SCIENTIFIC STATUS SUMMARY

Irradiation of Food

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THE INSTITUTE OF FOOD TECHNOLOGISTS’
EXPERT PANEL ON FOOD SAFETY AND NUTRITION

The Food and Drug Administration’s (FDA) approval of irradiation for red meats in December 1997 ended a long chapter in the tumultuous history of an important food safety and preservation technology. Federal acceptance validates what food scientists have long known: that appropriate absorbed doses of radiation effectively kill disease-causing bacteria and delay food spoilage. When irradiated ground beef becomes available, consumers once again may enjoy their hamburgers rare or medium rare. Low doses of radiation can kill at least 99.9% of *Salmonella* in poultry and an even higher percentage of *Escherichia coli O157:H7* in ground beef.

This summary briefly addresses the remaining questions about food irradiation. In addition, it provides a useful summary of the regulatory history and the current state of scientific knowledge of the technology as applied to food. Federal regulators, food scientists, food processors, and consumers will write the next chapter in the story of irradiation. New challenges awaiting resolution include safely and successfully implementing irradiation in the meat and poultry processing industries; maintaining the quality of raw, irradiated meats; developing packaging suitable for irradiation; developing methods to detect irradiated foods; and educating the public about the wholesomeness of foods made safer by irradiation.

Regulatory Acceptance and Commercial Application

Research on the application of ionizing radiation to food began in earnest in the early 1950s. This processing technology was ready to be commercialized by the late 1950s. In the United States, however, passage of the Food Additives Amendment to the Food, Drug, and Cosmetics Act in 1958 effectively delayed the commercialization of irradiation for three decades. The Food Additives Amendment classified sources of radiation as food additives. The amendment, thus, required an authorizing regulation prescribing safe conditions of use and pre-market review and acceptance by the FDA. The agency has authorized ionizing radiation for several specific food uses, shown in Table 1.

Although irradiation of medical devices and disposables has a long history of use (Derr, 1993), irradiated foods were not produced commercially in the United States until 1992. Radiation is cleared for use on at least one food product in 35 countries, and irradiated foods are commercially available in 28 developing as well as developed countries (IAEA, 1995; Loaharanu, 1996). Spices are the most commonly irradiated food. Other commercially-available irradiated foods include a variety of fruits and vegetables, rice, potatoes, onions, sausage, and dried fish (in Bangladesh only). At least one irradiated muscle food (meat, poultry, and seafood) is cleared for use in 18 countries, including Chile, France, and the Netherlands.

The number of retail outlets offering irradiated foods and the amount of irradiated foods commercially available in the United States has grown slowly. Only four retail stores in the United States continuously offer irradiated foods. Use of irradiated foods has grown slightly faster in the food service sector, primarily in hospitals for reducing the potential for cross contamination in food preparation and for immune-compromised patients.

Effects of Irradiation

Irradiation exposes food to a source of ionizing radiation sufficient to create positive and negative charges. The amount of radiation energy absorbed is measured in units of grays (or kilograys, kGy). One gray equals one joule per kilogram. Radiation sources approved for food use are gamma rays (produced by the radioisotopes cobalt-60 or cesium-137), machine generated X-rays (with a maximum energy of 5 million electron volts, MeV), and electrons (with a maximum energy of 10 MeV). Depending on the dose of radiation energy applied, foods may be pasteurized to reduce...
or eliminate pathogens, or they may be sterilized to eliminate all microorganisms, except for some viruses (Crawford and Ruff, 1996; IFT, 1983). For example, low (up to 1 kGy) to medium doses (1–10 kGy) kill insects and larvae in wheat and destroy pathogenic bacteria and parasites. Low to medium doses also inhibit sprouting of potatoes and other foods and slow the ripening and spoilage of fruit. Higher doses (10-50 kGy) sterilize foods for a variety of uses such as for astronauts during space flight and immune-compromised hospital patients who must have bacteria-free food.

When molecules absorb ionizing energy, they become reactive and form ions or free radicals that react to form stable radiolytic products (Woods and Pikaev, 1994). The Council for Agricultural Science and Technology (CAST, 1989) estimated that a dose of 1 kGy would break fewer than 10 chemical bonds for every ten million bonds present, an extremely small percentage. Cooking, or applying infrared radiation to foods, produces similar changes in chemical bonds.

