Facts about food irradiation

A series of Fact Sheets from the International Consultative Group on Food Irradiation

ICGFI is an international group of experts designated
by Governments to evaluate and advise on global
activities of food irradiation

For further information contact:

Head
Food and Environmental Protection Section
Joint FAO/IAEA Division of Nuclear Techniques in Food and Agriculture
International Atomic Energy Agency
Wagramer Strasse 5, P.O.Box 100, A-1400 Vienna, Austria
Telex:112645, Cable:INATOM VIENNA, Facsimile: (+43 1) 26007
Telephone:(+43 1) 2600-21640, E-Mail: Official.Mail@iaea.org
Also visit ICGFI-Web Page (http://www.iaea.org/icgfi/)

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Consultative Group on Food Irradiation (ICGFI), Vienna, Austria,
provided by
PURIDEC Irradiation Technology,
6 Chiltern Court, Asheridge Road, CHESHAM, Buckinghamshire,
England HP5 2 PX

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Illustrations: Camilo Melgar

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Contents

Foreword

The safety and benefits of foods processed by ionizing radiation are well documented. In an effort to provide governments with scientifically accurate information on issues of general interest to the public, the International Consultative Group on Food Irradiation (ICGFI), which was established under the aegis of the Food and Agriculture Organization of the United Nations (FAO), the World Health Organization (WHO), and the International Atomic Energy Agency (IAEA), decided at its 7th Annual Meeting in Rome, Italy, in October 1990, to issue a series of "Fact Sheets" on the subject. The Fact Sheets were first issued by the ICGFI Secretariat (Joint FAO/IAEA Division of Nuclear Techniques in Food and Agriculture, Vienna, Austria) in May 1991.

ICGFI, an inter-governmental body with a membership of 46 governments in 1999, has as one of its mandates the function to provide information to Member States of the FAO, WHO, and IAEA and to the three organizations themselves on the safe and proper use of food irradiation technology. Since publication of the Fact Sheets in 1991, many developments have taken place in the field of food irradiation. This booklet reports the latest developments in the use of food irradiation. The revised Fact Sheets included here cover issues relating to: status and trends; scientific and technical terms; benefits of food irradiation; food irradiation facilities; safety of food irradiation; nutritional quality of irradiated foods; packaging of irradiated foods; food irradiation costs; trade in irradiated foods; detection methods for irradiated foods; and irradiated foods and the consumer.

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TREATED BY
IRRADIATION
For Freshness
and Quality

Status and Trends

Food irradiation is the treatment of food by a certain type of energy. The process involves exposing the food, either packaged or in bulk, to carefully controlled amounts of ionizing radiation for a specific time to achieve certain desirable objectives as will be detailed later in the text. The process cannot increase the normal radioactivity level of the food, regardless of how long the food is exposed to the radiation, or how much of an energy "dose" is absorbed. It can prevent the division of microorganisms which cause food spoilage, such as bacteria and moulds, by changing their molecular structure. It can also slow down ripening or maturation of certain fruits and vegetables by modifying/altering the physiological processes of the plant tissues.

Who is interested in the process?

Alongside traditional methods of processing and preserving food, the technology of food irradiation is gaining more and more attention around the world. Although regarded as a new technology by some individuals, research on food irradiation dates back to the turn of the century with the first USA and British patents being issued in 1905 for the use of ionizing radiation to kill bacteria in food. Today, health and safety authorities in over 40 countries have approved irradiation of over 60 different foods, ranging from spices to grains to deboned chicken meat, to beef, to fruits and vegetables. As of August 1999, over 30 countries are irradiating food for commercial purposes. There are approximately 60 irradiation facilities being used for this purpose with more under construction or at the planning stage.

Decisions in these and other countries to irradiate food have been influenced by the adoption, in 1983, of a worldwide standard covering irradiated foods. The standard was adopted by the Codex Alimentarius Commission, a joint body of the Food and Agriculture Organization of the United Nations (FAO) and the World Health Organization (WHO), responsible for issuing food standards to protect consumer health and facilitate fair practice in food trade, representing more than 150 governments. The Codex General Standard for food irradiation was based on the findings of a Joint Expert Committee on Food Irradiation (JECFI) convened by the FAO, WHO, and the International Atomic Energy Agency (IAEA). The JECFI has evaluated available data in 1964, 1969, 1976, and 1980. In 1980, it concluded that "the irradiation of any food commodity" up to an overall average dose of 10 kGy "presents no toxicological hazard" and requires no further testing. It

stated that irradiation up to 10 kGy "introduces no special nutritional or microbiological problems" in foods. In September 1997 a Study Group was jointly convened by the WHO, FAO and IAEA to evaluate the wholesomeness of food irradiated with doses above 10 kGy. This Study Group concluded that there is no scientific basis for limiting absorbed doses to the upper level of 10 kGy as currently recommended by the Codex Alimentarius Commission. Food irradiation technology is safe to such a degree that as long as the sensory qualities of food are retained and harmful microorganisms are destroyed, the actual amount of ionizing radiation applied is of secondary consideration.

The use of irradiation alone as a preservation technique will not solve all the problems of post-harvest food losses, but it can play an important role in cutting losses and reducing the dependence on chemical pesticides.

Why are countries interested?

Interest in the irradiation process is increasing because of persistently high food losses from infestation, contamination, and spoilage; mounting concerns over food-borne diseases; and growing international trade in food products that must meet strict import standards of quality and quarantine, all areas in which food irradiation has demonstrated practical benefits when integrated within an established system for the safe handling and distribution of food. In addition, with increasingly restricted regulations or complete prohibition on the use of a number of chemical fumigants for insect and microbial control in food, irradiation is an effective alternative to protect food against insect damage and as a quarantine treatment of fresh produce.

The FAO has estimated that worldwide about 25% of all food production is lost to insects, bacteria and rodents after harvesting. The use of irradiation alone as a preservation technique will not solve all the problems of post-harvest food losses, but it can play an important role in cutting losses and reducing the dependence on chemical pesticides. Many countries lose vast amounts of grain because of insect infestation and moulds. For roots and tubers, sprouting is the major cause of losses. Several countries, including Bangladesh, Chile, China, Hungary, Japan, Republic of Korea and Thailand are irradiating one or more food products (grains, potatoes, spices, dried fish, onions, garlic, etc.) to control food losses on a commercial basis.

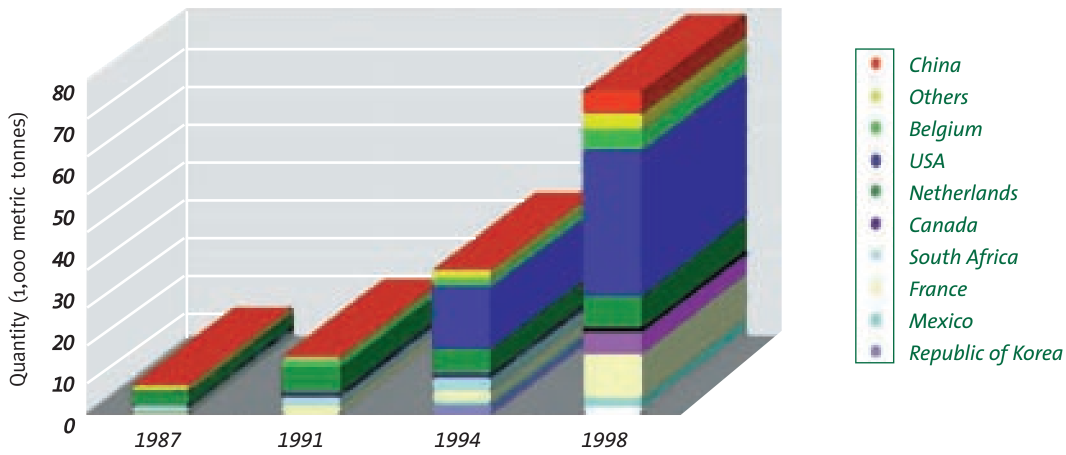
Foodborne diseases pose a widespread threat to human health and they are an important cause of reduced economic productivity even in advanced countries which have modern food processing and distribution systems. Although the amount of foodborne disease caused by pathogenic bacteria in the United States is not known with accuracy, it was estimated in 1994 by a task force of the Council for Agricultural Science and Technology (CAST) that the number of cases likely range from 6.5 million to 33 million annually and that deaths may be as high as 9,000 annually. The United States Department of Agriculture's (USDA) Economic

Research Service estimates that diseases caused by *E. coli* O157:H7 due to consumption of insufficiently cooked ground beef result in US $200 million to $440 million in annual medical costs and productivity losses. In developing countries, diseases caused by parasites such as *Taenia solium* and *Trichinella spiralis* constitute a major problem, and together with bacterial foodborne diseases, account for hundreds of millions of cases per year.

The relatively low doses of radiation needed to destroy certain bacteria in food can be useful in controlling foodborne disease. Considerable amounts of frozen seafoods and frog legs, as well as dry food ingredients, are irradiated for this purpose in Belgium, France and the Netherlands. Electron beam irradiation of blocks of frozen mechanically deboned, poultry meat is carried out industrially in France. Spices are being irradiated (instead of being fumigated) in many countries including Argentina, Belgium, Brazil, Canada, China, Denmark, Finland, France, Hungary, Indonesia, Israel, Mexico, the Netherlands, Norway, Republic of Korea, South Africa, the United Kingdom and the USA. The volume of irradiated spices and dried vegetable seasonings globally has increased significantly in recent years to over 60,000 tonnes in 1997.

Trade in food products is a major factor in regional and international commerce, and markets are growing. The inability of countries to satisfy each other's quarantine and public health regulations is a major barrier to trade. For example, not all countries allow importation of chemically-treated fruit. Moreover, major importing countries, including

Estimated quantities of irradiated spices and dried vegetable seasonings



Irradiation can expand widely trade in fresh fruits and vegetables

the USA and Japan, have banned the use of and the import of produce treated with certain fumigants identified as health hazards. During 1996, the United States Department of Agriculture (USDA) issued a new policy to allow importation of fresh fruits and vegetables treated by radiation against fruit flies. The problem is most acute for developing countries whose economies are still largely based on food and agricultural production and the revenues from export. Radiation processing offers these countries an alternative to fumigation and some other treatments.

How much food is being commercially irradiated?

Each year a few hundred thousand tonnes of food products and ingredients are irradiated worldwide. This amount is small in comparison to the total volumes of processed foods and not many of these irradiated food products enter international commerce.

One factor influencing the speed with which food irradiation is being adopted is public understanding and acceptance of the process. Contrary to earlier estimates it has been demonstrated that when irradiated foods are available, consumers have purchased them because of their satisfaction with product quality and safety. It is normal to seek reassurance as to the safety and effectiveness of any new process or technology. Therefore, it is hoped that this revised publication will help address concerns and correct myths about food irradiation.

