Facts about Food Irradiation
The safety and benefits of foods processed by ionizing radiation are well documented. In an effort to provide governments, especially those of developing countries, 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 IAEA, decided at its 7th Annual Meeting in Rome, Italy, on October 1990, to issue a series of "Fact Sheets" on the subject.

ICGFI, an inter-governmental body with a membership of 37 governments, 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. The Fact Sheets included here cover issues relating to: status and trends; scientific and technical terms; food irradiation and radioactivity; chemical changes in irradiated food; nutritional quality of irradiated foods; genetic studies; microbiological safety of irradiated food; irradiation and food safety; irradiation and food additives and residues; packaging of irradiated foods; safety of irradiation facilities; controlling the process; food irradiation costs; and irradiated foods and the consumer.

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.
CONTENTS

Status and Trends ................................................................. 1
Scientific and Technical Terms .................................................. 3
Food Irradiation and Radioactivity ............................................ 5
Chemical Changes in Irradiated Foods ....................................... 7
Nutritional Quality of Irradiated Foods ....................................... 9
Genetic Studies ................................................................. 11
Microbiological Safety of Irradiated Food ..................................... 15
Irradiation and Food Safety ..................................................... 19
Irradiation and Food Additives and Residues ............................... 21
Packaging of Irradiated Foods .................................................. 23
Safety of Irradiation Facilities ................................................ 25
Controlling the Process .......................................................... 29
Food Irradiation Costs .......................................................... 33
Irradiated Foods and the Consumer .......................................... 35
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. 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 living cells, such as bacteria, and cells of higher organisms, by changing their molecular structure. It can also slow down ripening or maturation of certain fruits and vegetables by causing biochemical reactions in physiological processes of 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. In 37 countries, health and safety authorities have approved irradiation of altogether some 40 different foods, ranging from spices to grains to deboned chicken meat to fruits and vegetables. Twenty-four of these countries are actually applying the process for commercial purposes.

Decisions in these and other countries 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 World Health Organization (WHO) representing more than 130 countries. It is based on the findings of a Joint Expert Committee on Food Irradiation (JECFI) convened by the FAO, WHO, and International Atomic Energy Agency (IAEA). JECFI has evaluated available data in 1969, 1976, and 1980. In 1980, it concluded that "the irradiation of any food commodity" up to an overall average dose of 10 kilogram "presents no toxicological hazard" and requires no further testing. It stated that irradiation up to 10 kilogram "introduced no special nutritional or microbiological problems" in foods.

Why are countries interested?

Governmental interest in the process is emerging for many reasons. They are largely related to persistently high food losses from infestation, contamination, and spoilage; mounting concerns over foodborne diseases; and growing international trade in food products that must meet stiff 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.

The FAO has estimated that worldwide about 25% of all food production is lost after harvesting to insects, bacteria and rodents. 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 huge amounts of grain because of insect infestation, moulds, and premature germination. For roots and tuber, sprouting is the major cause of losses. Several countries, including Belgium, France, Hungary,
Japan, Netherlands, and USSR are ir-radiating grains, potatoes, onions, and other products on an industrial scale. Pilot quantities of potatoes, onions, and garlic have been irradiated in Argentina, Bangladesh, Chile, China, Israel, Philippines, and Thailand.

Foodborne diseases pose a widespread threat to human health and they are an important cause of reduced economic productivity. Studies by the US Center for Disease Control show that even in the highly developed country of the United States, foodborne diseases caused by pathogenic bacteria, such as Salmonella and Campylobacter and by Trichinae and other parasites, claim an estimated 7000 lives annually and cause 24-81 million cases of diarrhoeal disease. Economic losses associated with foodborne diseases are high — estimated between US $5 billion and $17 billion by the US Food and Drug Administration.

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, as well as dry food ingredients, are irradiated for this purpose in Belgium and the Netherlands. Electron beam irradiation of blocks of mechanically deboned, frozen poultry products is carried out industrially in France. Spices are being irradiated in Argentina, Brazil, Denmark, Finland, France, Hungary, Israel, Norway, United States, and Yugoslavia.

