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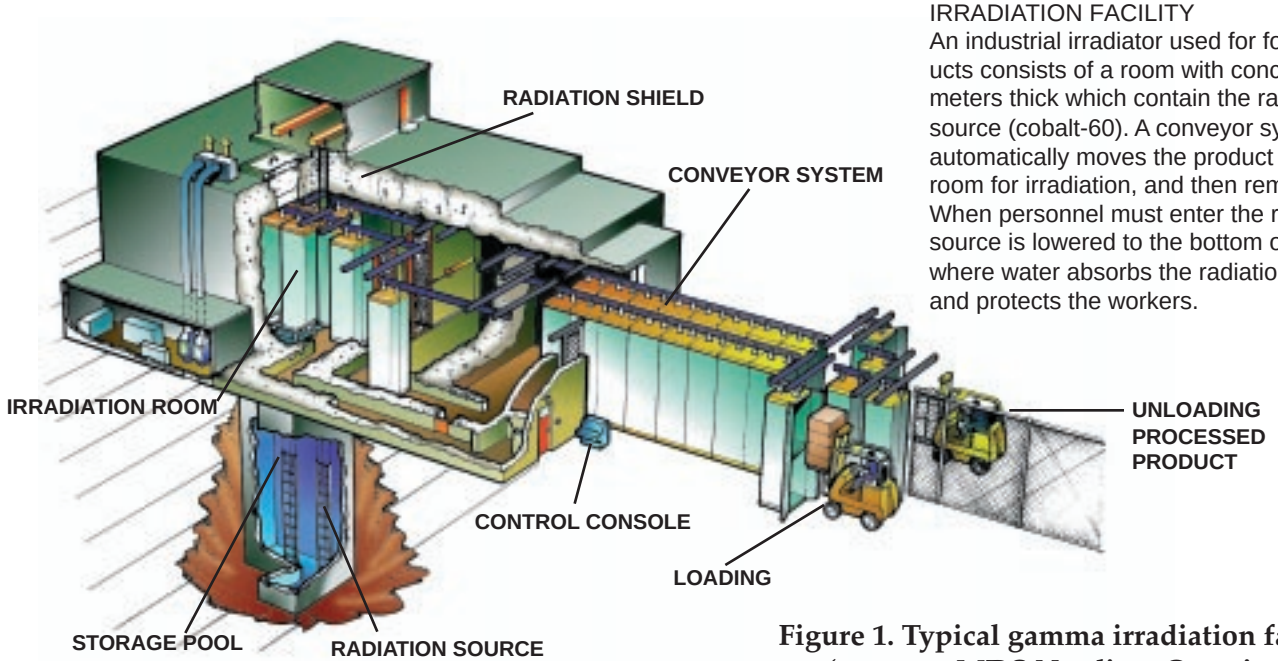
COLD PASTEURIZATION OF FOOD BY IRRADIATION

Tim Roberts, Extension Specialist, Food Safety, Virginia Tech

Food irradiation is a preservation process of exposing foods to high-energy rays to improve product safety and shelf life. Red meats, poultry, potatoes, onions, spices, seasonings, fresh fruits and vegetables may be irradiated to prevent growth of food poisoning bacteria, eliminate parasites, or delay ripening and spoilage. Also, irradiation could be used to replace chemical preservatives in foods. More than 40 years of research on food irradiation has shown that foods exposed to low levels of irradiation are safe and wholesome, and they retain high quality.

Principles of Food Irradiation

Two different processes, gamma rays or electron beams, may be used to irradiate foods. Gamma radiation is used to preserve bulk quantities of food such as boxed, frozen chicken breasts or ground beef. With this method the food is processed at the food plant, packaged with oxygen-permeable film and transported to an irradiation facility. Currently the only commercial food irradiation facility approved by the U.S. Department of Agriculture (USDA) is FOOD TECHnology Service, Inc. in Mulberry, Florida. At the irradiation facility, a conveyor transfers the palletized product to an irradiation chamber (Figure 1). Here the food is



IRRADIATION FACILITY
An industrial irradiator used for food products consists of a room with concrete walls 2 meters thick which contain the radiation source (cobalt-60). A conveyor system automatically moves the product into the room for irradiation, and then removes it. When personnel must enter the room, the source is lowered to the bottom of a pool, where water absorbs the radiation energy and protects the workers.