Even though an extremely small percentage of chemical bonds are broken when a food is irradiated, the effect can be dramatic. For example, breaking bonds in the deoxyribose nucleic acid (DNA) results in the loss of a cell’s ability to replicate. A relatively small change in the DNA of a bacterial cell can destroy the cell. The cellular destruction caused by disruption of the genetic material in a living cell is the principal effect of radiation on food (Murano, 1995a), enabling destruction of insects, inactivation of parasites, delaying of ripening, and prevention of sprouting. Ionizing radiation cannot make food radioactive.

The physical laws that govern the nature of chemical reactions and the stability of chemical substances are the same whether the enhanced molecular reactivity created by heat energy is supplied by infrared radiation, microwaves, ionizing radiation, or other sources (CAST, 1986). The radiolytic products that form when food is irradiated are generally the same as those that are formed when food is cooked. Investigators developing methods for detecting irradiated foods have identified alkylcyclobutones in some irradiated foods that were not detected in unirradiated samples. These substances may serve as markers for irradiated foods. Despite concerns expressed by those who decry the use of radiation, no unique radiolytic products of toxicological significance have been found in irradiated foods (Crawford and Ruff, 1996).

### Wholesomeness

Pauli and Tarantino (1995) prepared a comprehensive review of the information FDA requires to establish the safety of proposed applications of radiation. The agency considers four broad areas: radiological safety, toxicological safety, microbiological safety, and nutritional adequacy (Table 2). With radiological safety, the question is whether radioactivity will be induced in the food. This issue is of no concern for the currently approved radiation sources because their energy is too low to induce radioactivity.

The issue of toxicological safety raises the question: (1) Is there evidence of adverse toxicological effects that can be attributed to toxic substances produced by irradiating the food? (2) What should be tested? (3) What tests provide useful information? The questions are difficult to address because radiation leads to the absorption of ionizing energy rather than the addition of a substance. The toxicological safety of food additives has traditionally been assessed by animal feeding studies and involves determining the highest dose of a substance that causes no toxicological effects, and the application of safety factors to account for individual variability and uncertainty in extrapolating from animals to humans (Pauli and Tarantino, 1995).

To assess the changes caused in foods by irradiation and recommend toxicological testing requirements for assessing their safety, the FDA formed the Bureau of Foods Irradiated Food Committee (BFIFC). Because no evidence of toxicity attributable to irradiation of food was found, the committee recommended that foods irradiated at doses less than 1 kGy, or foods representing only a very small fraction of the diet, should be exempt from requirements for toxicological testing. FDA then organized a task group to assess animal feeding and mutagenicity studies. The group concluded that toxic effects are not expected from foods irradiated at doses below 1 kGy and concurred with the recommendation of the BFIFC. Because available data were not adequate to evaluate the safety of irradiation of all foods at doses greater than or equal to 1 kGy, the task group also recommended that the agency consider authorizations of the process on a case-by-case basis for foods that are consumed in significant amounts or that are irradiated at higher doses. Hence, the poultry petition that was cleared by FDA in 1990 (9 CFR Part 381) was considered separately because the petition requested radiation dose levels greater than 1 kGy.

With the red meat petition, however, the concept of chemi-generic clearance was used. This concept is that radiation

### Table 1

**Applications of Ionizing Radiation Accepted in the U.S. by the Food and Drug Administration.**

<table>
<thead>
<tr>
<th>Product</th>
<th>Dose (kGy)</th>
<th>Purpose</th>
<th>Date</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wheat, wheat flour</td>
<td>0.2 - 0.5</td>
<td>Insect disinfestation</td>
<td>1963</td>
</tr>
<tr>
<td>White potatoes</td>
<td>0.05 - 0.15</td>
<td>Sprout inhibition</td>
<td>1964</td>
</tr>
<tr>
<td>Pork</td>
<td>0.3 - 1</td>
<td><em>Trichinella spiralis</em> Control</td>
<td>7/22/85</td>
</tr>
<tr>
<td>Enzymes (dehydrated)</td>
<td>10 max.</td>
<td>Microbial Control</td>
<td>4/18/86</td>
</tr>
<tr>
<td>Fruit</td>
<td>1 max.</td>
<td>Disinfection, Ripening Delay</td>
<td>4/18/86</td>
</tr>
<tr>
<td>Vegetables, fresh</td>
<td>1 max.</td>
<td>Disinfection</td>
<td>4/18/86</td>
</tr>
<tr>
<td>Herbs</td>
<td>30 max.</td>
<td>Microbial Control</td>
<td>4/18/86</td>
</tr>
<tr>
<td>Spices</td>
<td>30 max.</td>
<td>Microbial Control</td>
<td>4/18/86</td>
</tr>
<tr>
<td>Vegetable Seasonings</td>
<td>30 max.</td>
<td>Microbial Control</td>
<td>4/18/86</td>
</tr>
<tr>
<td>Poultry, fresh or frozen</td>
<td>3 max.</td>
<td>Microbial Control</td>
<td>5/2/90</td>
</tr>
<tr>
<td>Meat, frozen, packaged*</td>
<td>44 min.</td>
<td>Sterilization</td>
<td>3/8/95</td>
</tr>
<tr>
<td>Animal Feed and Pet Food</td>
<td>2 - 25</td>
<td>Salmonella Control</td>
<td>9/28/95</td>
</tr>
<tr>
<td>Meat, uncooked, chilled</td>
<td>4.5 max.</td>
<td>Microbial Control</td>
<td>12/2/97</td>
</tr>
<tr>
<td>Meat, uncooked, frozen</td>
<td>7.0 max.</td>
<td>Microbial Control</td>
<td>12/2/97</td>
</tr>
</tbody>
</table>

