa beans, which are prone to contamination by microorganisms and infestation by insects. Large quantities of such products are rejected by importing countries each year on the grounds of poor quality and hygiene. The economic losses from rejections can be enormous.

Many fruits produced in developing countries are not allowed to enter lucrative markets in the United States, Japan, Australia, and other countries because of insect infestation, especially by fruit flies of the *Tephritidae* family. Such commodities have to be treated either by chemical fumigation, hot water or vapour heat, or refrigeration near 0° C before importation by these countries. The problem is compounded by the fact that most tropical fruits and vegetables cannot tolerate drastic temperature treatments. Considering the volume and value of fruits and vegetables exported to countries having strict quarantine regulations, developing countries could suffer seriously if there were no effective alternative treatments available.

The impending ban of methyl bromide could create enormous economic losses for both advanced and developing countries. For example, some 300 000 tonnes of fruits and vegetables imported annually into the United States require methyl bromide fumigation for insect control. The bulk of these imports consists of grapes from Chile (close to 200 000 tonnes per annum). Irradiation is probably the best alternative treatment method available. Its use on four selected commodities being imported by the United States can yield an economic benefit ranging from US $650 million to $1100 million over a 5-year period, based on an analysis by the US Department of Agriculture (USDA).

Currently, developing countries can export their fresh fruits and vegetables to most countries of the European Community without any restrictions. As some of the European and Mediterranean countries have started growing commercial quantities of tropical fruits (such as mangoes and papayas), the European and Mediterranean Plant Protection Organization (EPPO) is evaluating phytosanitary regulations in line with the free movement of goods within the European Community. This is being done to protect these countries from exotic quarantine pests. This action of EPPO is going to seriously affect trade in food and agricultural products from developing countries. Regional plant protection organizations including EPPO have recognized food irradiation as an effective quarantine treatment to overcome such a problem.

Trade in food products which are contaminated by disease-causing microorganisms (for example, *Salmonella*) could create a liability problem for manufacturers, especially of ready-to-eat food. A recent incident in Germany in late 1993 concerning a snack food flavoured by paprika contaminated by *Salmonella* has cost its manufacturer between 30 to 40 million Deutschmark due to product recall and destruction. The paprika was imported from a developing country. It was not known whether the paprika was treated in any way prior to its use in the snack food. Proper irradiation of paprika would overcome the problem of such contamination.

## Interest in food irradiation

***Food losses.*** Depending on the absorbed doses, irradiation is effective as a method for reducing post-harvest losses of a range of foods. Low-dose irradiation (0.05 to 0.15 kGy) is effective for inhibiting sprouting, which is the most important cause of deterioration of crops such as potatoes, onion, garlic, and yam. Irradiation provides an important alternative to chemical sprout inhibitors which are not always effective under tropical conditions. For example, it is the only effective method to control storage loss of yams due to sprouting. It also reduces the use of refrigeration for storing these crops, as irradiated products may either be stored at ambient or chilled ($10^{\circ}$ to $15^{\circ}$ C) conditions, instead of at low temperatures ($0^{\circ}$ to $2^{\circ}$ C) to reduce losses caused by spoilage microorganisms.

***Food spoilage.*** Ripening and maturity of fruits and vegetables — such as mangoes, papayas, mushrooms and asparagus — may be delayed by low-dose irradiation of approximately 1 kGy, thereby extending their shelf-lives. By combining irradiation with mild heat treatment, e.g., hot water dip ($50^{\circ}$ C for 5 minutes), both a delay in ripening and in disease control of fruits such as mangoes and papayas can be achieved.

Most spoilage microorganisms of meat, fish, and seafood are relatively sensitive to low-dose irradiation. Thus, irradiating these products with doses between 1 and 5 kGy after proper packaging results in significant reduction of spoilage microorganisms. Together with proper storage under refrigeration, the shelf-lives of these products may be extended significantly.

***Disinfestation.*** For insect disinfestation, irradiation offers an attractive alternative to chemicals for grains, dried fish , dried fruits, and tree nuts. A dose between 0.25 and 0.5 kGy is effective for controlling infestation by practically all species of insects in stored products. Irradiation is economically attractive as demonstrated by the two large electron irradiators situated at Port Odessa, Ukraine. They process approximately 400 000 tonnes of grain per annum.

Cured and dried fish provides important sources of animal protein for populations in many developing countries in Africa and Asia. These products are normally infested by several species of insects during sun drying and storage. In several countries, the use of insecticides to control insect infestation of these products is still practiced. Irradiation of properly packaged dried fish with a dose of 0.5 kGy is an attractive and residue-free alternative to chemical control of insects in these products.

***Safety and hygiene.*** Spices and dried vegetable seasonings have to be processed to meet the microbiological specifications of food manufacturers before their incorporation in processed food such as sausages, canned meat, soups, sauces, and salad dressings.