Figure 1. Typical gamma irradiation facility (courtesy MDS Nordion, Ontario, Canada)

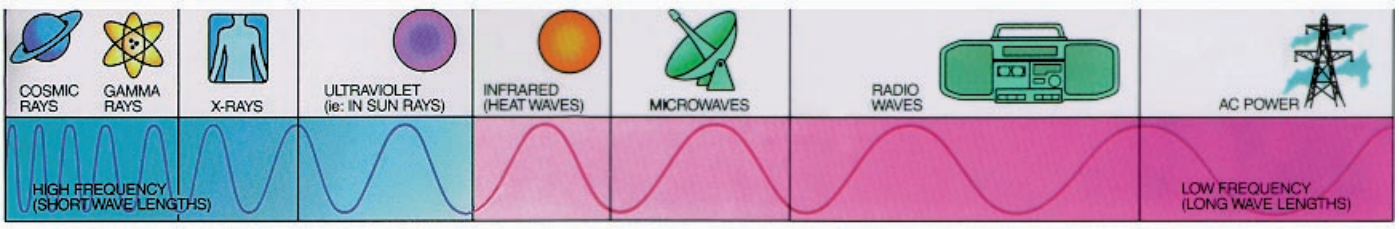


Figure 2. Electromagnetic energy spectrum (courtesy MDS Nordion, Ontario)

exposed to a controlled amount of gamma rays from a radioactive source such as cobalt-60. The gamma rays evenly penetrate the food, rapidly killing food poisoning bacteria, harmful parasites or insects without altering the nature of the food. Irradiated foods are not radioactive since the rays do not remain in the food.

The gamma radiation source consists of cobalt-60 rods in stainless steel tubes. The tubes are stored in water and raised into a concrete irradiation chamber to treat the food. The gamma rays emitted are more powerful than the rays emitted by a microwave oven (Figure 2). Rays from a microwave cause the food to heat rapidly, whereas gamma rays with much shorter wavelengths and higher frequencies penetrate the food so rapidly that little or no heat is produced. For this reason, food irradiation has often been referred to as cold pasteurization. No radioactive waste is produced at a food irradiation facility. The cobalt-60 rods slowly decay to non-radioactive nickel. A food irradiation facility does not contain a nuclear reactor. The food is only exposed to the degrading cobalt-60. As with other food preservation methods such as canning and drying, food irradiation only eliminates microorganisms currently present within the food. Therefore, the irradiated product must be handled appropriately to prevent recontamination.

Certain foods, such as hamburger patties, may also be irradiated with electron beams emitted from linear accelerators. In this method, the food is exposed to a stream of electrons that kill bacteria, parasites, or insects. This method of irradiation can only be used on foods less than 2 inches thick due to the limiting penetrating capacity of the electron beams. Unlike a gamma irradiator, linear accelerator units can be turned on and off with a switch.

The irradiation dose applied to a food product is measured in terms of kiloGrays (kGys) (Table 1). One kiloGray is equivalent to 1,000 grays (Gy), 0.1 megarad (Mrad), or 100,000 rads. The basic unit is the gray, which is the amount of irradiation energy that 1 kilogram (2.2 pounds) of food receives. The amount of irradiation applied to a food product is carefully controlled and monitored by plant quality control personnel and USDA inspectors. The irradiation dose applied to the food will depend upon its composition, the degree of perishability, and the potential to harbor harmful microorganisms. The amount of radiation that the food product absorbs is measured by a dosimeter. Highly sophisticated scientific methods can be used to test foods for radiation exposure. This would be very important for controlling imports of unlabeled irradiated products.

Table 1. Irradiation conversion units.

1,000,000 rads =	**1 megarad (Mrad)**
1 gray (Gy) =	**100 rads**
1 kilogray (kGy) =	**100,000 rads**
1 kGy =	**0.1 Mrad**
10 kGy =	**1 Mrad**

Safety Of Irradiated Foods

Irradiated foods have been found to be safe and wholesome, while maintaining flavor, aroma, and texture (mouthfeel). More than 40 years of scientific research has shown that irradiated foods do not cause cancer, genetic mutations, or tumors. For example, research supported by the U.S. Army and the USDA found 600,000 pounds of irradiated chicken fed to several generations of laboratory animals over a 6-year period to be safe and pose no toxic hazards to these animals. Also, dry milk powder irradiated at 45 kGy (four and a half-times greater than the international maximum approved level) has been found to cause no mutations or tumors in nine successive generations of laboratory animals. No adverse effects were observed in 400 Chinese human volunteers fed a balanced diet, 60 to 66 percent of which was irradiated food, over a 15-week period.