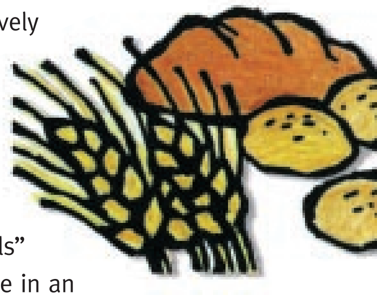
Scientific and Technical Terms

The type of radiation used in processing materials is limited to radiations from high energy gamma rays, X-rays and accelerated electrons. These radiations are also referred to as **ionizing radiations** because their energy is high enough to dislodge electrons from atoms and molecules and to convert them to electrically-charged particles called ions.

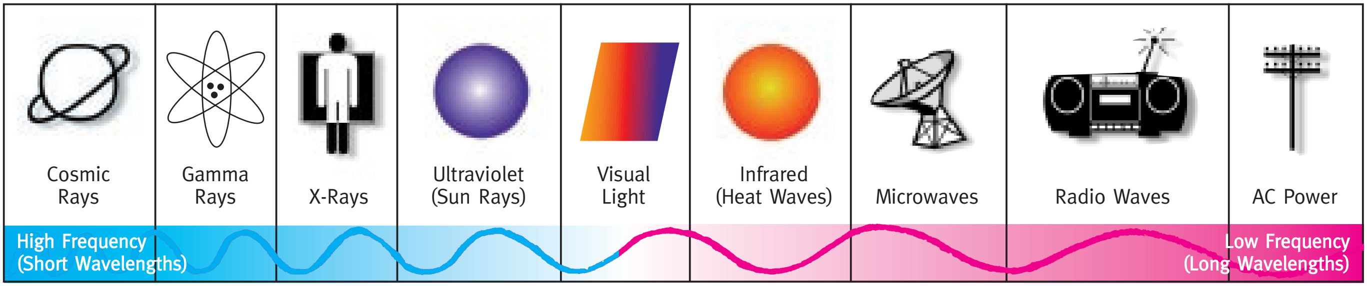
Gamma rays and **X-rays**, like radiowaves, microwaves, ultraviolet and visible light rays, form part of the electro-magnetic spectrum and occur in the short-wavelength, high-energy region of the spectrum and have the greatest penetrating power. They have the same properties and effects on materials, their origin being the main difference between them. X-rays with varying energies are generated by machines. Gamma rays with specific energies come from the spontaneous disintegration of radionuclides.

Naturally occurring and man-made **radionuclides**, also called **radioactive isotopes** or **radioisotopes**, emit radiation as they spontaneously revert to a stable state. The time taken by a radionuclide to decay to half the level of **radioactivity** originally present is known as its **half-life**, and is specific for each radionuclide of a particular element. The **becquerel** (Bq) is the unit of radioactivity and equals one disintegration per second.

Only certain radiation sources can be used in food irradiation. These are the radionuclides **cobalt-60** or **cesium-137**; X-ray machines having a maximum energy of five million electron volts (MeV) (an electron volt is the amount of energy gained by an electron when it is accelerated by a potential of one volt in a vacuum); or **electron accelerators** having a maximum energy of 10 MeV. Energies from these radiation sources are too low to induce radioactivity in any material, including food.



The radionuclide used almost exclusively for the irradiation of food by gamma rays is **cobalt-60**. It is produced by neutron bombardment in a nuclear reactor of the metal cobalt-59, then doubly encapsulated in stainless steel "pencils" to prevent any leakage during its use in an irradiator. Cobalt-60 has a half-life of 5.3 years, the gamma rays produced are highly penetrating and can be used to treat full boxes of fresh or frozen food. **Cesium-137** is the only other gamma-emitting radionuclide suitable for industrial processing of materials. It can be obtained by reprocessing spent, or used, nuclear fuel elements and has a half-life of 30 years. However, there is no supply of commercial quantities of cesium-137. Cobalt-60 has therefore become the choice for gamma radiation source; over 80% of the cobalt-60 available in the world market is produced in Canada. Other producers are the Russian



Electromagnetic spectrum

Federation, the People's Republic of China, India and South Africa.

High energy electron beams can be produced from machines capable of accelerating electrons to near the speed of light by means of a linear accelerator. Since electrons cannot penetrate very far into food, compared with gamma radiation or X-rays, they can be used only for treatment of thin packages of food and free flowing or falling grains. **X-rays** of various energies are produced when a beam of accelerated electrons bombards a metallic target. Although X-rays have good penetrability into food, the efficiency of conversion from electrons to X-rays is generally less than 10%, and this has hindered the use of this type of radiation source so far.

Radiation dose is the quantity of radiation energy absorbed by the food as it passes through the radiation field during processing. It is measured using a unit called the **Gray** (Gy). In early work the unit was the rad (1 Gy = 100 rads; 1 kGy = 1000 Gy). International health and safety authorities have endorsed the safety of irradiation for all foods up to a dose level of 10,000 Gy (10 kGy). Recent evaluation of an international expert study group appointed by FAO, IAEA and WHO showed that food treated according to good manufacturing practices (GMPs) at any dose above 10 kGy is also safe for consumption, making irradiation parallel to heat treatment of food. In terms of energy relationships, one gray equals one joule of energy absorbed per kilogram of food being irradiated. The maximum dose of 10 kGy recommended by the Codex General Standard for Irradiated Foods is equivalent to the heat energy required to increase the temperature of water by 2.4°C. Irradiation is often referred to as a "cold pasteurization" process as it can accomplish the same objective as thermal pasteurization of liquid foods, for example milk, without any substantial increase in product temperature.

Table Units of Radiation Dose and Radioactivity

	Absorbed dose	Radioactivity
Unit	gray (Gy)	becquerel (Bq)
Definition	1 Gy = 1 J/kg	1 Bq = 1 disintegration/sec
Former unit	rad	curie (Ci)
Conversion	1 rad = 0.01 Gy	1 Ci = 3.7 X 10^{10}Bq = 37 GBq
	1 krad = 10 Gy	1 kCi = 37 TBq
	1 Mrad = 10 kGy	1 mCi = 37 PBq

Benefits of food irradiation

What are the benefits which can be gained from irradiating food?

Finding ways to prevent the deterioration of food and control infection by microorganisms has been a major pre-occupation of man over the centuries. Controls such as refrigeration or pasteurization are now commonplace, and it is expected that one day the technique of food irradiation will also be widely used. Food irradiation can offer a wide range of benefits to food industry and the consumer. From a practical point of view, there are three general application and dose categories that are referred to when foods are treated with ionizing radiation:

Low-dose irradiation – up to ≈ 1 kGy (sprout inhibition; delay of ripening; insect disinfestation; parasite inactivation).

Medium-dose irradiation – 1 to 10 kGy (reduction in numbers of spoilage microorganisms; reduction in numbers or elimination of non-spore-forming pathogens, *i.e.* disease causing microorganisms).

High-dose irradiation – above 10 kGy (reduction in numbers of microorganisms to the point of sterility).

Perhaps the most important application of this method of food preservation is to ensure the hygienic quality of solid or semi-solid foods, especially those of animal origin, through inactivation of foodborne pathogens. This application is comparable to thermal pasteurization of liquid foods, for example milk, which is effective and widely applied but is unsuitable for foods such as poultry, meat and seafood that are to be marketed in raw form.

Reduction of pathogenic microorganisms

The incidence of foodborne disease arising from the consumption of food contaminated with pathogenic micro-organisms is increasing, and there is a heightened public awareness of the health threat posed by pathogens in or on food. Among these, *Escherichia coli* O157:H7, *Salmonella, Campylobacter jejuni, Listeria monocytogenes*, and *Vibrio* are of primary concern from a public health standpoint because of the severity of the illnesses and/or because of the higher number of outbreaks and individual cases of foodborne illness associated with these pathogens. Of these food poisoning bacteria, *Salmonella* and *C. jejuni* are usually associated with poultry. E. coli O157:H7 has also been linked to major foodborne disease outbreaks through many sources including meat and dairy products in the United Kingdom, hamburger meat, apple juice and water in the USA, and vegetables in Japan. *Listeria*

Irradiation is a unique method to ensure microbial safety in raw foods.

monocytogenes has been associated with dairy products, processed meats and other foods having a relatively long shelf-life under refrigeration. *Vibrio* spp. in turn have been the causitive agents in world cholera pandemics and of many outbreaks of disease caused by consumption of raw mollusks.

Adherence to good manufacturing practice (GMP) is obviously essential but this alone may not be sufficient to reduce the number of food poisoning outbreaks. Pathogens such as those mentioned previously are sensitive to low levels of ionising radiation. As the irradiation dose increases more microorganisms are affected but a higher dose, although not creating any harmful products, may simultaneously introduce changes in sensory qualities and therefore a balance must be attained between the optimum dose required to achieve a desired objective and that which will minimise any sensory changes. This is also the case for thermal-pasteurization – following his research on spoilage in wine, Louis Pasteur recommended a level of heat treatment that was sufficient to inactivate spoilage microorganisms but not high enough to destroy the quality or character of the products processed. He therefore determined the minimum processing required to attain the desired objective without impairing the product's overall acceptability.

With fresh poultry carcasses, irradiation up to a dose of 2.5 kGy will virtually eliminate *Salmonella* and *Campylobacter* under proper production conditions. The same dose of irradiation destroys E. coli O157:H7, a highly virulent bacteria which can lead to illness and death, and which is estimated to cause 20,000 infections and 250 deaths in the USA annually. Irradiation is currently the only known method to inactivate these pathogens in raw and frozen food.

Frog legs can be heavily contaminated by *Salmonella* and other pathogens, and irradiation provides an effective means of decontamination. French importers have routinely irradiated this product for a number of years, and irradiated frozen frog legs can be purchased in most French food markets. Eggs and egg products are often contaminated with *Salmonella* and have been the subject of many food irradiation studies. Early work in the United Kingdom showed that frozen egg and dried egg could be irradiated at doses of up to 5 kGy without quality loss and that this dose provided sufficient hygienic protection. More recent work suggests 2 kGy as the most suitable dose for inactivation of *Salmonella* in egg powder; at the same time preserving the sensory and technological properties.

Seafood, especially shellfish, is often contaminated with pathogenic organisms such as *Salmonella, Vibrio parahaemolyticus,* and *Shigella*. Consumption of raw and inadequately cooked shellfish is considered to present unacceptable risk factors. Nevertheless, many people do eat raw shellfish such as oysters and clams. In frozen shrimp, reduction of pathogens to a safe level requires a dose of about 3 kGy for inactivating Vibrio spp., *Salmonella* spp. and *Aeromonas hydrophila*.

It is well known in some countries that fresh pork meat must be cooked thoroughly because it may contain *Trichinella spiralis*, a parasite which may cause illness and death. The larvae of this parasite can be rendered non-infective by irradiation with a minimum dose of 0.3 kGy. Pork treated in this manner is known as "trichina-safe". Another pork parasite *Toxoplasma gondii* can also be inactivated with a minimum dose of 0.5 kGy.