Trade in food products is a major factor in regional or 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, some countries, including the USA and Japan, have banned the use of certain fumigants identified as health hazards.

The problem is most acute for developing countries whose economies are still largely based on food and agricultural production. Radiation processing offers these countries an alternative to fumigation and some other treatments.

How much food is being commercially irradiated?

Each year about half a million 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 pace of the development of food irradiation is public understanding and acceptance of the process. So far, this has been difficult to achieve, in view of the misconceptions and fears often surrounding nuclear-related technologies and the use of radiation.

To help address concerns and correct myths about food irradiation, a series of fact sheets has been prepared by the International Consultative Group on Food Irradiation (ICGFI). Currently (early 1991) 37 countries are participating in the work of ICGFI. The Group was established under the auspices of the FAO, IAEA, and WHO to advise the organizations and their Member States on the use of irradiation to solve food problems related to international trade, public health, economics, regulations, and public information. Information about ICGFI and the technology of food irradiation may be obtained by writing:

The ICGFI Secretariat
Joint FAO/IAEA Division of Nuclear Techniques in Food and Agriculture
Wagramerstrasse 5, P.O. Box 100
A-1400 Vienna, Austria
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 electromagnetic spectrum, occurring in the short wave length, high energy region of the spectrum. 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, are unstable, and emit radiation as they spontaneously disintegrate, or decay, 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 caesium-137; X-ray machines having a maximum energy of five million electron volts (MeV); or electron machines 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 a radiation plant. Cobalt-60 has a half-life of 5.3 years. Caesium-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, because there are few reprocessing facilities worldwide, the uncertainty of market supply of commercial quantities of caesium-137 has meant that there is almost no demand for its use in radiation plants. In a report on irradiated foods, the American Council on Science and Health noted that “as of November 1988 all interested parties including the (US) Department of Energy now appear to agree that caesium-137 has no future in gamma processing”.

Some machine sources of radiation are suitable for irradiating certain materials. High energy electron beams can be produced from machines capable of accelerating electrons. Electrons cannot penetrate very far into food, compared with gamma radiation or X-rays. 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%.

**Radiation dose** is the quantity of radiation energy absorbed by the food as it passes through the radiation field during processing. It is now generally measured by a unit called the **Gray** (Gy). In early work the unit was the **rad** (1 Gy = 100 rads). 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). In terms of energy relationships, one gray equals one joule of energy absorbed per kilogram of food being irradiated.
1 Does the irradiation process make food radioactive?

A: No. Irradiation under controlled conditions 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) of natural radioactivity (from elements such as potassium) is unavoidably 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 — 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 induced 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.
What is the difference between the terms "irradiated food" and "radioactive food"?

Scientific and technical references:


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.

INTERNATIONAL CONSULTATIVE GROUP ON FOOD IRRADIATION (ICGFI)

Joint FAO/IAEA Division of Nuclear Techniques in Food and Agriculture
Wagramerstrasse 5, P.O. Box 100
A-1400, Vienna, Austria

ELECTROMAGNETIC SPECTRUM

Wavelength in Meters
Q: Are chemical changes in irradiated foods, such as the formation of radiolytic products, harmful?

A: No. In general, the irradiation process produces very little chemical change in food. None of the changes known to occur have been found to be harmful or dangerous.

Some of the chemical changes produce so-called "radiolytic" products. These products 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 heat processing. The safety of these radiolytic products has been examined very critically, and no evidence of their harmfulness has been found.

Many scientific tests using highly sensitive analytical techniques have been done over the past 30 years in attempts to isolate and identify radiolytic products caused by irradiation. No substances truly unique to irradiated foods have been identified. The same products are always found, albeit in varying amounts, in fruits, vegetables, meats, and fish, for example, and in many other types of processed and unprocessed foods.