*For meats used solely in the National Aeronautics and Space Administration space flight programs.*
Irradiation of Food
CONTINUED

The chemistry of the constituent components (e.g., water, protein, lipid, carbohydrates) among a food group produces common and predictable stable end-products. Muscle foods, for example, have similar macronutrient composition and, therefore, are expected to yield similar radiolytic products. The database of the toxicological studies completed for the poultry petition can thus be used to address toxicological questions about different meat species and fish. For foods to be irradiated above 1 kGy, FDA's principal interest is with the conditions for food irradiation (temperature, packaging atmosphere, dose range) and their impact on microbiological safety and nutritional adequacy.

The issue of microbiological safety of irradiated foods raises many questions; the two most important are: (1) Can irradiation mutate microorganisms, producing more virulent pathogens? (2) Will irradiation reduce the numbers of spoilage microorganisms, allowing pathogens to grow undetected without competition? FDA does not consider radiation-induced mutation a concern with respect to increased virulence or heat resistance since there is no evidence for such effects. In fact, radiation is much more likely to reduce the virulence of any surviving pathogens (Farkas, 1989). FDA requires evidence that radiation, under realistic conditions, achieves the intended microbiological effect without allowing Clostridium botulinum to grow and produce toxin undetected.

The two most important questions of nutritional adequacy of irradiated foods are: (1) Does irradiation result in a significant loss of any nutrient in the food under the proposed conditions of use? (2) Is the food proposed for irradiation an important dietary source of the affected nutrient? Many food processes, like cooking, alter nutrient content much more than irradiation. Trace elements and minerals are not affected by irradiation. Macronutrients such as protein, carbohydrates, and fats are not significantly affected by doses up to 10 kGy. Even with sterilization doses of 50 kGy, macronutrient losses are small and non-specific (Diehl, 1995; WHO, 1994).

Some vitamins, however, are sensitive to radiation. The amount of vitamin loss due to food irradiation is affected by several factors, including dose, temperature, presence of oxygen, and food type. Generally, radiation at low temperatures in the absence of oxygen reduces any vitamin loss in foods, and storage of irradiated foods in sealed packages at low temperatures also helps prevent future vitamin loss (WHO, 1994).

Not all vitamins have the same sensitivity to irradiation. For water-soluble vitamins, the order of sensitivity is generally: thiamin > ascorbic acid > pyridoxine > riboflavin > folic acid > cobalamin > nicotinic acid. For fat-soluble vitamins, the order of sensitivity is generally: vitamin E > carotene > vitamin A > vitamin K > vitamin D (WHO, 1994).

FDA requires that the affected vitamin(s) in the irradiated food are not significant in the overall diet. The nutritional significance of vitamin loss due to irradiation depends on the level of loss and the proportion of the irradiated food in the diet. It is doubtful that any vitamin deficiency would develop from consuming irradiated foods. For example, pork is a major source of thiamin, the most radiation sensitive water-soluble vitamin, but only 2.3% of thiamin in American's diets would be lost if all the pork in the United States were to be irradiated (CAST, 1996).

The most recent World Health Organization (WHO) review of the safety and nutritional adequacy of irradiated foods concluded that food irradiation: (1) will not lead to toxicological changes in the composition of food that would have an adverse effect on human health; (2) will not increase microbiological risk; and (3) will not lead to nutrient losses that would have an adverse effect on the nutritional status of people (WHO, 1994). Furthermore, a meeting of the Food and Agriculture Organization of the United Nations, International Atomic Energy Agency, and the World Health Organization (WHO) concluded on the basis of knowledge derived from over 50 years of research that irradiated foods are safe and wholesome at any radiation dose (WHO, 1997).