Decontamination

Spices, herbs and vegetable seasonings are valued for their distinctive flavours, colours and aromas. However, they are often heavily contaminated with microorganisms because of the environmental and processing conditions under which they are produced. Therefore, before they can be safely incorporated into other food products, the microbial load should be reduced. Because heat treatment can cause significant loss of flavour and aroma, a "cold process", such as irradiation, is ideal. Until recently, most spices and herbs were fumigated, usually with sterilizing gases such as ethylene oxide to destroy

Irradiation is an effective residue free method for microbial decontamination of spices

contaminating microorganisms. However, the use of ethylene oxide was prohibited by an European Union (EU) directive in 1991 and has been banned in a number of other countries because it is a carcinogen. Irradiation has since emerged as a viable alternative and its use results in cleaner, better quality herbs and spices compared to those fumigated with ethylene oxide. Irradiation of spices on a commercial scale is practised in over 20 countries and global production has increased significantly from about 5,000 tonnes in 1990 to over 60,000 tonnes in 1997. In the USA alone over 30,000 tonnes of spices, herbs and dry ingredients were irradiated in 1997 as compared to 4,500 tonnes in 1993.

Extension of shelf-life

The shelf-life of many fruits and vegetables, meat, poultry, fish and seafood can be considerably prolonged by treatment with combinations of low-dose irradiation and refrigeration that do not alter flavour or texture. Many

Shelf-life of strawberries can be extended by irradiation

spoilage microorganisms, such as *Pseudomonas* spp., are relatively sensitive to irradiation. For example, a dose of 2.5 kGy applied to fresh poultry carcasses processed according to good manufacturing practices (GMPs) will be enough to eliminate *Salmonella*, and will also kill many, but not all, spoilage bacteria. This will double meat shelf-life, provided it is kept below 5°C.

Extension of the very short shelf-life of many commercially important plant commodities is highly desirable, and in some cases, critical. Exposure to a low dose of radiation can slow down the ripening of some fruits, control fungal rot in some others and maturation in certain vegetables, thereby extending their shelf-life. For example, ripening in bananas, mangoes,and papayas can be delayed by irradiation at 0.25 to 1 kGy. Strawberries are frequently spoiled by *Botrytis* mould. Treatment with a dose of 2 to 3 kGy followed by storage at 10°C can result in a shelf-life of up to 14 days, but the extension obtained depends on the initial quality of the fresh food, which should be as good as possible. Irradiation of mushrooms at 2 to 3 kGy inhibits cap opening and stem elongation. Shelf-life extension can be increased at least two-fold by irradiation and subsequent storage at 10°C, and even longer when stored at a lower temperature compared with non-irradiated mushrooms.

Not all fruits and vegetables are suitable for irradiation because undesirable changes in colour or texture, or both, limit their acceptability. Also, different varieties of the same fruit or vegetable may respond differently to irradiation. The time of harvest and the physiological state also affects the response of fruits and vegetables to irradiation. For example, if strawberries are irradiated before they are ripe, the red colour does not develop satisfactorily. For delaying ripening in fruits it is important to irradiate them before ripening starts.

At high doses of irradiation (>25 kGy), foods which are pre-heated to inactivate enzymes can be commercially sterilized such as occurs in canning. The sterilized products can be stored at room temperature almost indefinitely. Radiation-sterilized foods are given to hospital patients who have immune system deficiencies and must therefore have a sterile diet. Irradiation sterilized products are also eaten by astronauts in the NASA space shuttle programme because of their superior quality, safety and variety, in preference to foods treated by other preservation techniques. Limited commercial-scale sterilization of various ready-to-eat foods by high dose irradiation has been carried out in South Africa during the past 10 years to serve military personnel and outdoor enthusiasts such as campers, yachters and hikers. In total, more than two million light weight food packs (weighing 150 g each) have been produced during this period.

Disinfestation

The chief problem encountered in preservation of grains and grain products is insect infestation. Most of the pests of concern, e.g. beetles, moths, weevils and others, are not quarantine insects, but they cause extensive damage to stored products. Irradiation has been shown to be an effective pest control method for these commodities and a good alternative to methyl bromide, the most widely used fumigant for insect control, which is being phased out globally because of its ozone depleting properties. Unlike methyl bromide, irradiation is not an ozone depleting substance and unlike phosphine, the other major fumigant used to control grain pests, irradiation is a fast treatment and its efficacy is not temperature dependent. Irradiation can kill or control phosphine-resistant pests. The dosage required for insect control is reasonably low, in the order of 1 kGy or less. Disinfestation is aimed at preventing losses caused by insects in stored grains, pulses, flour, cereals, coffee beans, dried fruits, dried nuts, and other dried food products including dried fish. Proper packaging is required, however, for irradiated products to prevent insect reinfestation.

Radiation disinfestation can facilitate trade in fresh fruits, such as citrus, mangoes, and papayas which often harbour insect pests of quarantine importance. Insects are easily

Irradiation is an effective alternative to fumigation for insect control

distributed by international trade in such fruits and also by tourism. To prevent or minimize this risk, many countries prohibit importation of such fruits or require quarantine treatment of imported fruits. These measures can create significant barriers to international trade and the free flow of plants and plant products, but they are fully justified from the receiving country's point of view. The occurrence of fruit flies, such as the Mediterranean, Oriental, Mexican or Caribbean fruit flies, has repeatedly disrupted trade among countries and between states within large countries, for example Australia and the USA. A number of quarantine treatments permitted in the past have recently been banned, fumigation with ethylene dibromide being the most prominent example. It has been demonstrated that low dosages of ionizing radiation, between 0.15 and 0.3 kGy, will very effectively control fruit fly and other insect problems. This makes the use of irradiation for quarantine treatment a very practical possibility. In 1996, the United

Sprouting losses in stored potatoes can be prevented by irradiation

States Department of Agriculture (USDA)/Animal and Plant Health Inspection Service (APHIS) issued a Notice of Policy accepting irradiation as a quarantine treatment against major species of fruit fly regardless of commodities. Subsequently, in 1997 a final rule was issued by the USDA/APHIS for the irradiation of papayas, carambola, and litchi as a phytosanitary treatment. The rule allows interstate movement of these commodities from Hawaii to the USA mainland and permits treatment either in Hawaii or in non-fruit fly supporting areas of the mainland USA. Small commercial scale irradiation of fruits from Hawaii has been carried out under special permission of the USDA/APHIS since 1995. Such irradiated fruits have been marketed successfully in the USA.

Inhibition of sprouting

In order to provide consumers with a year-round supply of potato tubers, onion bulbs, yams and other sprouting plant foods, storage over many months is necessary unless shipments from other climatic zones, usually at a much higher price, can replace local production during off-season. Such long-term storage is possible with the aid of refrigeration, which is costly, particularly in subtropical and tropical regions. For many of these crops, the desired inhibitory effects can also be obtained using chemical sprout inhibitors such as maleic hydrazide, propham, or chloropropham. These chemicals, however, are either not effective under tropical conditions or leave residues in the produce, and for health reasons they are considered by some to be harmful. Thus many countries have prohibited their use.

A very low radiation dose of 0.15 kGy or less, inhibits sprouting of products such as potatoes, yams, onions, garlic, ginger, and chestnuts. It leaves no residues and allows storage at higher temperatures. Irradiation of potatoes, stored at higher temperatures (10°-15°C), have better processing quality. Commercial processing of irradiated potatoes has been carried out in Japan since 1973.

But can irradiation be used to make spoiled food good or to clean up "dirty" food?

NO. Neither irradiation nor any other food treatment can reverse the spoilage process and make bad food good. If food already looks, tastes or smells bad – signs of spoilage – before irradiation, it cannot be "saved" by any treatment including irradiation. While irradiation can reduce or eliminate spoilage bacteria or pathogenic microorganisms which may be present in a spoiled food, it cannot improve its sensory properties – the bad appearance, taste or smell will remain.

Treatments such as heat pasteurization, chemical fumigation, and irradiation, however, are effective in destroying or suppressing microbial contamination of food. Heat pasteurization and fumigation have been effectively used in this way for decades to "clean up" foods, specifically to destroy pathogenic microorganisms in milk and other liquid products, and to destroy spoilage microflora or microorganisms and insects in spices and dry foods. These treatments are done intentionally for public health reasons; for example, to destroy microorganisms such as *Salmonella*, *Shigella,* and *Campylobacter* that are associated with food-borne diseases. Irradiation is especially effective as a control measure for pathogenic microorganisms transmitted through solid food, especially foods of animal origin even when in the frozen state.

Food processes such as heating, freezing, chemical treatment, and irradiation are not intended to serve as substitutes for good hygienic practice. Both at the national and international levels, good manufacturing practices (GMPs) govern the handling of specific foods and food products. They must be followed in the preparation of food, whether the food is intended for further processing by irradiation or any other means. An additional step in the further processing of food, such as irradiation, requires a stricter adherence to GMP so that the products reach the final stages at the highest possible quality level.

But is the use of this technology really necessary?

A similar question was asked of pasteurization when it was first proposed as a means of improving the safety of milk. Pasteurized milk was demonstrated to be safe, practical and fit for the needs of most urban consumers. It was very similar in taste and colour to fresh milk and required no change in consumption or cooking habits. However, the pasteurization of milk did not become a commercial reality for many years after its introduction in the early 1900s. A similar situation has arisen with irradiated food. Although the safety and benefits of food irradiation have been thoroughly documented, the commercial application of the process has been hindered due to some misconception by the general public on its safety and the conservative position of the food industry.

Other processes such as chemical and heat treatments can also kill insects, moulds and microorganisms, including pathogens in food. However, chemicals can leave residues, and heating food, such as canning, changes its texture, colour and flavour and converts it into a cooked product. Irradiation, on the other hand, achieves its effects without significantly raising the temperature of the food, leaving it closer to the unprocessed state. Unlike the fumigants used for disinfestation and quarantine purposes, for example ethylene oxide and methyl bromide, irradiation does not leave residues in the food and is safer to use. Irradiation is unique, however, in its ability to inactivate pathogenic microorganisms, such as *Salmonella, E. coli* O157:H7 and *Campylobacter*, in food in the frozen state, particularly in food of animal origin.

Food irradiation has an important role to play in the production of safe, wholesome food just as heat-pasteurization has. At a time when the number of food poisoning outbreaks is on the increase, when fumigants are being phased out, and the consumer is looking for safer, higher quality foods, the overwhelming benefits of food irradiation cannot be overlooked. Irradiation helps to ensure a safer and more plentiful food supply by extending shelf-life and controlling pests and pathogens in food. Most importantly, it is a safe process.