The United States Food and Drug Administration has estimated that the total amount of undetected radiolytic products that might be formed when food is irradiated at a dose of 1 kilogray 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. There is no evidence to suggest that free radicals, per se, affect the safety of irradiated food.

Free radicals — which in scientific terms are atoms or molecules with an unpaired electron — can be formed during the irradiation process, as well as by certain 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 laboratory study in which animals were fed a very dry milk powder irradiated at 45 kilogray, more than four times the maximum approved dose for food irradiation. No mutagenic effects were noted and no tumours were formed. No toxic effects were apparent in the animals over nine successive generations. Similarly, a toast of bread (unirradiated), which actually contains more free radicals than very dry foods that have been irradiated, can be expected to be harmless.

Scientific and Technical References:


Q: Does irradiation adversely affect the nutritional value of food?

A: No more so than other food processing and preservation methods used to achieve the same purpose.

Nutritional Quality of Irradiated Foods

Extensive research has shown that macronutrients, such as protein, carbohydrates, and fat, are relatively stable to radiation doses of up to 10 kilogram. Micronutrients, especially vitamins, may be sensitive to any food processing method, including irradiation. Different types of vitamins have varied sensitivity to irradiation and to some other food processing methods. For example, vitamins C and B-1 (thiamine) are sensitive to irradiation as well as to heat processing. 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 induce special nutritional problems in food.

The change in nutritional value caused by irradiation depends on a number of factors. They include the radiation dose to which the food has been exposed, the type of food, packaging, and processing conditions, such as temperature during irradiation and storage time.

INTERNATIONAL CONSULTATIVE GROUP ON FOOD IRRADIATION (ICGFI)
Joint FAO/IAEA Division of Nuclear Techniques in Food and Agriculture
Wagramerstrasse 5, P.O. Box 100
A-1400, Vienna, Austria

ICGFI is an international group of experts designated by Governments to evaluate and advise on global activities of food irradiation. It was established under the aegis of the Food and Agriculture Organization of the United Nations, World Health Organization, and International Atomic Energy Agency.
Most of these factors are also true for other food preservation technologies. For example, measurement of vitamin C content in three varieties of apples kept in cold storage for up to 1 year showed decreases of between 40% to 70%, depending on the variety of apple. Yet it has never been suggested that cold storage is an inappropriate technology for apples and should not be used.

Reports of high vitamin losses from irradiation of pure vitamin solutions, or by using doses higher than those which would be used at commercial irradiation facilities, have no relevance for predicting the radiation sensitivity of a particular vitamin in food. The complexity of the composition of foods often protects individual vitamins from radiation decomposition.

Seemingly conflicting results of low versus high losses of vitamin C for some foods may be attributed to differences in analytical approaches used by researchers. Some have measured only ascorbic acid, while others have measured total vitamin C, 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.

Just as vitamins vary in their sensitivity to heat, so do they vary in their sensitivity to radiation. This sensitivity depends upon the conditions under which food is irradiated. Vitamins A, E, C, K and B-1 (thiamine) in foods are relatively sensitive to radiation, while some other B vitamins such as riboflavin, niacin, and vitamin D are much more stable.

Losses are generally less if oxygen is excluded and if the temperature during irradiation is low. Under optimal conditions, vitamin losses in foods irradiated at doses up to 1 kilogray are considered to be insignificant. At higher doses the effect of irradiation will depend on the specific vitamin, temperature, dose, food, and packaging. Depending on the food, thiamine levels may be reduced further by storage and cooking if the food has been exposed to air during storage, but not necessarily if it has been packaged without oxygen.

Scientific and Technical References:


Status of Food Safety and Inspection Service Irradiation Activities, USDA (September 1988).
Q: Some media reports claim that studies in India have shown that eating irradiated food causes development of abnormal chromosomes — is this true?

A: No. The issue of abnormal chromosomes as a result of eating irradiated food has been more sensationalized 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 a multiple set 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; the significance of polyploidy is not known.