Prior to and during the 1960s, the U.S. Army conducted research on high-dose sterilization of meat products such as ham, corned beef, cooked salami, and turkey. The army found that these products could be held for many years without refrigeration. After a 10-year safety testing program, including a feeding study with human volunteers consuming 32 to 100 percent of the diet as irradiated food for seven 15-day periods within a year, the army concluded that irradiated foods are safe and wholesome. These results led NASA to provide irradiated foods for astronauts to consume during space flights (Figure 3). Also, many immuno-suppressed hospital patients on sterile diets have been fed irradiated dairy products, breads, pastry products, cereals, dry beverages, snacks, and condiments.

A misconcep- tion of irradiated foods is that un- known by-products may be produced in the food during the irradiation process and that the safety of these products is unknown. Yet, ac- cording to the Inter- national Consulta- tive Group on Food Irradiation (ICGFI), the by-products produced in foods treated with irra- diation are naturally present in foods and formed by heat processing. The Joint Expert Com- mittee on Food Irra- diation (JECFI) of the World Health Orga- nization (WHO), Food and Agricul- ture Organization (FAO) and the In- ternational Atomic Energy Agency (IAEA) concluded that irradiated foods were safe and wholesome at irra- diation levels up to 10 kGy. The FDA Bureau of Foods Irradiated Food Committee (BFIFC) found that more than 90 percent of all these compounds in irradiated foods are similar to those foods treated by other preservation methods such as freezing, drying, or heating. The BFIFC concluded that a diet consisting of food irradiated at 1 kGy (the approved level for fruits, vegetables, pork, and grains in the United States) would not contain a significant amount of these compounds. The irradiation process produces very small changes in the chemical composition of foods. These changes have not been found to be harmful or dangerous.

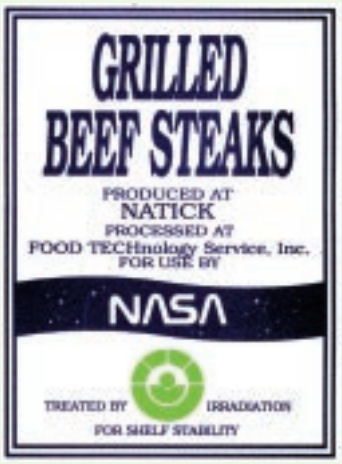


Figure 3. Label for irradiated beef steaks. (Courtesy of FOOD TECHnology Service, Inc., Mulberry, Florida.)

Foods Currently Being Irradiated

Internationally, foods such as apples, strawberries, bananas, mangoes, onions, potatoes, spices, seasonings, meat, poultry, fish, and grains have been irradiated for many years. Since 1991, Japan has irradiated more than 20,000 pounds of potatoes each year to prevent sprouting. In the Netherlands, more than 18,000 pounds of foods such as strawberries, spices, poultry, and dehydrated vegetables are irradiated daily. Belgium irradiates more than 8,000 tons of food per year. Canada irradiates potatoes, onions, wheat flour, fish fillets, spices, and seasonings. More than 35 countries have approved irradiation of some 40 different food products.

In 1986, the United States Food and Drug Administration (FDA) approved irradiation of spices and seasonings up to 30 kGy to reduce microorganisms and insects. Irradiation of spices and seasonings reduces the dependency on chemical fumigants. Fruits such as avocados, mangoes, and papayas imported into the U.S. have been approved to receive irradiation treatments of 1 kGy maximum to control non-native insects such as the Medfly. Potatoes and onions have been approved to receive 0.05 to 0.15 kGy to inhibit sprouting, while a maximum of 1 kGy can be applied to grains, such as wheat and oats, to prevent insect infestation. Raw pork has been approved to receive irradiation doses up to 1 kGy to destroy *Trichinella spiralis*, a deadly parasite.