Food Irradiation Applications

Benefit	Dose (kGy)	Products
Low-dose (up to 1 kGy)		
(i) Inhibition of sprouting	0.05 - 0.15	Potatoes, onions, garlic, root ginger, yam etc.
(ii) Insect disinfestation and parasite disinfection	0.15 - 0.5	Cereals and pulses, fresh and dried fruits, dried fish and meat, fresh pork, etc.
(iii) Delay of physiological processes (e.g. ripening)	0.25 - 1.0	Fresh fruits and vegetables.
Medium-dose (1-10 kGy)		
(i) Extension of shelf-life	1.0 - 3.0	Fresh fish, strawberries, mushrooms etc.
(ii) Elimination of spoilage and pathogenic microorganisms	1.0 - 7.0	Fresh and frozen seafood, raw or frozen poultry and meat, etc.
(iii) Improving technological properties of food	2.0 - 7.0	Grapes (increasing juice yield), dehydrated vegetables (reduced cooking time), etc.
High-dose (10-50 kGy)		
(i) Industrial sterilization (in combination with mild heat)	30 - 50	Meat, poultry, seafood, prepared foods, sterilized hospital diets.
(ii)Decontamination of certain food additives and ingredients	10 - 50	Spices, enzyme preparations, natural gum, etc

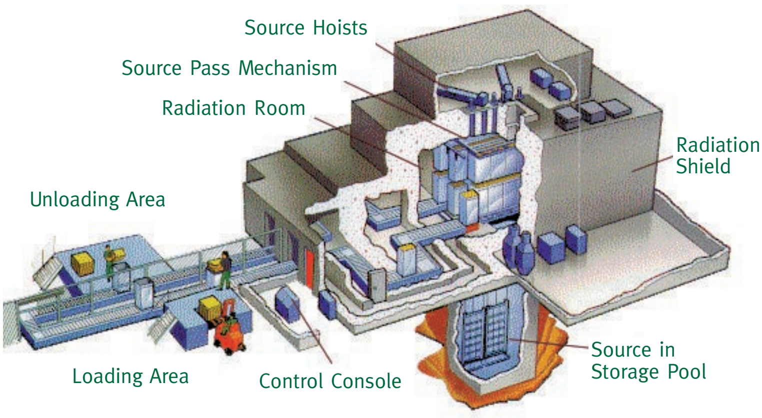
Food Irradiation Facilities

What are the main features of a food irradiation facility?

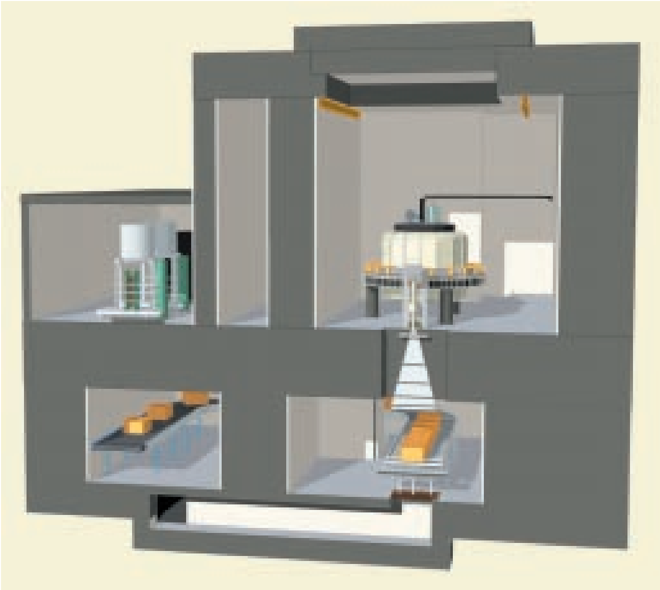
Industrial food irradiation facilities must be licensed, regulated and inspected by national radiological safety and health authorities, many of whom base their rules upon irradiation standards and codes of practice jointly established by the IAEA, FAO and WHO. The common features of all commercial irradiation facilities are the irradiation room and a system to transport the food into and out of the room. The major structural difference between this type of plant and any other industrial building is the concrete shielding (1.5 – 1.8 metres thick) surrounding the irradiation room, which ensures that ionising radiation does not escape to the outside of the room.

In the case of a gamma irradiator, the radionuclide source continuously emits radiation and when not being used to treat food must be stored in a water pool (usually 6 metres in depth). Known as one of the best shields against radiation energy, water absorbs the radiation energy and protects workers from exposure if they must enter the room. In contrast to gamma irradiators, machines producing high-energy electrons operate on electricity and can be switched off.

The transport system employed in a large food irradiation facility is similar to that used for sterilization of medical products and can be either a conveyor or a rail system. In a gamma irradiator, the size of the containers in which the food is moved through the irradiation chamber can vary and pallets up to 1 m^3 may be used. On the other hand, with machines, the bulk or thickness of a product which can be treated is much less and hence there is a fundamental design difference between the two types of irradiator.



Gamma Irradiator for food processing



Electron beam irradiator for food processing

How can we be sure that foods are properly treated in irradiation facilities?

Over the past 30 years, laws and regulations have been promulgated to govern operations at industrial irradiators used to process non-food products, such as medical supplies. About 170 such irradiators are operating around the world. The plants, which must be approved by governmental authorities before construction, are subject to regular inspections, audits, and other reviews to ensure that they are safely and properly operated. These types of governmental controls would also be valid for irradiation facilities processing food. For example, the principle of lot traceability is an essential part of process controls, whether the product is a pharmaceutical or a fruit, and irrespective of the technology involved.

At the international level, provisional guidelines for good manufacturing practices (GMPs) and good irradiation practices for a number of foods have been issued by the International Consultative Group on Food Irradiation (ICGFI). They cover all aspects of treatment, handling, and distribution. These guidelines provide a good basis for preparing the detailed protocols needed to implement irradiation on a commercial scale. Some of the guidelines have converted to standards of the American Society for Testing and Materials (ASTM).

The guidelines emphasise that, as with all food technologies, effective quality control systems need to be installed and adequately monitored at critical control points at the irradiation facility. Foods should be handled, stored, and transported according to good manufacturing practices (GMPs) before, during, and after irradiation. Only high-quality food should be accepted for irradiation.

The Codex Alimentarius Commission of FAO and WHO adopted in 1983 a Codex General Standard for Irradiated Foods, and an associated International Code of Practice for the Operation of Radiation Facilities Used for the Treatment of Foods. These standards state that irradiated foods should be accompanied by shipping documents identifying the irradiator, date of treatment, lot identification, dose, and other details of treatment. ICGFI additionally has established an international registry of irradiators that meet standards for good operations. It also organizes training courses for irradiator operators, plant managers, and supervisors on proper processing, with emphasis on GMPs, dosimetry, record-keeping, and lot identification, and for food control officials on proper inspection procedures required for food irradiation processing and trade in irradiated foods.

Do workers at irradiation facilities face dangers from long-term or accidental exposure to radiation?

Any industrial activity includes certain risks to human beings and the environment. One of the risks at irradiation facilities is associated with the potential hazard of accidental exposure to ionizing radiation. Irradiators are designed with several levels of redundant protection to detect equipment malfunction and to protect personnel from accidental radiation exposure. Under normal operating conditions, all exposures of workers to radiation are prevented because the radiation source is shielded. Potentially hazardous areas are monitored and a system of interlocks prevents unauthorized entry into the radiation room while products are being irradiated. Worker safety further rests upon strict operating procedures and proper training. All radiation plants must be licensed. In most countries, regulations require periodic inspection of facilities to ensure compliance with the terms of operating licenses. In the United Kingdom, the Health and Safety Executive has reported to a parliamentary committee that personnel working in the country's 10 irradiation facilities face no unusual

Processing of food by irradiation can be safely monitored and controlled

dangers: "...the risk is kept under effective control by the use of sophisticated safety control systems. The plants are constructed with very heavy radiation shielding and thus the process presents no risk to the general public. We do not expect that the legalisation of foodstuffs irradiation will present any novel health and safety issues within our area of interest".

Have there been any major accidents at industrial irradiation facilities?

Over the past 30 years, there have been a few major accidents at industrial irradiation facilities that caused injury or death to workers because of accidental exposure to a lethal dose of radiation. All of the accidents happened because safety systems had been deliberately bypassed and proper control procedures had not been followed. None of these accidents endangered public health and environmental safety.

In most cases, reports of "accidents" have actually turned out to be operational incidents. Such incidents have caused the irradiator to be shut down but they did not harm anyone or pose a risk to the environment. The distinction between accidents and incidents is used by authorities responsible for safety in all industries. This is the case for many other food technologies, such as canning, fumigation and the agro-chemical industry, which are also potentially hazardous to workers. At irradiation facilities, controls and formal protocols are strictly required to prevent accidents.

The radiation processing industry is considered to have a very good safety record. Today there are about 170 industrial gamma irradiation facilities operating world-wide, a number of which process food in addition to other types of products. Most irradiation facilities are used for sterilizing disposable medical and pharmaceutical supplies, and for processing other non-food items. Facilities are constructed to standard designs with multiple safeguards to protect worker health and safeguard the community should a natural disaster such as an earthquake or tornado occur.

More radioactive materials will need to be transported if more food irradiators are built. What steps have been taken to minimize the danger of radioactive spills from transport accidents?

Radioactive materials required for irradiators is transported in lead-shielded steel casks. These casks meet national and international standards modelled upon the Regulations for Safe Transport of Radioactive Materials of the International Atomic Energy Agency (IAEA) and are designed to withstand the most severe accidents, including collisions, punctures, and exposure to fire and water depths. Large quantities of radioactive material are safely shipped all over the world to supply some 170 irradiators processing a variety of goods, mainly medical products such as syringes, physician gloves, sutures, and hospital gowns. From 1955 to date, Canada has shipped approximately 480 million curies of cobalt-60 without any radiation hazard to the environment or release of radioactive materials. Over the same period, approximately one million shipments of radioisotopes for industrial, hospital, and research use were made in North America without radiation accidents. This excellent safety record far exceeds that of other industries shipping hazardous materials such as toxic chemicals, crude oil, or gasoline. The same procedures used so successfully and safely to transport radioactive materials to existing irradiators will of course be used for transporting radioactive materials to any additional irradiators constructed for food processing.

Can an accident at a gamma irradiation facility lead to "meltdown" of the irradiator and release of radioactivity that would contaminate the environment and endanger people living nearby?

It is impossible for a "meltdown" to occur in a gamma irradiator or for the radiation source to explode. The source of radiation energy used at irradiators cannot produce neutrons which can make materials radioactive, so no nuclear "chain reaction" can occur at an irradiator. The walls of the irradiation cell through which the food passes, the machinery inside the cell, and the product being processed cannot become radioactive. No radioactivity is released into the environment.

Do gamma irradiators have radioactive waste disposal problems?