Media reports frequently cite results that were published in the mid-1970s by a group of scientists from the National Institute of Nutrition (NIN) in India. The scientists reported increases in the frequency of polyploid cells in rats, mice, monkeys, and even malnourished children that they attributed to consumption of products made from wheat immediately after irradiation at 0.75 kilogram. 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 repeat the studies conducted at NIN based on information made available to them. None of these institutions could come up with results similar to those found at NIN.
Reviews included one done by an independent investigative committee appointed by the Government of India. In 1976, the Committee 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, United Kingdom, and United States also have evaluated the alleged incidence of polyploidy. They all concluded that the reported data from NIN do not support the incidence of increased polyploidy.

In 1988 D. MacPhee and W. Hall, advisers to an Australian Parliamentary Committee Inquiry into the use of ionizing radiation, examined the NIN results. They concluded that the inability of other researchers to replicate the NIN results casts doubts upon the reliability of the NIN conclusions; that polyploidy is a poor measure of genetic damage; and that “major biological implausibilities” exist in the chain of occurrences “which allegedly links the consumption of irradiated food with the occurrence of genetic events”.

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 the test groups could be discovered in any of the experiments. Incidences of polyploidy in those who consumed non-irradiated food and those who consumed irradiated samples were within the nor-
Feeding studies using irradiated food have been done in many countries, including China. Chinese irradiation facilities are operating in Shanghai and other cities to process fruits and other foodstuffs.

What are some of the other studies that have been done in this area?

Some other studies are occasionally cited as corroborating the NIN research. They include one by D.T. Anderson and colleagues reported in 1981. This study, which looked at dominant lethal mutations in mice that were fed irradiated diets, was among those reported by MacPhee and Hall, advisers to a parliamentary committee in Australia, as failing to replicate the NIN results. Another study sometimes cited as supporting the NIN research examined the level of polyploidy in the bone marrow cells of Chinese hamsters fed freshly irradiated laboratory animal diets. These diets were irradiated at 100 kilogray, a dose at least 125 times higher than that used for
the NIN studies, and 10 times the internationally recommended limit for food irradiation. Frequently not cited is the author’s own conclusion about the significance of his study: “There is no evidence for any mutagenic effect being produced as a result of testing an irradiated diet”.

Extensive feeding tests have validated this conclusion. 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 kilogram, has been fed to laboratory animals at many institutions involved in food, drug, and pharmaceutical research in Austria, Australia, Canada, France, Germany, Japan, Switzerland, United Kingdom, and United States. No transmittable genetic defects — teratogenic or oncogenic — have been observed which could be attributed to the consumption of irradiated diets.

Scientific and Technical References:


Q: Can irradiation of food increase the risk of botulism?

A: Irradiation at internationally recommended levels of up to 10 kilogram does not increase the risk from botulism any more so than other "sub-sterilizing" food processes, such as pasteurization. Food treated by these methods 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 kilogram) can be used to destroy any Clostridium botulinum organisms present in the food.

Some types of Clostridia cause more concern than others. Clostridium ICGFI is an international group of experts designated by Governments to evaluate and advise on global activities of food irradiation. It was established under the aegis of the Food and Agriculture Organization of the United Nations, World Health Organization, and International Atomic Energy Agency.
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 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. 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.

Can irradiation of food lead to increased microbiological hazards?

No. The microbiological safety of irradiated foods has been investigated by international scientific bodies. One area that scientists have specifically looked at is the reduction of microorganisms that cause spoilage. These microorganisms warn consumers, through off odours or discoloration, that the food may be bad, or unsafe, to eat. Even if irradiation suppressed microorganisms in spoiled food, it cannot suppress the outward signs of spoilage and thus cannot be used to cover up spoiled food. In addition, scientific evidence indicates that proper irradiation can neither increase virulence of pathogenic microorganisms nor their ability to "grow better" in irradiated food.

