Irradiating Ground Beef To Enhance Food Safety

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Insufficiently cooked ground beef was identified as the cause of a 1993 outbreak of *Escherichia coli* O157:H7 illness in the Western United States when four children died and over 700 people became ill. The magnitude and media coverage of this and other recent foodborne illness outbreaks have helped elevate public awareness of foodborne microbial pathogens.

The food industry and Federal agencies are enhancing their efforts to improve and ensure the safety of U.S. foods. These efforts include providing consumers with safe food handling information; revamping the inspection systems for meat, poultry, and seafood; and exploring alternative production processes to reduce pathogen contamination in animals and foods. One of the processes believed to be effective in reducing pathogen contamination is irradiation.

Irradiation can offer consumers safer foods by controlling or reducing microbial pathogens which cause foodborne illness (see box). Irradiation can also extend the shelf-life for some perishable food products, such as potatoes and strawberries. In the United States, irradiation is approved to control insects in foods and to delay ripening and sprouting in fresh fruits and vegetables. Federal regulators have also approved irradiation to decontaminate spices and dried vegetable seasonings. Among meat, poultry, and seafood products, Federal regulators have approved irradiation for pork and poultry. Approval of irradiation of seafood and other meats—including ground beef—is pending Federal review.

Technical feasibility and regulatory approval of irradiation do not ensure its commercial adoption by the food industry. For companies to adopt irradiation, they must find that irradiation improves food quality and safety at a lower cost than do other technologies and they must be convinced that consumers will buy irradiated food products.

Other processes, such as chemical and heat treatments, can also kill insects, mold, and microorganisms, including microbial pathogens in

Irradiation Kills Foodborne Pathogens

Irradiation is a process that exposes products to ionizing radiation. Ionizing radiation has sufficient energy to remove electrons from atoms, creating positive and negative charges that harm or kill the rapidly growing cells of insects, molds, and microbial pathogens.

The U.S. Food and Drug Administration (FDA) permits three types of ionizing radiation to be used on foods: gamma rays (from radioactive isotopes cobalt-60 and cesium-137), high-energy electrons, and x-rays. The latter two types of radiation are produced by electron accelerator machines powered by electricity. FDA has established maximum energy levels for these machines to prevent the treated foods from becoming radioactive. The energy levels of the gamma rays are too low to induce radioactivity.

The effects of the radiation depend on the dose absorbed by the food, measured in kilograys (kGy). Doses of 2.5 to 3.0 kGy are sufficient to control or reduce many of the foodborne pathogens, such as *Salmonella, Escherichia coli (E. coli)* O157:H7, and *Vibrio vulnificus*, that may be found in or on meat, poultry, and seafood. Higher doses would be needed to control or reduce viruses and the spores of spore-forming bacteria, such as *Clostridium botulinum*.

Radiation doses of 2.5 to 3.0 kGy do not make meat, poultry, and seafood sterile and shelf- stable. Meat, poultry, and seafood irradiated at these doses are still perishable, and must be refrigerated and handled properly to be protected from recontamination.

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food. However, chemicals can leave residues, and heating a food changes its texture, color, and flavor. Irradiation, on the other hand, achieves its effects without significantly raising the food's temperature, leaving the food closer to its unprocessed state. Some studies have found that irradiation can create off-flavors, odors, and discoloration in beef and chicken, although other studies found no such effects. Irradiation dose, product temperature, and packaging used during irradiation play a role in the extent of these effects.

Irradiation Approved for Pork and Poultry, But Not Yet Beef

Use of irradiation on foods requires approval by the U.S. Food and Drug Administration (FDA). In the case of meat and poultry, USDA's Food Safety and Inspection Service (FSIS) must also grant approval. At the current time, Federal regulators have approved two uses of irradiation for meat and poultry: inactivating *Trichinella spiralis* (the parasite responsible for causing trichinosis) in fresh or previously frozen pork, and controlling *Salmonella*, and other pathogens, including *Campylobacter* and *Listeria monocytogenes*, in uncooked poultry. Although irradiation of pork to control *Trichinella spiralis* was approved in 1986, it has never been used commercially in the United States.