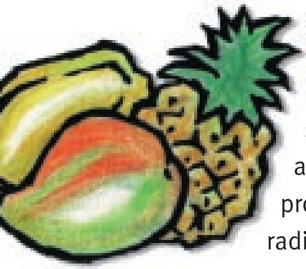
It is a misconception that the existence of gamma irradiation facilities will lead to a growing accumulation of radioactive waste material. At gamma irradiators, radionuclide sources, typically cobalt-60 or cesium-137, are used as the sources of radiation energy. These elements decay over time to non-radioactive nickel and non-radioactive barium, respectively. The sources are removed from the irradiator when the radioactivity falls to a low level, usually between 6% and 12% of the initial level (this takes 16 to 21 years for cobalt-60). The elements are then returned in a shipping container to the supplier who has the option of reactivating them in a nuclear reactor or storing them. It has been estimated that when the useful life of the cobalt-60 is finally over, all the used cobalt-60 produced in North America could be stored in a space of about 1.25 cubic metres, which is roughly equivalent to the size of a small office desk.

Basically, the same procedures are followed when an irradiation plant closes down. The sources can be acquired by another user or returned to the supplier, the machinery dismantled, and the building used for other purposes. There is no radiation hazard for the new occupants or the general public.

Safety of Irradiated Food

Does the irradiation process make food radioactive?

NO. Irradiation does not make food radioactive. Everything in our environment, including food, contains trace amounts of radioactivity. This means that this trace amount (about 150 to 200 becquerels/kg) of natural radioactivity from elements such as potassium is unavoidable in our daily diets. In countries where food irradiation is permitted, both the sources of radiation and their energy levels are regulated and controlled. The irradiation process involves passing the food through a radiation field at a set speed to control the amount of energy or dose absorbed by the food. The food itself never comes into direct contact with the radiation source. The maximum allowable energies for electrons and X-rays from the two machine-generated sources of radiation that can be used, are 10 million electron volts (MeV) and 5 MeV, respectively. Even when foods are exposed to very high doses of radiation from these sources, the maximum level of radioactivity would be just one-thousandth of a becquerel per kilogram of food. This is 200,000 times smaller than the level of radioactivity naturally present in food. Food undergoing irradiation does not become radioactive any more than luggage passing through an airport X-ray scanner or teeth that have been X-rayed.



Irradiation does not induce radioactivity in food just as fruit exposed to sun energy does not emit sunlight

What is the difference between the terms "irradiated food" and "radioactive food"?

Irradiated foods are those that have been deliberately processed with certain types of radiation energy to bring about some desirable properties (for example, to inhibit sprouting or to destroy food-poisoning bacteria). Apart from foodstuffs, many other materials are commercially irradiated during manufacturing. These include cosmetics, wine bottle corks, hospital supplies and medical products, and some types of food packaging. **Radioactive foods**, on the other hand, are those that have become accidentally contaminated by radioactive substances from weapons testing or nuclear reactor accidents. This type of contamination is totally unrelated to irradiated food which has been processed for preservation and other purposes.

Can irradiated food become toxic?

NO. Since the late 1940s irradiated foods were considered to require careful toxicological investigation before this process could be applied to food manufacturing. In actual fact it was firmly concluded by a study conducted in Germany as far back as 1926 that irradiation did not produce any toxic factors in animal diets. The standard procedure for this purpose was to feed the foodstuff to be tested to laboratory animals and look for possible effects of longevity, reproductive capacity, tumour incidence, and other indicators of the animals' health status.

Several hundred toxicological studies have been conducted on experimental animals over the past four decades. Many animal feeding tests including genetic studies of different types of irradiated food were carried out in many countries including China, Germany, India, Japan, Thailand, the United Kingdom and the USA in the past five decades. FAO, IAEA and WHO convened a number of Joint Expert Committees on the Wholesomeness of Irradiated Foods in 1964, 1969, 1976 and 1980 as data became available to evaluate the safey for consumption of irradiated foods. These evaluations together with those carried out independently by national expert groups in Denmark, France, the Netherlands, Japan, the United Kingdom and the USA demonstrated no toxic effects as a result of consuming irradiated food. Another expert committee

The wholesomeness of irradiated food is well established

evaluated for the WHO in 1992 all literature and data which had been available since 1980; as a consequence, the previous findings were reconfirmed. During September 1997 a study group meeting was organised jointly by the WHO, FAO and IAEA to evaluate the wholesomeness of food treated by high dose irradiation. This group of experts concluded that doses greater than 10 kGy "will not lead to changes in the composition of the food that, from a toxicological point of view, would have an adverse effect on human health".

Among the many extensive animal feeding studies of irradiated food, those conducted at the Raltech Laboratory, USA, are generally acknowledged to be among the best and most statistically powerful of all. The studies involved using chicken irradiated either by a cobalt-60 source or electron machine up to a dose of 58 kGy. Some 134 tonnes of chicken meat, or nearly a quarter of a million birds, were used in the study to compare high-dose irradiation with heat-sterilization of chicken. The study involved chronic feeding studies in mice and dogs, teratology studies and mutagenicity tests. The comprehensive results were reviewed by scientists of the United States Food and Drug Administration (FDA) at the time a petition for low dose irradiation of chicken was submitted in the mid-1980s. No adverse effects from consuming chicken processed with high doses of radiation were reported. The lack of treatment-related effects in the many well-conducted studies provides additional assurance that the consumption of irradiated food does not pose a hazard.

Other types of extensive feeding tests also have been done. Over the last 20 years millions of mice, rats, and other laboratory animals have been bred and reared exclusively on an irradiated diet. The diet, treated at doses between 25 and 50 kGy, has been fed to laboratory animals at many institutions involved in food, drug, and pharmaceutical research in Austria, Australia, Canada, France, Germany, Japan, Switzerland, the United Kingdom, and the USA. No transmittable genetic defects – teratogenic or oncogenic – have been observed which could be attributed to the consumption of irradiated diets.

Can eating irradiated food cause development of abnormal chromosomes?

NO. The issue of abnormal chromosomes as a result of eating irradiated food has been more sensationalised than any other. The claims focus on the incidence of "polyploidy", which is alleged to result from consumption of products made from wheat immediately after irradiation. Polyploidy means the occurrence of cells containing twice or more the number of chromosomes. Human cells normally have 46 chromosomes. If they are polyploid they could have 92 or even 138 chromosomes. The incidence of polyploid cells is naturally occurring and varies among individuals, and even in one individual from day to day. It can also vary from organ to organ within one individual. The biological significance of polyploidy is unknown. When undertaking studies on polyploidy, it is important that many thousands of cells are counted in order to see the effect of a treatment. As polyploid cells are rare, it is essential that enough cells are observed before any valid conclusions can be reached. It can also be extremely difficult to recognise polyploid cells; if normal (diploid) cells happen to be superimposed on the microscope slide they look very much like one polyploid cell.

Media reports have frequently cited results published in the mid-1970s by a group of scientists from the National Institute of Nutrition (NIN) in Hyderabad, India. This group of scientists reported increases in the frequency of polyploid cells in malnourished children, rats, mice and monkeys that they attributed to consumption of products made from wheat immediately after irradiation at 0.75 kGy. When the report is examined more closely, among other shortcomings, it is found that only 100 cells from each of the five children in each group were counted – an incredibly small sample upon which to base any conclusion. In addition, although the results in each group were averaged, there is no indication of the actual incidence in each child. No polyploidy at all was seen when wheat was irradiated and stored for 12 weeks before consumption.

A number of institutions in India and elsewhere have tried to reproduce the results found at NIN based on information made available to them. Some used absorbed radiation doses as high as 45 kGy. For example, a rat feeding study carried out at the Bhabha Atomic Research Centre (BARC) in Mumbai, with freshly irradiated wheat, in which the incidence of polyploidy was determined by counting 3,000 cells from each animal, showed no effect from consuming the irradiated wheat.

None of the studies carried out came up with results similar to those found at NIN. In order to investigate the reasons for the discrepancy between the results reported by the researchers in Hyderabad and Mumbai a committee of experts was appointed by the Indian government in October 1975 to review the findings. In 1976, the report of the Committee was very critical of the work of the Hyderbad authors and concluded that the available data failed to demonstrate any mutagenic potential of irradiated wheat. A number of national scientific committees and independent researchers in Australia, Canada, Denmark, France, the United Kingdom, and the USA also have evaluated the alleged incidence of polyploidy. They all concluded that the study was simply unacceptable and the reported data from NIN do not support the incidence of increased polyploidy.

Besides feeding tests using laboratory animals, have there been any human feeding studies of irradiated foods?

YES. In the early 1980s, eight feeding studies using several irradiated food items, including irradiated wheat, were conducted in China using human volunteers. More than 400 individuals consumed irradiated food under controlled conditions for 7 to 15 weeks. One focus of the research was the possibility of chromosomal changes. Seven of the eight experiments involved investigation of chromosomal aberrations in 382 individuals. No significant difference between the number of chromosomal aberrations in the control and test groups were discovered in any of the experiments. Incidence of polyploidy in those who consumed non-irradiated food and those who consumed irradiated samples were within normal range of the overall value of polyploid cells in participants.

Although not aimed at testing the safety of irradiated foods it is worth noting at this point that radiation-sterilized foods are used in the diet of severely ill patients. A number of hospitals in the USA and the United Kingdom used irradiated foods for patients who have to be kept in a completely sterile environment due to their susceptibility to bacterial or viral infections. Patients undergoing chemotherapy, or organ transplant patients who receive immunosuppressive medication may be fed only sterilized foods for weeks or even months. Supplementing heat-sterilized foods with radiation-sterilized items can provide more varied, more palatable, and more nutritious menus for these patients. Irradiated foods were fed to such patients at the Fred Hutchinson Cancer Research

"Radiolytic" products formed in irradiated foods are similar to products formed by cooking ("thermolytic products")

Center, Seattle, USA for several years during the mid 1970s with excellent results.

Are chemical changes in irradiated foods, such as the formation of "radiolytic" products, harmful?

The so-called "radiolytic" products produced in irradiated food have proven to be familiar ones, such as glucose, formic acid, acetaldehyde, and carbon dioxide, that are naturally present in foods or are formed by thermal processing (thermolytic products). The safety of these radiolytic products has been examined very critically, and no evidence of their harmfulness has been found.

The United States Food and Drug Administration (FDA) has estimated that the total amount of undetected radiolytic products that might be formed when food is irradiated at a dose of 1 kGy would be less than 3 milligrams per kilogram of food or less than 3 parts per million.

Do the "free radicals" which are produced during irradiation affect the safety of the food?

NO. The fact that irradiation causes the formation of free radicals – which in scientific terms are atoms or molecules with an unpaired electron – and that these are quite stable in dry foods has often been mentioned as a reason for special caution with irradiated dry foods. However, free radicals are also formed by other food treatments, such as toasting of bread, frying, and freeze drying, and during normal oxidation processes in food. They are generally very reactive, unstable structures, that continuously react with substances to form stable products. Free radicals disappear by reacting with each other in the presence of liquids, such as saliva in the mouth. Consequently, their ingestion does not create any toxicological or other harmful effects.