In 1982, at the request of the Food and Agriculture Organization (FAO) of the United Nations and the World Health Organization (WHO), the Board of the International Committee on Food Microbiology and Hygiene considered the evidence for the microbiological safety of food irradiation. It concluded that modern food handling technology was adequate to control potential problems created by the suppression of
spoilage microorganisms and that food irradiation does not present any increased microbiological hazards to health. Independent national expert committees in Denmark, Sweden, United Kingdom, USA, and Canada have since reaffirmed these conclusions. They essentially endorse the findings of the Joint Expert Committee on the Wholesomeness of Irradiated Foods convened in 1980 by the FAO, WHO, and International Atomic Energy Agency.

Important to note is that irradiation is not the only food processing technique which suppresses microorganisms signalling spoilage. Heat pasteurization, chemical treatments, and certain packaging methods have the same effect. Food processed by pasteurization-type methods must be properly packaged, handled, and stored to ensure safety.

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

3 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 totally 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 good manufacturing practices (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.
Raw and frozen poultry products are almost always contaminated with pathogenic microorganisms such as Salmonella. Irradiation is a highly effective method to ensure the hygienic quality of these products.

Scientific and Technical References:


"Irradiation in the Production, Processing, and Handling of Food", US Food and Drug Administration, final rule, Federal Register, 55 (85) 18538-18544 (2 May 1989).


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. The bad appearance, taste or smell will remain. Food irradiation is not magic.

Irradiation is increasingly used as a method to ensure the hygienic quality of spices and dried vegetables in many countries.

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 parasitic diseases transmitted through solid food, especially those of animal origin.

INTERNATIONAL CONSULTATIVE GROUP ON FOOD IRRADIATION (ICGFI)

ICGFI is an international group of experts designated by Governments to evaluate and advise on global activities of food irradiation. It was established under the aegis of the Food and Agriculture Organization of the United Nations, World Health Organization, and International Atomic Energy Agency.
Scientific and Technical References:

"Food Irradiation", by Geoffrey Campbell-Platt, Professor of Food Technology, Department of Food Science and Technology, University of Reading, United Kingdom, The Food Safety Advisory Centre, London.


Food processes such as heating, freezing, chemical treatment, and irradiation are not intended to serve as substitutes for good hygienic practices. 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.
Q: Does irradiating food that contains pesticide residues or additives present any health hazards?

A: No. There is no scientific evidence to indicate any health hazard associated with irradiation of food containing pesticide residues and additives.

In the United States, the Food and Drug Administration (FDA) has examined the irradiation of foods containing pesticide residues. It specifically calculated the amount of radiolytic products that would be expected to be formed if foods containing pesticide residues were irradiated at a dose of 1 kilogray. This dose is in the upper range of that expected to be used for fruits, vegetables, and grains for disinestation purposes. If the pesticide residue level in the food is about 1 part per million (an average level) then the calculated total...
yield of all radiolytic products from the pesticide residue would be about 0.000033 milligrams per kilogram of food, or 1 gram in 3000 tonnes of food. The FDA regards this amount as “virtually nil”. It concludes that “the potential toxicity of each radiolytic product from a pesticide chemical residue in foods that are irradiated would be negligible” and that “such pesticide residues do not pose a hazard to health.”

Studies have been done on food additives that assume the use of higher doses of radiation. A food additive is defined by the Codex Alimentarius Commission of the Food and Agriculture Organization and World Health Organization as a substance not normally used as a food ingredient but which is deliberately added to the food to produce a technological result. Colourants, man-made antioxidants, preservatives such as potassium sorbate, and polyphosphates are examples of food additives, forming 0.01 to 0.1% of the total food weight.

These studies indicate that at a radiation dose of 10 kilogray, which is the maximum dose allowed for food irradiation, yields of all radiolytic products from food additives range from 3 to 30 parts per billion. For a person with a total annual diet of 500 kilograms of food, these figures correspond to a negligible annual individual intake of radiolytic products — between 0.1 and 1 milligram — from an additive in a processed irradiated food that accounts for 5% of the total diet. The probability of harm occurring from radiolytic product formation from food additives is therefore considered to be extremely low indeed.