In 1990, FDA approved the irradiation of poultry up to doses of 3 kGy to eliminate harmful bacteria such as *Salmonella* spp., *Escherichia coli* O157:H7, *Campylobacter jejuni*, and *Listeria monocytogenes*. In September of 1992, USDA Food

Safety and Inspection Service (FSIS) approved facilities to irradiate raw, packaged poultry. In December of 1997, FDA approved the irradiation of red meats up to doses of 4.5 kGy for fresh and 7.0 kGy for frozen product for the elimination of food poisoning bacteria such as *Escherichia coli* O157:H7. The irradiation and inspection of meat and poultry products is under the jurisdiction of the FSIS.

Nutritional Quality of Irradiated Foods

Food proteins, carbohydrates, and fats have been found to be relatively stable to irradiation up to 10 kGy. Minerals have also been reported to be stable to irradiation. However, vitamins A, C, E, and B1 (thiamin) tend to be susceptible to irradiation at doses of 1 kGy or above. However, these vitamins are also sensitive to heat processing. The reduction of these vitamins in foods is minimal and would not create a risk of deficiency in the diet. A joint committee of the FAO, WHO, and IAEA claim that losses of vitamins in foods treated with irradiation doses of 1 kGy or less are minimal and compatible with losses of vitamins in foods heat treated and stored for extended periods of time. Low- dose irradiation does not cause a significant decrease in the nutritional quality of foods.

The percent of vitamins lost in a food product will depend upon the irradiation dose, the food's composition, temperature of the food being irradiated, and the presence or absence of oxygen. Vitamins tend to be more susceptible to irradiation in the presence of oxygen and at temperatures above freezing. Therefore, frozen foods are normally vacuum-packed in oxygen-permeable film to minimize loss of vitamins and preserve product quality.

Consumer Response To Irradiated Foods

Consumer response to irradiated foods has been positive. In March 1987, test markets of irradiated Hawaiian papayas in two Southern California stores outsold the non-irradiated product by more than 10 to 1. During the first quarter of 1993, Carrot Top, Inc. in Northbrook, Illinois, reported irradiated strawberries outsold non-irradiated berries by a ratio of 20 to 1 when consumers were provided information on food irradiation. This store currently sells irradiated strawberries, Vidalia onions, and chicken to consumers. In July 1993, Laurenzoís Market and Italian Grocery in Miami, Florida, reported selling their first shipment of irradiated poultry (approximately 1,200 pounds) at a rate of 100 pounds of poultry per day initially followed by 40 to 80 pounds per day thereafter. The store offers irradiated as well as non-irradiated poultry to its customers. The irradiated poultry make up approximately 10 percent of the store's total poultry sales.

These results indicate that informed consumers like and will buy irradiated foods. The reasons consumers choose irradiated foods are safety from food poisoning bacteria, increased shelf life, and superior product quality. For instance, strawberries stored in the refrigerator normally mold after 5 days. However, strawberries treated with 1 kGy of irradiation have been found to be free of mold after 25 days in the refrigerator (Figure 4). To date, no single test market of irradiated foods has been unfavorable when the consumer has been provided information about food irradiation.

Consumers favor FDA approval of labeling irradiated foods with the international logo and the words "treated by irradiation," "treated with irradiation," or "irradiated" (Figure 5). Processed foods containing irradiated ingredients do not require

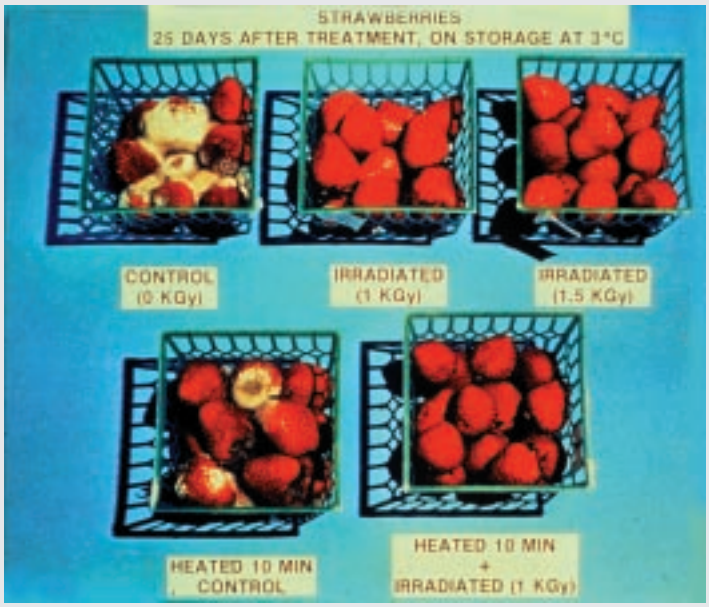


Figure 4. Strawberries treated by irradiation.