This has been confirmed by a long-term feeding study carried out a the Federal Research Centre for Nutrition in Karlsruhe, Germany. This study was especially designed to look for possible effects of a diet containing a high free radical concentration. Animals were fed a very dry milk powder irradiated with electrons at 45 kGy. No mutagenic effects were noted and no tumours were formed. Nine generations of rats were continually fed this diet without any indication of toxic effects. Similarly, a slice of toasted bread (non-irradiated), which actually contains more free radicals than very dry foods that have been irradiated, can be expected to be harmless.

Can irradiation of food increase the risk of botulism?

Under Good Manufacturing Practices (GMPs), irradiating food of animal origin to ensure its hygienic quality does not increase the risk from botulism any more than other "sub-sterilizing" food processes, such as pasteurization. It is true that bacterial spores such as those of *Clostridium botulinum* are resistant to most preservation treatments, including low doses of irradiation. However, these spores are usually present in relatively low numbers and, although they survive sub-sterilizing doses of irradiation, other microorganisms also survive irradiation can grow, cause spoilage and inhibit the growth of *Clostridium botulinum*. The survival of spores is therefore not considered to introduce any additional hazard in irradiated foods than in food subjected to other sub-sterilizing heat-treatments, for example, in pasteurized or cooked foods.

Food treated by irradiation or traditional pasteurization must be handled, packaged, and stored following good manufacturing practices (GMPs). Doing so prevents the growth and toxin production of *Clostridium botulinum*. Alternatively, high-dose irradiation (30-60 kGy) can be used to destroy any *Clostridium botulinum* spores present in the food.

Some types of clostridia cause more concern than others. *Clostridium botulinum* Type E, for example, is found at low levels in fish and seafood caught in some areas. It can grow and produce toxin even when the food is refrigerated at temperatures as low as 4° C. Thus, fish and seafood, including their products, treated by any of the sub-sterilizing processes, including irradiation, must be kept at 3° C or below at all times during marketing. Most other types of *Clostridium botulinum* cannot grow and produce toxin at temperatures below 10° C. Good manufacturing practices (GMPs) require that raw foods such as fish, meat, and chicken are stored at a specific temperature, whether irradiated or not, to prevent the growth of *Clostridium botulinum*. It has been concluded by various workers in this field of research that low-dose irradiation does not increase the risk from sporogenous bacteria. On the contrary, it has been emphasised that low-dose irradiation can increase the safety of foods.

Are foods in which microbial toxin or viruses are already present suitable for irradiation?

NO. Only foods of good hygienic quality should be irradiated. In this respect, irradiation does not differ from heat pasteurization, freezing, or other food processes. While these processes can destroy bacteria, they may not destroy preformed toxins and viruses already in the food. It is very important that foods intended for processing – by whatever method – are of good quality and handled and prepared according to GMPs established by national or international authorities. In some cases, strict regulations prohibit distribution of some foods. Many countries, for example, do not permit oysters to be harvested from areas known to be contaminated with raw sewage because of the danger of hepatitis viruses. No food processing methods should be used to substitute for GMPs in food production and handling.

Nutritional Quality of Irradiated Foods

Does irradiation adversely affect the nutritional value of food?

NO more so than any other methods of food processing and preservation used to achieve the same purpose. As irradiation is a 'cold process', that is, it does not substantially raise the temperature of the food being processed, nutrient losses are small and often significantly less than losses associated with other methods of preservation such as canning, drying and heat pasteurization. Much of the early work on irradiation examined foods treated at sterilizing doses, but since recent applications often use doses well below 10 kGy, a realistic evaluation of the nutritional adequacy of irradiated food should be based on results of experiments carried out using doses likely to be used in commercial practice. The change in nutritional value caused by irradiation depends on a number of factors. These include the irradiation dose to which the food has been exposed, the type of food, packaging, and processing conditions, such as temperature during irradiation and storage time.

Carbohydrates, proteins and fats are the main components of foods. These macronutrients provide energy and serve as building blocks for the growth and maintenance of the body. Extensive research has shown that carbohydrates, proteins, and fats, undergo little change during irradiation even at doses over 10 kGy. Similarly, the essential amino acids, minerals, trace elements and most vitamins do not suffer significant losses.

Different types of vitamins have varied sensitivity to irradiation and to some other food processing methods. The sensitivity of the vitamins to irradiation depends on the complexity of the food system and the solubility of the vitamins in water or fat. Irradiation of vitamins in pure solution results in considerable destruction of these compounds thus some reports in literature have over-estimated the losses. For example, vitamin B1 (thiamin) in aqueous solution showed 50% loss after irradiation at 0.5 kGy, while irradiation of dried whole egg at that dose caused less than 5% destruction of the same vitamin. This is due to the mutually protective action of various food constituents on each other. Vitamin losses can be minimized by irradiating the food in frozen form or by packaging it in an inert atmosphere such as under nitrogen.

Four vitamins are recognised as being highly sensitive to irradiation: B1, C (ascorbic acid), A (retinol) and E (α-tocopherol). However, B1 is even more sensitive to heat than to irradiation. It has been demonstrated that pork and beef sterilized by irradiation retain much more vitamin B1 than canned meat sterilized thermally.

Seemingly conflicting results of low versus high losses of vitamin C for some irradiated foods may be attributed to differences in analytical approaches used by researchers. Some have measured only ascorbic acid, while others have measured total ascorbic acid, a mixture of ascorbic acid and dehydroascorbic acid. Both acids have vitamin C biological activity and are easily transformed from one to the other. If only ascorbic acid were measured, any apparent reduction in vitamin C level would be exaggerated. Research has shown that the natural differences in total vitamin C content of four varieties of strawberry are much greater than the reduction which occurs on irradiation. With, for example, potatoes it has been demonstrated that although irradiation does reduce vitamin C content, cooking and storage also have a significant effect. The benefit of irradiating potatoes is to inhibit sprouting during storage. Following six months of storage the vitamin C content of irradiated and unirradiated potatoes have been shown to be similar. Since the optimal dose for irradiation treatment of fruit and vegetables, is generally below 2 kGy, effects on vitamin C at higher doses are irrelevant.

The significance of any losses of vitamins E and A due to irradiation are marginal because the main sources of these vitamins in the human diet are butter and milk and these are unsuitable for irradiation treatment. Irradiation has practically no effect on the levels of beta carotene and other carotenoids, the precursors of vitamin A, formed in fruits during ripening.

On the whole, the effects of irradiation on the nutritional value of foods are minimal and these observations are substantiated by the results of many feeding studies which have been undertaken to establish the wholesomeness of irradiated food. It should also be remembered that irradiated food will be consumed as part of a mixed diet, and therefore the process will have little impact on the total intake of specific nutrients.

Irradiation does not significantly change the nutritive value of food

The Joint Expert Committee of the Food and Agriculture Organization (FAO), World Health Organization (WHO), and International Atomic Energy Agency (IAEA), which examined these and other issues, stated in its conclusions in 1980 that irradiation does not introduce special nutritional problems in food. This was also the finding of the group of experts who convened at a meeting organised by the FAO, IAEA and WHO in Geneva, Switzerland in 1997 to discuss the effects of high dose irradiation. It was concluded at this meeting that doses greater than 10 kGy “will not lead to nutrient losses to an extent that would have an adverse effect on the nutritional status of individuals or populations”.

Packaging of Irradiated Foods

With the exception of such applications as sprout inhibition in potatoes or onions, insect disinfestation in bulk grains, or delay of post-harvest ripening of fruits, irradiation of foodstuffs is usually carried out on packaged food items. There may be different reasons for this: prevention of microbial reinfection or insect exposure, prevention of water loss, exclusion of oxygen, prevention of mechanical damage during transport, or simply improved handling and marketing. The packaging material used must not release radiation-induced reaction products or additives onto the food, nor should it lose functional qualities such as mechanical strength, seal stability, or impermeability to water upon irradiation.

Is there any risk in irradiating foods in contact with plastic or other packaging materials?

NO. Results of extensive research have shown that almost all commonly used food packaging materials tested are suitable for use at any dose likely to be applied to food including sterilization treatment. Only packaging materials which have been specifically authorized for such use may be subjected to irradiation of prepackaged foods.

Various types of packaging materials have been approved for use when food is irradiated. Their suitability for food intended for irradiation has been studied in Canada, the United Kingdom, the USA, and a few other countries. A number of food packaging materials were approved for use in food irradiation by the United States Food and Drug Administration (FDA) more than 20 years ago. More recently, Canada, India and Poland have approved additional materials, including a multi-layered polyethylene film, as safe for packaging foods to be irradiated.

Sophisticated tests have been used to evaluate the effect of radiation on plastic and other types of packaging materials. Researchers looked at the post-irradiation

Most commonly used food packaging materials are suitable for irradiated foods stability, mechanical strength, and permeability to water and gases of the packaging materials, and at the extractability of the plastics, additives, and adhesives.

Are irradiated materials used to package foods?

YES. Plastic films laminated with aluminium foil are routinely sterilized by radiation as part of the manufacturing process. They are used for hermetically sealed “bag-in-a-box” products, such as tomato paste, fruit juices, and wines. Other aseptic packaging materials, dairy product packaging, single-serving containers (for example, for cream), and wine bottle corks are also routinely sterilized by irradiation prior to filling and sealing to prevent product contamination.

Other types of materials used to wrap food or other products also are routinely processed by radiation in many countries. The radiation process is used to "cross-link” the material’s polymer chains for greater strength and heat resistance, and for producing plastics with special properties (for example, heat-shrink wrap).

Food Irradiation Costs

Will irradiation increase the cost of food?

Any food process will add cost. In most cases, however, food prices do not necessarily rise just because a product has been treated. Many variables affect food costs, and one of them is the cost of processing. Canning, freezing, pasteurization, refrigeration, fumigation, and irradiation add cost to the product. These treatments will also bring benefits to consumers in terms of availability and quantity, storage life, convenience, and improved hygiene of the food. Reduced losses will bring revenue to producers and traders, thus in turn, compensating treatment costs.

The major factors influencing the economics of food irradiation using cobalt-60 include: irradiation design parameters such as applied dose, packing density of the products, handling conditions (dry versus perishable products), dose uniformity and throughput; capital costs consisting of the irradiator, radiation source, spare parts for linear accelerators, warehouse capacity; and operating costs such as salaries, utilities, replenishments of cobalt-60, maintenance, etc.

Irradiation costs range from US $10 to $15 per tonne for a low-dose application (for example, to inhibit the growth of sprouts in potatoes and onions) to US $100 to $250 per tonne for a high-dose application (for example, to ensure hygienic quality of spices). These costs are competitive with alternative treatments. In some cases, irradiation can be considerably less expensive. For disinfestation of fruit to satisfy the quarantine requirements of an importing country, for example, it has been estimated that the cost of irradiation would be only 10% to 20% of the cost of vapour-heat treatment.