Scientific and Technical Reference:

Irradiation in the Production, Processing and Handling of Food; Final Rule, Federal Register 51: 13376-89, U.S. Food & Drug Administration (18 April 1986)
Q: Is there any risk in irradiating foods in contact with plastic or other packaging materials?

A: No. Results of extensive research have shown that almost all commonly used food packaging materials tested are suitable for use at doses up to 10 kilogram, which is the internationally approved limit for irradiating 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 United States, and a few other countries. A number of food packaging materials were approved for use in food irradiation by the US Food and Drug Administration more than 20 years ago. More recently, Canada has approved additional materials, including a multi-layered polyethylene film, as safe for packaging foods which will be irradiated.

Sophisticated tests have been used to evaluate the effect of radiation on plastic and other types of packaging materials. Researchers look at the material’s post-irradiation stability, mechanical strength, and permeability to water and gases, and at the extractability of the plastics, additives, and adhesives.

INTERNATIONAL CONSULTATIVE GROUP ON FOOD IRRADIATION (ICGFI)

Joint FAO/IAEA Division of Nuclear Techniques in Food and Agriculture
Wagramerstrasse 5, P.O. Box 100
A-1400 Vienna, Austria
Are irradiated materials used to package foods?

Yes. Laminated plastic films with aluminium foil are routinely sterilized by radiation. 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 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 “crosslink” the material’s polymer chains for greater strength and heat resistance, and for producing plastics with special properties (for example, shrink wrap).

Scientific and Technical References:


Q: Have there been major accidents at industrial irradiation facilities?

A: Yes. Over the past 25 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. As at irradiation facilities, controls and formal protocols are required to prevent accidents.

The radiation processing industry is considered to have a very good safety record. Today there are about 160 industrial gamma irradiation facilities operating worldwide, 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.
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. Under normal operating conditions, all exposures of workers to radiation are prevented because the radiation source is shielded. Irradiators are designed with several levels of redundant protection to detect equipment malfunction and to protect personnel from accidental radiation exposure. Potentially hazardous areas are monitored and a system of interlocks prevents unauthorized entry into the radiation cell when the source is exposed. 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 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".

3 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?

IRRADIATION ROOM
Products are treated inside a central chamber with thick concrete walls and specially designed doors to prevent radiation from escaping. Interlocks and warning devices do not allow the radiation source to be raised until all doors are securely closed.
Credit: Nordion International

STORAGE POOL
A deep storage pool of water holds the radiation source when not in use. 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.

ROC
Radioactive material required for irradiators is transported in lead-shielded steel casks. These are designed to meet national and international standards modelled upon the Regulations for Safe Transport of Radioactive Materials of the International Atomic Energy Agency. Large quantities of radioactive material are safely shipped all over the world to supply some 160 irradiators processing a variety of goods, mainly medical products such as syringes, physician gloves, sutures, and hospital gowns. From 1955 to early 1988, for example, Canada shipped approximately 190 million curies of cobalt-60 in 870 separate shipments 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.
4. 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?

5. Do gamma irradiators have radioactive waste disposal problems?

Scientific and Technical References:

Memorandum to the United Kingdom House of Lords Select Committee on the European Communities Irradiation of Foodstuffs by the United Kingdom Health and Safety Executive, HMSO, London (1989).


4. No. 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, substances 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.

5. No. Radioactive waste does not accumulate at irradiation facilities because no radioactivity is produced. The radiation energy used at some irradiators — namely electrons or X-rays — is generated by industrial machines called accelerators. At gamma irradiators, radionuclide sources, typically cobalt-60 or more rarely caesium-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. Canada has calculated that all the cobalt-60 it supplied for use in 1988 (about 100 million curies) would require a storage space of about 1.25 cubic metres, roughly equivalent to the space occupied by a small 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.
Q:
1. Do measures exist to control the irradiation process to ensure that foods are properly treated?