## Irradiation facilities around the world

Twenty-seven countries worldwide have irradiation facilities available for commercial applications of food irradiation; six others are either building or planning such facilities. A listing by country follows. *Countries in italics are irradiating food products for commercial use.*

**ALGERIA:** a facility at Mascara is under construction for processing potatoes.

***ARGENTINA:*** a facility in Buenos Aires started irradiating spices, spinach, and cocoa powder in 1986.

***BANGLADESH:*** a facility at Chittagong started irradiating potatoes, onions, dried fish, and pulses in 1986.

***BELGIUM:*** a facility at Fleurus started irradiating spices, dehydrated vegetables, and deep frozen foods in 1981.

***BRAZIL:*** a facility in Saõ Paulo started irradiating spices and dehydrated vegetables in 1985.

***CANADA:*** a facility at Laval started irradiating spices in 1989.

***CHILE:*** a facility in Santiago started irradiating spices, dehydrated vegetables, onions, potatoes, and poultry meat in 1983.

***CHINA:*** facilities at Chengdu (since 1978) started irradiating spices, vegetable seasonings, Chinese sausage, and garlic; at Shanghai (since 1986) apples, potatoes, onions, garlic, dehydrated vegetables; at Zhengzhou (since 1986) garlic, seasonings, and sauces; at Nanjing (since 1987) tomatoes; and at Jinan (since 1987), Lanzhou (since 1988), Beijing (since 1988), Tienjin (since 1988), Daqing (since 1988), and Jianou (since 1991) unspecified products.

**CÔTE D'IVOIRE:** a facility is being built at Abidjan for irradiating yams, cocoa, and beans.

***CROATIA:*** a facility at Zagreb started irradiating spices, rice, and food ingredients in 1985.

***CUBA:*** a facility in Havana started irradiating potatoes, onions, beans, and cocoa powder in 1987.

***DENMARK:*** a facility at Riso started irradiating spices in 1986.

***FINLAND:*** a facility at Ilomantsi started irradiating spices in 1986.

***FRANCE:*** facilities at Lyon (since 1982) started irradiating spices; Paris (since 1982) spices and vegetable seasonings; Nice (since 1986) spices; Vannes (since 1987) poultry (frozen deboned chicken); Marseille (since 1989) spices, vegetable seasonings, dried fruit, frozen frog legs, and shrimp; Pousauges and Osmanville (since 1991) unspecified products; and Sablé-sur-Sarthe (since 1992) Camembert.

***HUNGARY:*** a facility at Budapest started irradiating spices, onions, wine cork, and enzymes in 1982.

**INDIA:** facilities are planned in Bombay for irradiating spices and in Nasik for onions.

***INDONESIA:*** facilities at Pasr Jumat (since 1988) and Cibitung (since 1992) started irradiating spices.

***IRAN:*** a facility in Tehran started irradiating spices in 1991.

***ISRAEL:*** a facility at Yavne started irradiating spices, condiments, and dry ingredients in 1986.

***JAPAN:*** a facility at Hokkaido started irradiating potatoes in 1973.

***KOREA, REPUBLIC OF:*** a facility at Seoul started irradiating garlic powder, spices, condiments, and food ingredients in 1986.

***MEXICO:*** a facility in Mexico City started irradiating spices and dry food ingredients in 1988.

***NETHERLANDS:*** a facility at Ede started irradiating spices, frozen products, poultry, dehydrated vegetables, rice, egg powder, and packaging material in 1981.

***NORWAY:*** a facility at Kjeller started irradiating spices in 1982.

**PHILIPPINES:** a facility in Quezon City started irradiating unspecified products in 1989.

**POLAND:** facilities started irradiating products at Warsaw (since 1984); Wlochy (since 1991); and Lodz (since 1984).

***SOUTH AFRICA:*** facilities at Pretoria (since 1971, 1978, 1980, respectively) started irradiating potatoes, onions, fruits, spices, meat, fish, and chicken; at Tzaneen (since 1981) onions, potatoes, and processed products; at Kempton Park (since 1981) fruits, spices, and potatoes; and at Milnerton (since 1986) fruits and spices.

***THAILAND:*** facilities at Bangkok started irradiating onions in 1971; and at Patumthani fermented pork sausages, enzymes, and spices in 1989.