Electron beam irradiators may have economic advantages over gamma irradiators where product throughput is large, the particle size or thickness of the product being treated is small, and where continuous treatment is possible by integrating the irradiator into the production line. As a result, they may be more efficient than gamma irradiators for treating large volumes of domestic or imported grains. In addition, these machine-type irradiators, based on electron acceleration rather than radionuclides, may not require as extensive regulatory approvals.

How much does a typical food irradiation facility cost?

The cost to build a commercial cobalt-60 food irradiation plant is in the range of US $3 million to $5 million, depending on its size, processing capacity, and other factors. This is within the range of plant costs for other technologies. For example, a moderately-sized, ultra-high temperature plant for sterilizing milk, fruit juices, and other liquids costs about US $2 million. A small vapour-heat treatment plant for disinfestation of fruits costs about US $1 million.

Often the capital costs of irradiation equipment are seen as prohibitive, even though low operating costs for most commodities make per unit costs very competitive with other treatments. Commercial contract multipurpose-irradiators operate in many countries offering irradiation services at reasonable cost. Most of these facilities successfully combine irradiation of various food products and treatment of other non-food items such as cosmetics, pharmaceutical and disposable medical products. Since irradiation gives the added economic benefit of prolonged fresh market life for many foods, decreased waste and increased market potential of the food should be considered in a cost-benefit analysis.

Irradiation costs only a fraction of that of the product

Trade in Irradiated Foods

Food imports and exports are important to the health and economy of nations and people, yet trade barriers caused by pests, diseases and food safety issues continually threaten or inhibit trade. Several technologies work to remove trade barriers. Irradiation is one such technology that could assist in the improvement of trade.

Are irradiated foods being traded internationally?

Some irradiated foods such as spices and dried vegetable seasonings, as well as food ingredients such as mechanically deboned poultry meat, have entered international commerce for use mainly by the food industry in various types of processed food. The nature of the spice trade requires that spices, for example pepper from various sources, be mixed to achieve certain grades to satisfy market demand. Thus, it is possible that only a portion of the spices within one single shipment has been irradiated. The production of, and trade in, irradiated spices have increased significantly in recent years from about 5,000 tonnes in 1990 to over 30,000 tonnes in 1994 to over 60,000 tonnes in 1997. Approximately 30,000 tonnes of irradiated spices and dried vegetable seasonings were produced in the USA alone in 1997.

Fresh fruits and vegetables could be irradiated to overcome quarantine barriers against fruit flies in the near future. The United States Department of Agriculture (USDA) has accepted irradiation as a quarantine treatment against major fruit fly species regardless of host. A policy to this effect was issued by the USDA in 1996. Phytosanitary guidelines for the use of irradiation as quarantine treatment will likely be applied in other countries. South East Asia, for example, is in the process of implementing a harmonized protocol on the use of irradiation as a quarantine treatment of horticultural commodities.

Will irradiated foods be labelled?

Some national regulations require that irradiated food be labelled with a statement indicating the treatment and, often, with an international logo known as the radura symbol. Experience with market trials and commercial sale of irradiated food has proven that informed consumers are not against irradiated food but prefer it to be labelled as such. The label provides consumers with the opportunity to choose. Label statements can also be used to state why products are irradiated. It has been demonstrated that people are more likely to buy irradiated food labelled with a statement conveying the positive benefits of the technology, for example, 'Irradiated to control microbes' or 'Irradiated to retard spoilage'.

For irradiated foods that are not packaged, such as bulk containers of fruit and vegetables, retailers in some countries are required to display the logo and phrase. Labelling regulations do, however, differ between countries. For example, in the USA, labelling requirements apply only to whole foods that have been irradiated but not to irradiated ingredients in a food. In the European Union it is proposed that food containing irradiated ingredients such as spices, but which are not themselves irradiated, must be labelled regardless of the percentage of irradiated product which has been incorporated.

Many governments have introduced regulations requiring labelling of irradiated food but not to those treated by competitive treatments such as fumigation. However, in August 1998 the United States Food and Drug Administration (FDA) amended the labelling requirements for irradiated food – a statement disclosing irradiation treatment is not required to be any more prominent than the declaration of ingredients.

Can a government deny entry of irradiated food into its country?

A government can deny entry of any product into its territory. However, under the provision of the Agreement on the Application of Sanitary and Phytosanitary Measures (SPS), being enforced by the World Trade Organization (WTO), such a government (if a member of WTO) may be requested to furnish scientifically-based justification for regulations that are stricter than the only recognized international standards for food, which are the guidelines, and recommendations of the Codex Alimentarius Commission (food safety), the International Plant Protection Convention (IPPC) (plant protection and quarantine), and the International Office of Epizootics (animal health and quarantine). With the existence of the Codex General Standard for Irradiated Foods, which recognizes the safety and effectiveness of food irradiation, and the endorsement of irradiation as a quarantine treatment of fresh agricultural produce by regional plant protection organizations operating within IPPC, irradiated food treated according to the principle of the Codex Standard can no longer be denied entry into countries on scientific grounds.

Trade in irradiated food is happening

Detection Methods for Irradiated Food

Are detection methods for irradiated foods necessary?

The need for reliable and routine tests to determine whether or not food has been irradiated arose as a result of the progress made in commercialisation of the food

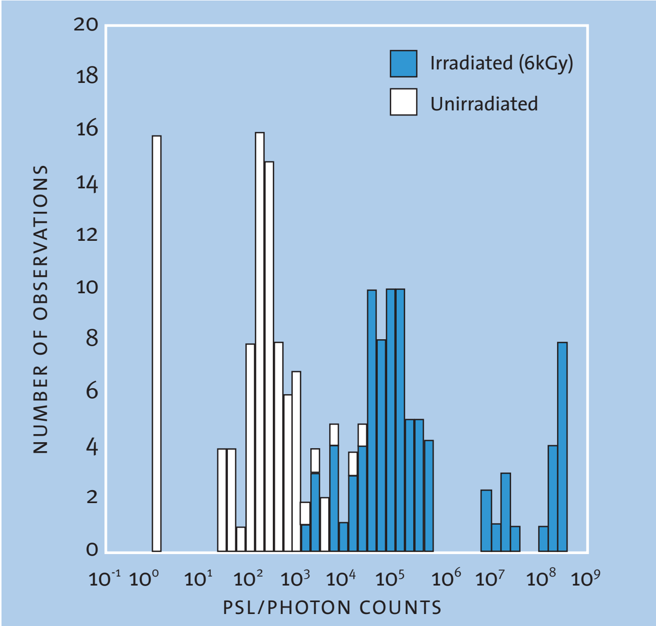
irradiation process, greater international trade in irradiated foods, differing regulations relating to the use of the technology in many countries, and consumer demand for clear labelling of the treated food. Although not essential for management of the process, it was envisaged that the availability of such tests would help strengthen national regulations on irradiation of specific foods, and enhance consumer confidence in such regulations. The availability of reliable identification methods would be of assistance in establishing a system of legislative control, and help to achieve acceptance of irradiated foods by consumers. In fact, an International Conference on Acceptance, Control of, and Trade in Irradiated Food held in Geneva in 1988 recommended that "governments should encourage research into methods of detection of irradiated foods so that administrative control of irradiated food once it leaves the facility can be supplemented by an additional means of enforcement, thus facilitating international trade and reinforcing consumer confidence in the overall process".

Are reliable detection methods available at present to determine whether or not food has been irradiated?

YES. Since the mid 1980s extensive research has resulted in the development of a range of tests which can be used to reliably determine the irradiation status of a wide variety of food. The methods which have been studied most extensively and which have the greatest scope of application include electron spin resonance (ESR) spectroscopy, thermoluminescence (TL), and monitoring the formation of long-chain hydrocarbons and 2-alkylcyclobutanones. These methods have been successfully evaluated in a number of interlaboratory blind trials with the result that, in 1996, five tests were adopted as standard reference methods for the detection of irradiated food by the European Committee for Normalisation (CEN). These in turn are being adopted by some national authorities, such as Germany and the United Kingdom. More tests are being considered by CEN for implementation as reference methods.

Standard methods for the detection of irradiated foods adopted by the European Committee for Normalization (CEN) in December 1997

Number	Title
en 1784	Foodstuffs - Detection of irradiated food containing fat - Gas chromatographic analysis of hydrocarbons
en 1785	Foodstuffs - Detection of irradiated food containing fat - Gas chromatographic / Mass spectrometric analysis of 2-alkylcyclobutanones
en 1786	Foodstuffs - Detection of irradiated food containing bone - Method by ESR spectroscopy
en 1787	Foodstuffs - Detection of irradiated food containing cellulose - Method by ESR spectroscopy
en 1788	Foodstuffs - Detection of irradiated food from which silicate minerals can be isolated - Method by Thermoluminescence.



Based on "Detection Methods for Irradiated Foods", The Royal Society of Chemistry 1996.

Irradiated Foods and the Consumer

The ultimate test for any product or process is the market place, as it is the consumer who determines whether or not a product is better than previous or competitive products. Such is the case for irradiated food which, at the end of the day, will not be a technical or marketing success unless it is accepted by the consumer. Progress in the commercial use of irradiation has been slow, mainly

because of misunderstanding. Many people mistakenly fear, for instance, that the process may induce radioactivity in the food product and that irradiation will result in the formation of toxic by-products in food. Given these fears, consumers often find it difficult to evaluate the benefits of this processing technique objectively.

Given proper information, will consumers be willing to accept irradiated food in a more positive light?

YES. While many consumers are unfamiliar with food irradiation, consumer research shows that, as more and more factual information is provided, the public increasingly views irradiation in a more positive light. In fact, some studies have even shown a consumer willingness to pay a premium price for irradiated products. Consumers indicate that endorsements by a respected health authority increase their confidence in the safety of this technology. A United States Department of Agriculture (USDA) funded project in California and Indiana evaluated the impact of a brief educational programme on community leaders' attitudes to and knowledge of food irradiation. After viewing a 10-minute video on food irradiation, those likely to try irradiated food increased from 57% to 83%.

An extensive marketing and educational programme was conducted in South Africa prior to the introduction of irradiated foods in the market. With regard to irradiated shelf-stable meat products, a marketing survey among the general population found that initially 15% of people surveyed indicated they were likely to purchase the irradiated food. After receiving visual information, those willing to buy increased to 54%. After receiving information and tasting the food, 76% indicated they would purchase the irradiated shelf-stable product, while 5% indicated that they probably would not buy.

Have many marketing trials been carried out to determine consumer response to irradiated foods?