A:
1. Yes. Over the past 30 years, laws and regulations have been promulgated to govern operations at irradiators used to process non-food products, such as medical supplies. About 160 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 radiation practices for a number of foods have been prepared by the International Consultative Group on Food Irradiation (ICGFI), a joint group of the Food and Agriculture Organization of the United Nations (FAO), World Health Organization (WHO), and International Atomic Energy Agency (IAEA). 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.

The guidelines emphasize 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 GMPs before, during, and after irradiation. Only foods meeting microbiological criteria and other quality standards should be accepted for irradiation.

The Codex Alimentarius Commission of FAO and WHO has further issued its recommended standards for the irradiation of food. 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.
Besides these regulatory controls, are there tests to detect whether food has been irradiated?

Yes, to some extent. Some scientific tests are being studied for use in determining whether foods have been irradiated. These include thermoluminescence measurement for detection of irradiated spices and electron spin resonance spectroscopy for determining irradiation of meats, poultry, and seafoods containing any bone or shells, and some specific chemical tests.

No single method, however, has yet been developed that reliably detects irradiation of all types of foods or the radiation dose levels that were used. This is partly because the irradiation process does not physically change the appearance, shape, or temperature of products and causes negligible chemical changes in foods.

The lack of a single test to identify a treated product is not unique to the irradiation process. Organically grown produce cannot be identified analytically, nor can meat slaughtered in accordance with Jewish or Islamic requirements. Additionally, chilled or frozen foods cannot be analyzed for unacceptable temperature fluctuations which might have occurred during distribution, nor can thermally sterilized (canned) foods be analyzed after treatment to assure that the correct time-temperature regime was applied.
The food irradiation process does not physically change the appearance, shape, or temperature of products and causes negligible chemical changes in foods.

Scientific and Technical References:

Q: Will irradiation increase the cost of food?

A: Any food process will add cost. In most cases, however, food prices would 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 will 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.

Broken down, 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 disinfection of fruit in Thailand and the United States, for example, it has been estimated that the cost of irradiation would be only 10%-20% of the cost of vapour-heat treatment.

INTERNATIONAL CONSULTATIVE GROUP ON FOOD IRRADIATION (ICGFI)
Joint FAO/IAEA Division of Nuclear Techniques in Food and Agriculture
Wagramerstrasse 5, P.O. Box 100
A-1400 Vienna, Austria

ICGFI is an international group of experts designated by Governments to evaluate and advise on global activities of food irradiation. It was established under the aegis of the Food and Agriculture Organization of the United Nations, World Health Organization, and International Atomic Energy Agency.
How much does a typical food irradiation facility cost?

The cost to build a food irradiation plant is in the range of US $1 million to $3 million, depending on its size, processing capacity, and other factors. This is within the range of plant costs for other food 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.

Scientific and Technical References:


Is it true that consumers are opposed to buying irradiated food?

Opinion polls conducted in several Western countries tend to indicate that the majority of consumers would be unwilling to buy irradiated food. Most of these surveys, however, were made by telephone or through on-the-spot interviews without providing sufficient background information on the safety, benefits, and limitations of food irradiation. Uninformed consumers often do not distinguish irradiated food from radioactive food contaminated with radionuclides.

With regard to food, consumers' attitudes tend to be conservative towards acceptance of any new food and especially new food technology. This was clearly brought out, for example, when pasteurization of milk was introduced.

When consumers are given the opportunity to offer an informed opinion or make an informed choice, the results are different. This is substantiated by opinion polls conducted in connection with the provisions of accurate, factual information which yield more positive results. In market trials of labelled irradiated foods sold alongside the non-irradiated ones, consumers willingly bought irradiated products, and in many cases, expressed a preference for the irradiated product. Marketing trials have been conducted over the past several years in Argentina, Bangladesh, Chile, China, France, Hungary, Indonesia, Israel, Philippines, Poland, Thailand, and the USA — all with results favourable to irradiated food.