### Table 2: Information Required by the U.S. Food and Drug Administration To Establish the Safety of Irradiated Food

<table>
<thead>
<tr>
<th>Considerations</th>
<th>Question(s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Radiological Safety</td>
<td>Will radioactivity be induced in the food?</td>
</tr>
<tr>
<td>Toxicological Safety</td>
<td>Is there evidence of adverse toxicological effects that can be attributed to toxic substances produced by irradiating the food?</td>
</tr>
<tr>
<td></td>
<td>What should be tested?</td>
</tr>
<tr>
<td></td>
<td>What tests provide useful information?</td>
</tr>
<tr>
<td>Microbiological Safety</td>
<td>Can irradiation mutate microorganisms, producing more virulent pathogens?</td>
</tr>
<tr>
<td></td>
<td>Will irradiation reduce the numbers of spoilage microorganisms, allowing pathogens to grow undetected without competition?</td>
</tr>
<tr>
<td>Nutritional Adequacy</td>
<td>Does irradiation under the proposed conditions of use result in a significant loss of any nutrient in the food?</td>
</tr>
<tr>
<td></td>
<td>Is the food proposed for irradiation an important dietary source of the affected nutrient?</td>
</tr>
</tbody>
</table>

From Pauli and Tarantino (1995)
Table 3  

<table>
<thead>
<tr>
<th>Pathogen</th>
<th>D values (kGy)</th>
<th>Suspending medium</th>
<th>Irradiation temperature (°C)</th>
<th>References</th>
</tr>
</thead>
<tbody>
<tr>
<td>A. hydrophila</td>
<td>0.14 - 0.19</td>
<td>Beef</td>
<td>2</td>
<td>Palumbo et al., 1986</td>
</tr>
<tr>
<td>C. jejuni</td>
<td>0.18</td>
<td>Beef</td>
<td>2 - 4</td>
<td>Clavero et al., 1994</td>
</tr>
<tr>
<td>E. coli O157:H7</td>
<td>0.24</td>
<td>Beef</td>
<td>2 - 4</td>
<td>Clavero et al., 1994</td>
</tr>
<tr>
<td>L. monocytogenes</td>
<td>0.45</td>
<td>Chicken</td>
<td>2 - 4</td>
<td>Huhtanen et al., 1989</td>
</tr>
<tr>
<td>Salmonella spp.</td>
<td>0.38 - 0.77</td>
<td>Chicken</td>
<td>2</td>
<td>Thayer et al., 1990</td>
</tr>
<tr>
<td>S. aureus</td>
<td>0.36</td>
<td>Chicken</td>
<td>0</td>
<td>Thayer et al., 1992</td>
</tr>
<tr>
<td>Y. enterocolitica</td>
<td>0.11</td>
<td>Beef</td>
<td>25</td>
<td>El-Zawahry and Rowley, 1979</td>
</tr>
<tr>
<td>C. botulinum (spores)</td>
<td>3.56</td>
<td>Chicken</td>
<td>-30</td>
<td>Anellis et al., 1977</td>
</tr>
</tbody>
</table>

pathogenic bacteria listed in Table 3 would be controlled within this dose range. A minimum dose of 1.5 kGy would destroy at least 6 logs of E. coli O157:H7, which has a D value of about 0.24 kGy. Irradiation, therefore, would be extremely effective at eliminating this pathogen, declared an adulterant in raw beef irradiated at low dose. Cooking appears to reduce or eliminate any irradiation-induced odor. (Kropf et al., 1995; Luchsinger et al., 1996). Odor resulting from irradiation may thus be important only in raw meat. Further investigation would enable full characterization of irradiation-induced odor and better understanding of the conditions that affect its development.

Irradiation can also cause some color changes in meat, that are greatly influenced by the packaging environment. For example, irradiated vacuum packaged meat can develop a fairly stable brighter red or pink color in pork, beef, and turkey breasts (Lebepe et al., 1990; Lynch et al., 1991; Niemand et al., 1983). In the presence of oxygen, however, irradiation can cause discoloration. Grant and Patterson (1991) observed discoloration in pork irradiated in the presence of oxygen. Irradiation of frozen grass prawns at 10 kGy reduced levels of polyunsaturated fatty acids (C20:5 and C22:6) by 25–32%, possibly due to oxidation and decomposition of lipids into volatile compounds (Hau et al., 1992). The threshold dose for development of irradiation flavor in the frozen grass prawns was 4.5 kGy.