FDA approved irradiation of poultry to control foodborne pathogens in 1990, and FSIS gave its approval in 1992. Doses of 1.5 to 3.0 kilograys (kGy) can be used on fresh or frozen uncooked whole carcasses and parts, including ground, hand-boned, and skinless poultry, as well as mechanically separated poultry products. Cooked or cured poultry products or those containing added ingredients may not be irradiated under the regulation.

To reduce the possibility of recontamination, poultry must be irradiated in its final retail package. The packaging must allow oxygen, but not moisture or microorganisms, to enter and leave the package. Retail packages of irradiated poultry must carry the statement "Treated with Radiation" or "Treated by Irradiation" and the logo shown below.

In 1993, Vindicator, Inc. (now FOOD TECHnology Service, Inc.), of Plant City, Florida, began irradiating poultry products for the retail and foodservice markets. Currently, all of FOOD TECHnology Service, Inc.'s, irradiated poultry goes to healthcare and foodservice outlets.

In the summer of 1994, Isomedix, Inc., in Whippany, New Jersey, petitioned FDA to approve irradiation of nonfrozen red meats with a maximum dose of 4.5 kGy and frozen red meats with a maximum dose of 7 kGy to control foodborne pathogens (the radiation dose for frozen meat must be higher to achieve the same pathogen destruction). The petition includes ground meat as well as cuts. FDA is reviewing the petition, and FSIS must grant approval before irradiation can be used on beef in the United States.

Irradiated foods must display this international symbol, which must be printed in green.

Pathogens in Ground Beef Pose Health Risks and Costs

Foods most likely to carry pathogens are high-protein, nonacid foods, such as meat, poultry, seafood, dairy products, and eggs. Ground beef poses higher food-safety risks than other cuts of beef because the grinding process spreads any pathogens that may be present on the surface of the meat throughout the ground beef. Also, an individual hamburger patty may contain meat from many cattle, thereby increasing the risk of contamination. When the hamburger patty is insufficiently cooked, pathogens in the middle of the patty can survive. Whether consumers get sick depends on a number of factors, including the type and number of pathogens ingested and the health of the individual. Two illnesses associated with ground beef are *E. coli* O157:H7 disease and salmonellosis.

E. coli O157:H7 disease

According to the American Gastroenterological Association, between 10,000 and 20,000 cases of *E. coli* O157:H7 disease occur each year in the United States. The disease usually produces a mild gastrointestinal illness that occurs 3 to 5 days after eating contaminated food. However, *E. coli* O157:H7 disease can result in two serious illnesses requiring hospitalization—hemorrhagic colitis and hemolytic uremic syndrome.

Hemorrhagic colitis is distinguished by the sudden onset of severe abdominal cramps and diarrhea which is often bloody. Approximately 16 percent of the annual cases of *E. coli* O157:H7 disease develop hemorrhagic colitis, mostly young children.

Less than 5 percent of *E. coli* O157:H7 disease cases develop hemolytic uremic syndrome. However, it is a severe, life-threatening illness characterized by red blood cell destruction, kidney failure, and neurological complications, such as seizures and strokes. Most hemolytic uremic syndrome cases occur in children under 5 years old, although the elderly may also be at risk.

The U.S. Centers for Disease Control and Prevention (CDC) estimates that 49 percent of the annual cases of *E. coli* O157:H7 disease (4,900 to 9,800) are due to consumption of insufficiently cooked ground beef. USDA's Economic Research Service (ERS) estimates that these cases result in $196 million to $441 million, respectively, in annual medical costs and productivity losses. (The range of costs reflects the range of estimated cases; all illness costs are in 1995 dollars.) Medical costs include expenses for doctor visits, medicine, and hospital care. Productivity losses refer to wages lost from missing work due to illness or premature death.

Salmonellosis

The CDC estimates that 800,000 to 4 million cases of salmonellosis occur each year in the United States. Illness from the bacterium *Salmonella* usually appears 6 to 72 hours after eating contaminated food and lasts for a day or two. Common symptoms are nausea, diarrhea, stomach pain, and sometimes vomiting. In rare cases, salmonellosis, like many other bacterial and parasitic infections, can cause chronic disease syndromes, such as arthritis and meningitis. Although the illness is generally regarded as a relatively mild disease, death can occur in some cases—especially for the very young, very old, or immunocompromised.