ICGFI is an international group of experts designated by Governments to evaluate and advise on global activities of food irradiation. It was established under the aegis of the Food and Agriculture Organization of the United Nations, World Health Organization, and International Atomic Energy Agency.
What irradiated food products have been commercially marketed on a trial basis?

Many irradiated food products have been sold in a number of marketing trials in countries over the past 10 years. They include apples, potatoes, onions, strawberries, mangoes, papaya, dried fish, and fermented pork sausages. Consumer response to the irradiated products was always positive.

**Mangoes.** In September 1986, about 3 tons of mangoes were irradiated up to a dose of 1 kilogray in Puerto Rico to eliminate fruitfly infestation and delay spoilage. They were then flown to Miami, Florida, for marketing. They were labelled as having been irradiated and sold (with an accompanying information brochure) alongside nonirradiated mangoes at the Farmers Market in North Miami Beach. The irradiated mangoes, sold at the same or higher price than nonirradiated ones, were bought by shoppers who showed preference for the irradiated ones.

**Papaya.** In March 1987, a shipment of Hawaiian papaya was flown to Los Angeles, California, and irradiated at a dose of 0.41-0.51 kilogray to satisfy quarantine regulations. The papayas were fully labelled according to US Food and Drug Administration requirements, and then sold alongside papayas that had been hot-water dipped in Hawaii at two supermarkets in Anaheim and Irvine, California. Over 200 consumer questionnaires were completed during sales of the two lots of papaya. At the end of the day's market test, 60 kilograms of irradiated papaya and 5.1 kilograms of hot-water dipped papaya were sold, representing a ratio of more than 11:1 in favour of irradiated papaya. Two of every three participating consumers at Anaheim, and four of five at Irvine, stated that they would buy irradiated papaya again.
Irradiated Foods and the Consumer

**Strawberries.** In separate marketing trials in 1987 and 1988 in Lyon, France, seven tonnes of strawberries irradiated at 2 kilogray were put on sale by a supermarket chain. The product was labelled with the “Radura” logo plus a statement of “ionization” and was sold at slightly higher cost than nonirradiated strawberries. Consumers said they bought irradiated strawberries because of their better quality.

**Fermented pork sausages.** In 1986, a popular fermented pork sausage (Nham) in Thailand was irradiated and sold alongside nonirradiated Nham in a few supermarkets in Bangkok. Normally consumed “raw” (without cooking or heating), Nham is often contaminated by microbial pathogens including *Salmonella* and occasionally by a parasite, *Trichinella spiralis*. To control these organisms, Nham was irradiated at a minimum dose of 2 kilogray and labelled as required by the Thai Food and Drug Administration. A survey of 138 consumers in 1986 showed that 34.1% bought irradiated Nham out of curiosity and 65.9% bought it because they believed it was safe from microbes. More than nine out of 10 consumers, 94.9%, indicated that they would buy irradiated Nham again. In the 3 months during which the survey was conducted in 1986, irradiated Nham outsold nonirradiated Nham by a ratio of 10:1.

In these tests and others, the most significant factor favouring irradiated food appears to be superior quality and safety. In none of these tests, which were carried out under actual market conditions, was there evidence to indicate that informed customers will not accept irradiated foods.

**Scientific and Technical References:**


"Consumer In-Store Response to Irradiated Papayas", by C.M. Bruhn and J.W. Noell, Food Technology, (September 1987).


Are irradiated foods being sold on a regular basis?

Yes. Most irradiated food currently produced in 23 countries is destined for food processing industries and institutional markets (for example, catering services and restaurants). However, in some countries, such as France, Netherlands, South Africa, and Thailand, commercial quantities of some irradiated food items — including strawberries, mangoes, bananas, shrimp, frog legs, spices, and fermented pork sausages — have been sold on a regular basis. These irradiated food items, labelled to indicate the treatment and its purpose, have been successfully sold alongside their non-irradiated counterparts. Consumers have shown no apparent reluctance to purchase the irradiated food products.