The extent of chemical changes that occur in the frozen state is less than that in non-frozen food due to decreased mobility of free radicals. With less mobility in the frozen state, free radicals tend to recombine to form the original substances rather than diffuse through the food and react with other food components (Taub et al., 1979). Irradiating foods at appropriate doses and under certain conditions, such as in a reduced oxygen or oxygen-free atmosphere, packaging, and the frozen state, can minimize or avoid the development of objectionable off-odors and flavors. Irradiated meat will be successful in the market place only if consumers are satisfied with its sensory quality.

- **Packaging**. To obtain the full benefit from the potential to reduce levels of microorganisms, eliminate pathogens, and prevent cross-contamination, muscle foods should be packaged before irradiation.
Irradiation of Food

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Irradiation of packaging film may result in evolution of gases, such as hydrogen, and production of low-molecular weight hydrocarbons and halogenated polymers (Kilcast, 1990). The impact of irradiation on the packaging material itself must, therefore, be considered (Lee et al., 1996).

Materials used to package foods before irradiation must be accepted for such use by the FDA. Acceptable materials are listed in 21 CFR 179.45. Any coextruded or laminate multicomponent films, commonly used for packaging non-irradiated muscle foods, must be accepted by FDA before use in food irradiation.

At radiation doses accepted for food, only low-molecular weight polymers and gases have the potential for migrating into the product and influencing product quality. Taint-transfer problems, for example, have been observed when the commonly used fresh meat overwrap polyvinylchloride (PVC) was irradiated at 3.9 kGy (Kilcast, 1990). PVC, however, is not accepted by FDA for use in food irradiation. Antioxidants used in packaging films may also be significantly degraded, although migration of antioxidants into the food product has not been observed (Buchalla et al., 1993).

The suitability for food irradiation of new types of polymeric packaging material, including co-extrudates and multilayer laminates requires further investigation. In addition, additives, adhesives, and printing materials should also be screened (Kilcast, 1990). Determination of the threshold level of migration of film components, resins, and additives is required to expand the availability of FDA-approved polymeric films. With FDA approval of individual film components, film manufacturers would be able to develop film structures that would have de facto FDA approval without having to petition for approval of each new film structure.

Detection of Irradiated Foods

Development of food irradiation detection methods, useful for regulatory compliance purposes, is an active area of investigation. Stevenson (1992) reviewed progress of several methods. Detection methods would likely accelerate approval of additional food irradiation applications and would enhance international trade of irradiated foods.

Because there are no major chemical, physical, or sensory changes in irradiated foods, detection methods must focus on minute changes. Gildewell et al. (1993) prepared a comprehensive review of over 200 references relating to detection methods for irradiated foods. Generally, detection methods focus on chemical, physical, histological, morphological, and biological changes in the foods.

Lipids and DNA are particularly sensitive to ionizing radiation. Crone et al. (1992) detected 2-alkyl-cyclobutone, a cyclic compound formed from fatty acids in irradiated but not cooked lipid-containing foods. An interlaboratory comparison of the cyclobutone method correctly identified, with no false positives, 99% of 134 samples (ADMIT, 1994). Detection of hydrocarbons from irradiated lipid-rich foods is also a promising detection method. In an interlaboratory comparison of irradiated and non-irradiated chicken, 93% of 239 samples were correctly identified. False negative results occurred only in samples irradiated at 0.5 kGy (ADMIT, 1994).

DNA base damage, single-strand and double-strand DNA breaks, and crosslinking between bases are the main effects of irradiation. Detection and quantification of these DNA changes hold some promise for determining that an uncooked food has been irradiated. Further development is needed to distinguish irradiation-induced DNA changes from those caused by other processing treatments (Stevenson, 1992).

Techniques for detecting measurable changes in physical properties of foods, such as cell membrane damage, hold potential. Detection methods for membrane damage include measurement of electrical impedance, viscosity, electric potential, electron spin resonance, and thermal and near-infrared analysis (WHO, 1994). Hayashi (1988) reported that electrical impedance may be effective in determining irradiation of potatoes. Electron spin resonance appears effective for detecting irradiated bone-containing food and possibly shellfish (Derosiers, 1989; Gray and Stevenson, 1989).