the irradiation label, nor do irradiated foods served in restaurants. The FDA considers the labeling of irradiated foods informative since preservation of foods by irradiation is no different from other preservation methods.

As with any food preservation process such as pasteurization, canning, freezing, and refrigeration, irradiation will add to the cost of food. Based on 1995 production figures and USDA Economic Research Service (ERS) estimates, consumers could expect to pay as much as 5 cents or more per pound for ground beef. Similar cost estimates have been reported for poultry. This is a small price to pay for improved product safety and increased shelf life.

Government agencies such as the FDA, USDA, FAO, and WHO have approved the use of food irradiation. The food industry has not actively pursued food irradiation since consumer response

Figure 5. Radura symbol for irradiated foods.

nationally is not known. Also, the food industry must be assured that irradiation is economical and improves quality and safety of their products. Retailers have been hesitant to place irradiated foods on their shelves in fear of boycotts and demonstrations by some citizen action groups whose claims and misconceptions about the safety of irradiated foods are unsubstantiated through years of scientific research.

As consumers become aware of the irradiation process and benefits of food irradiation, such as elimination of harmful bacteria and extended shelf life, more irradiated foods will begin to appear in grocery stores across the country.

Effects of Irradiation on Harmful Bacteria In Poultry and Meat Products

In the United States, it is estimated that six million cases or more of foodborne disease are reported annually with more than 9,000 of these cases resulting in death. These numbers are likely to increase as more individuals eat away from home and consume more convenience or processed foods. For instance, in 1993, an outbreak of *Escherichia coli* O157:H7 in Washington state resulted in the death of three children and hundreds hospitalized from eating undercooked hamburger prepared at a fast-food chain. These casualties might have been averted, if the ground beef had been irradiated or properly cooked. Irradiation at a dose level of 3 kGy or less in combination with proper handling, processing, and storage would help eliminate the incidence of foodborne disease. Irradiation doses of 3 kGy were found to eliminate more than 99 percent of food poisoning bacteria such as *Salmonella* spp., *Staphylococcus aureus, Listeria monocytogenes, Campylobacter jejuni,* and *Escherichia coli* O157:H7 in poultry and fresh meats. Irradiation destroys food poisoning bacteria and other microorganisms by altering the genetic material needed for their growth and reproduction.

Although irradiation doses of 3 kGy or less are effective in destroying most harmful bacteria, it does not prevent the growth and toxin production of *Clostridium botulinum*, the organism that produces the deadly toxin that causes botulinum. Irradiation doses greater than 30 kGy are needed to destroy this organism in foods.

Irradiation suppresses the microbiological contamination of foods and cannot be used to cover up spoiled foods. Thus, irradiation of quality food coupled with good food handling practices would reduce the incidence of foodborne disease.

Summary

Food irradiation can be used to combat foodborne diseases, including the emergence of disease causing organisms such as *Escherchia coli* O157:H7, *Campylobacter jejuni,* and *Listeria monocytogenes.* Food irradiation is not a substitute for proper handling, cooking, and storage of food. Care must be taken to ensure that irradiated foods do not become recontaminated. Also, food irradiation could be used in place of harmful fumigants used to kill mold and insects on produce and grain. Food irradiation has been studied more extensively than any other food additive, yet there is only limited application in this country.

Food irradiation has been endorsed by FAO, WHO, USDA, the American Medical Association (AMA), and the Institute of Food Technologists (IFT) as a safe and practical method for preserving a variety of foods and reducing the risk of foodborne disease. International imports and exports of fresh foods could be expanded, increasing the abundance of food worldwide. Food irradiation provides safer food, improves quality, and extends shelf life.

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