USDA estimates that 3 percent of the annual cases of salmonellosis (24,000 to 120,000 cases) are attributed to consumption of insufficiently cooked ground beef. ERS calculates that the annual medical costs and productivity losses for these cases range between $30 million and $111 million, respectively. Although more people are stricken with salmonellosis than with *E. coli* O157:H7 disease from eating ground beef, medical costs and productivity losses from salmonellosis are lower because the disease is generally less severe.

Therefore, annual medical costs and productivity losses related to salmonellosis and *E. coli* O157:H7 disease from consuming ground beef total between $226 million for the lower end of the estimated annual number of cases to $552 million for the higher end of the range (table 1).

Table 1

Two Illnesses Related to Ground Beef Consumption Cost Up to Half a Billion Dollars a Year

Illness	Estimated cases per year	Estimated medical costs and productivity losses[1]
	Number	*Million dollars*
Salmonellosis	24,000-120,000	30-111
E. coli O157:H7 disease	4,900-9,800	196-441
Total	28,900-129,800	226-552

Note: [1]In 1995 dollars.

Irradiating Ground Beef Can Produce Societal Benefits

Societal benefits from irradiating ground beef would come from the savings from fewer foodborne illnesses. If the savings exceed the industry costs of irradiation, there are positive net societal benefits. FDA and FSIS have not approved irradiation of ground beef, so we have no commercial experience from which to derive costs for the irradiation treatment.

A 1989 ERS study on the costs of irradiating chicken and other foods gives us an idea of the costs of irradiating ground beef. The 1989 study looked at the investment and operating costs for various sized hypothetical irradiators physically integrated into chicken processing plants. The study assumed the plants had to be fitted with thick concrete walls and labyrinth arrangements to shield workers from the radiation. The volume of food irradiated is critical to unit costs because of the multimillion dollar initial investment required to add irradiation equipment and shielding to a plant.

Some of the larger beef processing plants in the United States that prepare ground beef for fast-food establishments and retailers handle up to 250,000 pounds a day, or about 65 million pounds a year, assuming the plant operates 5 days a week, year round. In the 1989 study, it cost 1.3 cents per pound to irradiate 50 million pounds of food a year. Irradiators treating smaller volumes would incur higher treatment costs per pound. For example, irradiation costs were close to 4 cents per pound for an irradiator treating 12 million pounds of food a year.

The size of the net societal benefits depends on the cost of irradiating ground beef and the extent of the foodborne illnesses prevented. Technical and economic considerations make it unlikely that the entire

Table 2
Net Benefits of Irradiating Ground Beef Depend on Costs[1]

Assumed cost per pound to irradiate	Range of estimated societal benefits[2]	Estimated industry costs	Range of estimated net benefits[2]
		Million dollars	
1.6 cents	56.4 to 137.7	28.3	28.1 to 109.4
5 cents	56.4 to 137.7	88.5	-32.1 to 49.2

Notes: [1]Benefits and costs are in 1995 dollars. Table assumes that by irradiating 25 percent of the U.S. ground beef supply, 25 percent of salmonellosis and *E. coli* O157:H7 disease associated with ground beef consumption would be prevented. [2]Range is due to the uncertainty in the annual number of foodborne illness cases.

U.S. ground beef supply would be irradiated if regulatory approval were granted. In the United States, if 25 percent of the 7 billion pounds of ground beef consumed in 1995 was irradiated and this treatment successfully prevented 25 percent of the ground-beef-caused salmonellosis and *E. coli* O157:H7 disease, $56.4 million to $137.7 million in medical costs and productivity losses would have been saved.

Irradiating 25 percent of the U.S. ground beef supply is estimated to cost the industry $28.3 million per year. This estimate is based on the assumption that all meat processors incur the same treatment cost, regardless of size. We also assumed the treatment cost of irradiation is 1.6 cents per pound by adjusting the 1.3-cents per pound irradiation cost from the 1989 ERS study by the producer price index for capital equipment to approximate the higher costs that meat processors would face in building and operating an irradiator in 1995. Comparing these costs and benefits yields net societal benefits of $28.1 million to $109.4 million per year (table 2). Therefore, the savings from reduced cases of salmonellosis and *E. coli* O157:H7 disease from consumption of ground beef outweigh industry costs of irradiating the food.