Thermoluminescence (TL) has been successfully used to identify over 20 irradiated spices (Heide and Bögl, 1990). Sanderson (1991) demonstrated that contaminated minerals in spices are responsible for their TL. The use of TL for field crops, such as vegetables, fruits, and grains would be possible, as they all contain some minerals (WHO, 1994).

Changes in cell structures due to irradiation may be measurable by histological and morphological methods. Measuring the percentage germination of viable seed in fruits and the microscopic changes in cell structure could indicate whether the food has been irradiated. Because such measurements can take from days to weeks to complete, the methods may be impractical.

Determining the ratio of viable to total (viable and dead) bacteria on a food using aerobic plate count and the direct epifluorescent filter technique could determine if the food has been irradiated (WHO, 1994). The technique becomes limited, however, if the initial contamination before irradiation is very low, radiation dose is very low, or the food was irradiated to delay ripening rather than to pasteurize. Differences in radiation sensitivity of Gram-negative bacteria and Gram-positive bacteria may be useful. If a large number of Gram-positive bacteria, which are not as sensitive to irradiation as Gram-negative bacteria, are found on a food concurrent with a very low number of Gram-negative bacteria, it is likely that the food has been irradiated. The assumption would have to be made, however, that the initial bacterial contamination on the food is a normal mix of Gram-negative and Gram-positive microorganisms.

In summary, there are several promising techniques to screen and detect a few irradiated foods. No one technique is likely to be applicable to all food materials. Methods likely to become internationally accepted protocols are hydrocarbon and cyclobutone for lipid-containing foods, electron spin resonance for bone-containing food, and thermoluminescence for foods containing silicate.
minerals. Considerably more collaborative work is necessary to develop universally accepted methods for detecting irradiated foods of all types.

**Labe**

Prior to the passage of FDA reform legislation (Public Law 105-115) in November 1997, irradiated foods at the wholesale level were required to bear either the phrase “Treated by irradiation, do not irradiate again” or “Treated with radiation, do not irradiate again.” At the retail level, food labels were required to bear the international radura symbol along with either of the statements “treated with radiation” or “treated by irradiation.” The regulation for these labeling requirements (FDA, 1986), issued by FDA under its statutory authority within the Federal Food Drug and Cosmetic Act, permitted additional statements about the purpose of the treatment process and the type of radiation used in the treatment. The food provisions of the 1997 FDA reform legislation directed the agency to review its labeling rule and, as appropriate, revise it so that the disclosure statement is not more prominent than the declaration of ingredients. The radura symbol was not excluded as a means of making an irradiation disclosure.

**Consumer Acceptance**

Irradiated foods marketed in numerous countries were judged superior by consumers and have sold well (Bruhn, 1995). The successful sale of these products, although limited to four stores in the United States, shows that consumers will accept irradiated food. Large segments of the population, however, have not had the opportunity to purchase these foods. Communication with consumers is believed to be critical for expansion of irradiated food markets. Consumer acceptance of irradiated food increases when consumers are provided with information about specific advantages of the radiation process (CAST, 1996).

A survey conducted by Resurrection et al. (1995) showed that 72% of respondents were aware of irradiation, but 87.5% of those did not know much about it. Survey participants expressed less concern about food irradiation than food additives, pesticide residues, animal drug residues, growth hormones, and bacteria. Risks to workers and the environment were among the top concerns expressed about irradiation. Further, Resurrection et al. (1995) found that 45% of the consumers would buy irradiated food, 19% would not buy it, and the others were undecided. Bruhn (1995) reported that the number of consumers concerned about the safety of irradiated food decreased from 42% to 35% in the last six years and was less than the number concerned about pesticide residues, microbiological contamination, and other food-related issues. Shin et al. (1992) reported that consumers were willing to pay to up to $0.81 per meal, more than 10-fold greater than the cost of irradiating food (Morrison, 1989), to avoid foodborne illness.

**Summary**

Irradiation of food can effectively reduce or eliminate pathogens and spoilage microorganisms while maintaining wholesomeness and sensory quality. Selection of appropriate treatment conditions can minimize or prevent objectionable changes in food quality. Methods to detect foods that have been irradiated are becoming internationally accepted. When informed of the benefits of irradiation, consumers are willing to purchase irradiated foods, even at higher cost.

**References**


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Loaharanu, P. 1996. Historical developments on food irradiation. Presented at Control of Foodborne Illness: Irradiation and Other Non-thermal Treatments, sponsored by the National Center for Food Safety and Technology and the Institute of Food Technologists in cooperation with the International Consultative Group on Food Irradiation, Rosemont, Ill., May 13-15.