Many market tests of irradiated foods have been carried out in several countries during the 1980s and 1990s, and to date, all have been successful. Market tests and the ongoing sales of irradiated foods provide the best source of information on whether irradiated foods meet consumer needs and wants. They provide excellent information about consumer acceptance and facilitate the commercialization of irradiation.

USA

Irradiated mangoes sold well in Florida in 1986, and in March 1987, irradiated Hawaiian papayas outsold their identically priced non-irradiated counterparts by more than ten to one. Irradiated apples marketed in Missouri were also favourably received. In March 1992, a retailer in the Chicago area featured irradiated strawberries, grapefruit and juice oranges. The irradiated produce outsold the non-irradiated produce by ten to one. Irradiated tomatoes, mushrooms and onions were later marketed with similar sales success. In the second year of operation and thereafter, irradiated produce continued to outsell non-irradiated produce by twenty to one. In 1995 the same store and several Midwest markets in the USA sold tropical fruits, including papaya, litchi and starfruit, from Hawaii in conjunction with a study to determine the potential of irradiation as a quarantine treatment. As of the end of August 1998, the total amount of Hawaiian fruits irradiated and sold in the USA has been about 280,00 pounds demonstrating that consumers are willing to buy these fruits, and do so repeatedly. In a small scale test of irradiated poultry in Kansas, USA in 1995, irradiated

Courtesy of Meat Marketing & Technology Magazine

poultry captured 60% of the market share when priced 10% lower than store brand, 39% when priced equally, and 30% when priced 10% higher. In 1996 when another test was conducted, the market share increased to 63% when the irradiated poultry was priced 10% lower than the store brand, 47% when priced equally, and 18% and 17% when priced 10% and 20% higher. The irradiated product sold better in the more up-market store, capturing 73% of the market when priced 10% lower, 58% when priced equally, and 31% and 30% when priced 10% and 20%

Palatability of food treated by irradiation remains unchanged

higher. This is consistent with other attitude surveys and market place data that indicate irradiation is more acceptable in up-scale markets.

Outside the USA

Irradiated onions and garlic were first sold in a supermarket in the Buenos Aires area in 1985. Prior to the first marketing, consumers were informed about food irradiation in the local TV, radio and press. Within three days of marketing, the entire 10 tonnes of irradiated product were sold. Subsequent trials gave similar results.

Irradiated dried fish and onions have been successfully test marketed in Bangladesh. In China, numerous irradiated foods have been tested during 1980s and early 1990s including apples, garlic, seasonings, meat products, sweet potato wine, potatoes, tomatoes, and dehydrated vegetables. Successful test markets using brown rice, mungbean, and glutinous rice have been conducted in Indonesia.

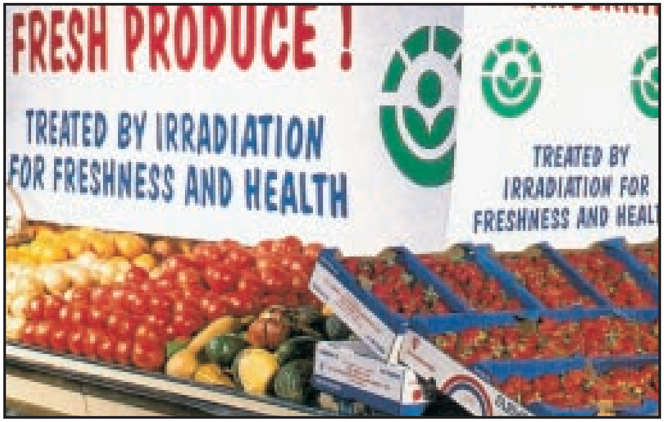
Several irradiated foods have been successfully test marketed in Thailand, including irradiated onions, fragrant rice and sweet tamarind. Nham, fermented pork sausage consumed raw in Thailand, is often contaminated with *Salmonella* and occasionally with *Trichinella spiralis*. In 1986, labelled irradiated Nham was sold side by side with the traditional product. A consumer survey showed that 34% of the buyers selected irradiated Nham out of curiosity and 66% considered it safer from harmful microorganisms. Satisfaction was high, with 95% of customers indicating that they would purchase irradiated Nham again. During the three-month test, irradiated Nham outsold the non-irradiated product by a ratio of ten to one. This product is presently available in Thailand on a commercial basis.

From 1994 to 1996 several irradiated products including dried mushrooms, dried meat, dried vegetables and dried fish, were market tested in the Republic of Korea and found acceptable to consumers. Irradiated potatoes, onions, and dried fruits were marketed at different times in various shops in Peshawar, Pakistan where consumers found them to be more acceptable than the non-irradiated products. One tonne each of onions and potatoes were test marketed at a provincial fruit and vegetable show in January and February 1991. Thirty-nine per cent of 300 consumers who completed a survey form said they were willing to buy irradiated food and to convince others to buy it, and 57% thought food irradiation should be commercialized. Market tests with irradiated onions have been carried out in the Philippines since 1985 and sales of irradiated onions have always been high. When irradiated onions and potatoes were marketed in two cities in Poland in 1988, 97% of the consumers responding to a survey evaluated the products positively, and say they would like to buy them again.

Irradiated strawberries were test marketed in Lyon, France in May and June 1987. Two tonnes of products, packed in covered plastic trays, labelled ‘Protected by Ionization’, and priced 30% higher than non-irradiated products, sold well. Market tests have also involved irradiated chicken breast meat and Camembert cheese.

In South Africa between 1978 and 1979 irradiated potatoes, mangoes, papayas, and strawberries were sold in 20 supermarkets where they were judged acceptable by 90% of buyers. Over a six-year period, several popular dishes, for example grilled chicken, curried chicken, bacon, curried beef, and a Malaysian dish called bobotie, were evaluated by a large number of groups, including hikers and sea voyagers. High acceptance was indicated by researchers. Approximately 200 members of the Defence Force tested the products and showed overwhelming preference for the irradiated product over freeze-dried and canned counterparts.

Thus, all of the marketing trials carried out have clearly demonstrated that consumers are receptive towards irradiated food and will select it in preference to a non-irradiated equivalent when they perceive benefits. In all of these trials it was evident that informed consumers will accept irradiated foods.



Irradiated fresh fruits and vegetables on sale in USA.

What kinds of irradiated food items are currently being marketed at retail level?

Several irradiated foods are used directly by the food industry. For example irradiated spices and mechanically-deboned poultry meat are used for manufacturing various types of processed food. Many irradiated foods are also being marketed at the retail level.

Fresh Fruits

Since the first commercial food irradiator in the USA (operated by FOOD TECHnology Service, Inc., formerly Vindicator Co.) began operating in Mulberry, near Tampa, Florida in 1992, irradiated strawberries, tomatoes and citrus fruits have been marketed at several retail outlets in Florida and Illinois. The USDA issued its policy in 1996 to accept irradiation as a quarantine treatment of fresh fruits against fruit flies regardless of the host commodities. Fruits from Hawaii including papaya, rambutan, litchis and cherimoya which are natural hosts of fruit flies have been irradiated and marketed under a special permission from the USDA at the retail level in several States in the USA since 1995. All irradiated products are labelled with the irradiation logo and a statement 'treated by irradiation' either on the package or at the point of sale. The USDA policy has also made it possible for irradiation to be used as a quarantine treatment of fresh fruits from other countries against major species of fruit flies, regardless of host commodity as long as the fruit is not a host for other quarantine pests.

In China, irradiated apples have been marketed at the retail level in Shanghai and other cities since the early 1990s.

Spices and Dried Vegetable Seasonings

Irradiated spices and dried vegetable seasonings have been retail marketed in South Africa over the past 10 years and the volume is increasing. In fact, irradiation is used so routinely by the spice trade in South Africa that it would be difficult to find spices treated by some other means (fumigation, heat) in the country. A variety of processed food (for example, sauces, salad dressings, sandwich spread) also incorporate irradiated spices and vegetable seasonings. All irradiated products have to be labelled with an irradiation logo plus the word 'Radurised'. Since 1995, irradiated spices and dried vegetable seasonings have been marketed at retail levels in Belgium. Irradiated spices, condiments and seasonings are also available in China.

Frog Legs

Because of strict microbiological specifications in France, most, if not all, frog legs marketed in the country have been treated by irradiation to ensure their hygienic quality. The product has to be labelled 'treated by ionization' and can be purchased in most French food markets.

Onions, Garlic

Vidalia onions have been irradiated in Florida, to prevent sprouting, and marketed at retail level in Chicago since 1992. Irradiated garlic has been sold in increasing quantities in several cities in China since the early 1990s. During 1995-98, about 166,000 tonnes of garlic were irradiated and marketed across China. All products are labelled to indicate the treatment.

Chicken

Following the approval of the United States Food and Drug Administration (FDA) and the quality control programme for irradiated poultry in 1993, small quantities of irradiated chicken have been offered for sale in some retail outlets in Florida, Illinois, Iowa and Kansas with success.

Consumers in these States are being given the choice to buy irradiated chicken without pathogens such as *Salmonella* for the first time.

Fermented Pork Sausages

Irradiated fermented pork sausages (Nham, a local delicacy in Thailand, which is almost always consumed raw) treated for controlling pathogenic microorganisms and parasites, are gaining popularity since their first market trial in 1986. During 1997, about 80 tonnes of Nham were irradiated in Thailand. Increasing quantities of this irradiated product are being supplied to supermarkets in Bangkok. In addition to marketing in Bangkok, the producers have developed new markets in the north and northwest of Thailand where Nham is a staple part of the diet. There is a widespread demand for this irradiated product as the risk from infection by *Salmonella* and *Trichinella spiralis* has been removed. The irradiation logo and a statement indicating irradiation treatment are required on the label.

Other Food Products

Since a semi-commercial irradiator in Chittagong, Bangladesh went into operation in 1993, small quantities of irradiated dried fish (for insect control) have been available in the market in Chittagong and other cities in Bangladesh, with labelling indicating irradiation treatment.

Nham (fermented pork sausage) is commercially irradiated and marketed in Thailand.

Shelf-stable, ready-to-eat meals are commercially available in South Africa. At present, 12 such meals are in existence, including beef curry, beef stroganoff, chicken curry, lasagna and a Malaysian dish called bobotie. These meals are labelled as irradiated and have a shelf-life of greater than two years, making them ideal for outdoor activities such as hiking, camping, yachting, safaris and mountaineering.

Successful market trials of other irradiated foods such as rice, mungbeans, potatoes and onions in several countries in recent years will likely lead to further commercialization of irradiated food in the near future. The actual sale of irradiated food in the market in several countries has clearly demonstrated that consumers will accept irradiated food if they have the choice.

World-wide Utilization of Food Irradiation

Countries which apply food irradiation for commercial purposes

Do not yet apply food irradiation

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The use of irradiation alone as a preservation technique will not solve all the problems of post-harvest food losses, but it can play an important role in cutting losses and reducing the dependence on chemical pesticides.