***UKRAINE:*** a facility at Odessa started irradiating grain in 1983.

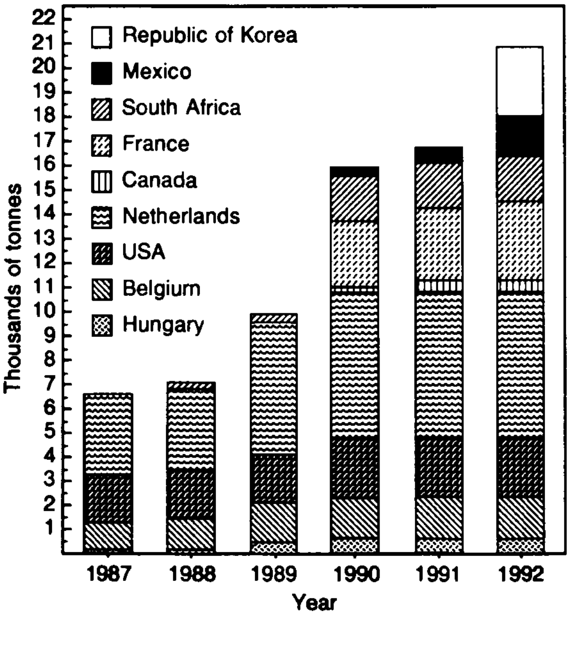
***UNITED KINGDOM:*** a facility at Swindon started irradiating spices in 1991.

***UNITED STATES:*** facilities at Rockaway, New Jersey (since 1984), Whippany, New Jersey (1984), and Irvine, California (since 1984) started irradiating spices; at Ames, Iowa (since 1993) unspecified products; and at Mulberry, Florida (since 1992) fruits and vegetables; a facility at Gainsville, Florida, is under construction.

**VIET NAM:** a facility at Hanoi started irradiating onions, potatoes, seafood, spices, rice, and dried tobacco leaves in 1991.

***YUGOSLAVIA:*** a facility at Belgrade started irradiating spices in 1986.

### Commercial irradiation of spices and vegetable seasonings in different countries



| Country | Irradiated food items | Date of testing | Remarks |
|---|---|---|---|
| Argentina | onions, garlic, garlic powder | 1985-1988 | Consumers positive to irradiated foods. 95% like to buy irradiated onions |
| Bangladesh | potatoes, onions, dried fish, pulses | 1984-1992 | Consumers preferred irradiated foods |
| China | spirit from sweet potatoes, sausages, apples, potatoes, hot pepper products, oranges, pears | 1984-1993 | Consumers positive to irradiated products |
| Cuba | potatoes, onions, garlic | 1988-1992 | Consumers positive to irradiated products. |
| France | strawberries, Camembert | 1987-1988 1991-1992 | Consumers positive to irradiated products |
| Indonesia | dried fish | 1986-1988 | Consumers positive to irradiated products |
| Pakistan | potatoes, onions, dried fruits | 1984-1992 | Consumers positive to irradiated products |
| Philippines | onions, garlic | 1984-1987 | Consumers positive to irradiated products |
| Poland | onions, potatoes | 1986-1988 | 90-95% of the consumers preferred irradiated foods |
| Thailand | nham (fermented pork sausage), onions, garlic | 1986-1992 | 95% consumers preferred irradiated nham. Consumers positive to irradiated onions and garlic |
| USA | mangoes, papaya, apples | 1986-1988 | Consumers preferred irradiated mangoes and apples. Irradiated papayas sold at a ratio of 11:1 over non-irradiated papayas |
| | strawberries, oranges, grape fruits, tomatoes, onions and mushrooms | 1992-1993 | Irradiated strawberries sold at a ratio of 20:1 over non-irradiated ones. Consumers positive to others. |
| Yugoslavia | herbal extracts | 1984-1985 | Consumers positive to irradiated products |

**Market trials of Irradiated foods (1984-1993)**

The once widespread use of ethylene oxide fumigation is being challenged, however, for health and safety reasons. Irradiation is slowly replacing it, especially in the European Community (where ethylene oxide fumigation was prohibited in 1991) and in its trading partners. The use of irradiation to ensure that the hygienic quality of spices is acceptable has increased significantly in recent years, i.e. from under 10 000 tonnes before 1990 to above 20 000 in 1993. *(See box.)* Most commercial irradiation of spices and vegetable seasonings is done in advanced countries, such as the Netherlands, France, Belgium, USA, and South Africa. Developing countries that produce and export these products would stand to gain if they would start processing them by irradiation.

***Food trade.*** Despite the wide variety and large quantities of fruits and vegetables produced in developing countries, only a few tropical fruits (such as mangoes, papayas, and star fruit) are traded with advanced countries. Certain advanced countries, including the USA, Australia, Japan, and New Zealand, have strict plant protection and quarantine regulations which prohibit entry of fruits and vegetables from countries endemic with quarantine pests, especially fruit flies of the *Tephritidae* family. Fresh commodities from these countries have to be given approved treatments prior to importation.

Irradiation (0.15 kGy minimum) offers the most effective treatment to satisfy quarantine regulations. A low dose effectively provides quarantine security against any species of fruit fly without damaging the quality of most fruits and vegetables. Irradiation as a quarantine treatment for fresh fruits and vegetables has been endorsed by regional plant protection organizations. They include the North American Plant Protection Organization, European Plant Protection Organization, and the Asia and the Pacific Plant Protection Commission.

***Refrigeration costs.*** Modern freezing technology not only facilitates wide trade in perishable foods (especially those of animal origin) but also enables foods to retain most of their fresh-like properties. Because of the Montreal Protocol, the most widely used refrigerants, chlorofluorohydrocarbons (CFCs), will no longer be available for the refrigeration industry by the year 2000. Although alternative refrigerants exist, the ban on CFCs could result in higher costs of refrigeration which most developing countries would find increasingly difficult to afford.

Developing countries will have to consider suitable alternatives, as well as technologies that reduce dependance on refrigeration in general. Irradiation offers a strong possibility to reduce the use of refrigeration for a range of food items, if used in combination with other food preservation technologies. Some semi-dried fruit products have been developed with excellent sensory properties and successfully marketed in France in recent years. Irradiated dried fish has been market tested in some Asian countries with success. Radiation-sterilized meat, poultry, and seafood have been developed by the US Army Natick Laboratories and they have been widely used by astronauts since the early 1970s.

The use of shelf-stable products, including those developed through irradiation processing, will be highly valuable to developing countries, especially those which could not afford to invest in the cold chain for food distribution.

## Consumer acceptance of irradiated food

There appears to be a perception by the food industry, consumer organizations, and even governments that consumers would be reluctant to purchase and consume irradiated food. Indeed, a number of consumer surveys conducted by organizations, especially during the 1980s when several Western countries were introducing regulations allowing the use of food irradiation, appear to support such perceptions.

It should be noted, however, that consumers have been exposed to misleading information during the past decade by some self-appointed "consumer groups" to oppose the introduction of food irradiation. Their sensationalized claims of "negative effects" from irradiated food were often highlighted through media reports. Following the Chernobyl accident in 1986, the public was further confused by the contamination of food by radionuclides in the food chain as compared with irradiation of food for preservation purposes.

Fortunately, starting in the mid-1980s, market tests of irradiated food were carried out in both advanced and developing countries. Such tests, together with correct dissemination of information about irradiated food, has helped to create a much better understanding among consumers of the safety, benefits, and limitations of this technology. A variety of irradiated food — including onions, potatoes, garlic, mangoes, papayas, strawberries, dried fish, and fermented pork sausages — were put on sale with labels indicating irradiation treatment, often alongside non-irradiated counterparts.

The positive outcome of the market tests was impressive; consumers were not only willing to purchase irradiated food but often bought them with overwhelming preference over the non-irradiated ones. The main factors which influenced consumers to purchase more irradiated food appear to be quality or safety. Thus, when consumers are offered irradiated food with proper information, they are willing to purchase it. *(See table.)*

## Commercial applications

The number of countries which use irradiation for processing food for commercial purposes has been increasing steadily from 19 in 1987 to 27 today. Most of this increase in recent years has been in developing countries, which either need the irradiated products for their domestic market or see an opportunity to develop markets overseas.

The most significant event creating an awareness among governments, the food industry, and the media was the opening of the first commercial food irradiator in the USA in 1992. It is located at Mulberry, near Tampa, Florida. The facility has treated strawberries, other fruits, and some vegetables for spoilage control and marketed the products in the Miami and Chicago areas with great success. Irradiated strawberries outsold non-irradiated ones by a margin ranging from 10 to 1 to 20 to 1 depending on the time of sale. Apparently, consumers were attracted by the premium quality of "natural field ripe" irradiated products as compared with "nearly" ripe non-irradiated strawberries normally available to them. The sale of other irradiated produce, such as onions, mushrooms, and citrus, registered similar success to the sale of strawberries. Retail stores which carried out the sales also reported significant savings. Spoilage losses were reduced considerably, to about 2% for irradiated strawberries, compared to about 10% for non-irradiated ones.

Since September 1993, limited quantities of irradiated poultry also have been on sale in the United States with success. Over the past 5 years, irradiated food with proper labelling has been successfully sold at the retail level elsewhere as well, including China, France, South Africa, and Thailand.

## A practical choice

The technology of food irradiation can provide developing countries with an additional weapon to combat high food losses and food-borne diseases, and to broaden trade markets for various food commodities. Increasing commercial applications in advanced countries are positive signs for the greater practical utilization of food irradiation in developing countries.

As the world's population grows and additional demands are placed on our agricultural resources, all available technologies to safely process and preserve food will have vital roles to play, both in health and economic terms. In many cases, irradiation could be a practical choice for developing countries. ❐