This 1.6-cents per pound treatment cost understates the cost of irradiation for smaller volume plants and for plants that do not have irradiation facilities on site. A meat processing plant that sends its products to a contract irradiator would be charged a fee for the irradiation treatment and for shipping. Assuming a higher irradiation cost of 5 cents per pound (roughly equal to the 4-cents per pound cost from the 1989 study when adjusted to 1995 prices) for all meat processing plants, it would cost $88.5 million to irradiate 25 percent of the U.S. ground beef supply. Under the lower societal benefits estimate of $56.4 million, industry costs for irradiation are $32.1 million higher than the societal benefits from saved medical costs and productivity losses (table 2). When societal benefits are estimated at $137.7 million, societal benefits outweigh industry costs for irradiation by $49.2 million.

The 1989 irradiation study reflected technology at the time of the analysis. Several U.S. engineering companies are trying to develop both isotope and electron accelerator systems that can more easily fit into a plant's numerous processing lines. These "on-line" irradiation units are being designed to be self-shielding and not require the separate concrete irradiation chamber assumed in the ERS study. The designers of these systems anticipate treatment costs will be lower than those of the present food irradiation systems.

Potential Market for Irradiated Meats

Despite scientific evidence of the effectiveness and safety of irradiation and regulators' approval of selected uses of the process, few food processors and retailers are offering irradiated products. Some processors and retailers are uncertain about whether consumers will buy irradiated products and fear boycotts threatened by groups opposed to food irradiation.

These groups claim that irradiation may cause genes to mutate and become cancerous. They also argue that long-term health effects from consumption of irradiated foods have not been examined thoroughly and are, therefore, unknown. Some people oppose irradiating food because they regard this as an act of tampering with nature. Others question the need for food irradiation, calling for foodborne illness to be minimized by more stringent Government inspection, higher food-safety standards, and more careful food preparation practices by consumers.

While some consumers may not be willing to buy irradiated meat, recent consumer surveys suggest that there may be potential markets for irradiated meat.

In a 1996 Food Marketing Institute telephone survey of adult grocery shoppers, 47 percent of the 1,007 respondents had heard nothing about irradiation, the purpose of which was described as "to reduce spoilage and harmful bacteria without leaving residues or affecting product flavor." Seventy percent of those who had some knowledge of irradiation, however, stated that they would likely buy "a food product like strawberries, poultry, pork, or beef if it had been irradiated to kill germs or bacteria." By comparison, 58 percent of those who had some knowledge of irradiation said they would buy irradiated food if it had been irradiated “to keep products fresh longer.”

Similar findings were also noted in a study conducted for the American Meat Institute Foundation. In a 1993 national telephone survey of 1,005 adults, 54 percent of the respondents said they would buy irradiated rather than nonirradiated meat after being told that irradiation can kill the bacteria that cause foodborne illness and are contained in raw meat. Furthermore, 60 percent said they were willing to pay 10 cents more than the regular price of $2.00 for hamburger “with bacteria levels greatly reduced by irradiating the meat.”

Market evidence also demonstrates the extent of acceptance of irradiated foods. For example, Carrot Top, Inc., a grocery store in Northbrook, Illinois, introduced irradiated produce and chicken for sale in 1993, after a consumer education campaign to explain relevant issues of the technology. The irradiated boneless, skinless chicken breasts were priced competitively with similar chicken breasts in local stores. According to the firm, the irradiated chicken breasts sold well. Carrot Top, Inc. has not carried irradiated chicken since mid-1995 because of lack of supply, but still carries irradiated fruits and vegetables.

In a 1995-96 market experiment by Kansas State University, about 40 percent of shoppers at two grocery stores in Manhattan, Kansas, chose irradiated chicken over the store brand when the two products were priced the same. The proportion of shoppers who purchased irradiated chicken rose to 60 percent when the irradiated chicken was priced 10 percent lower than the store brand chicken.

Education about food irradiation appears to increase consumers’ willingness to purchase irradiated ground beef. After answering a questionnaire on food safety and irradiation, 52 percent of the 104 consumers in a simulated supermarket setting experiment in Georgia purchased ground beef labeled as irradiated rather than regular ground beef when both products were priced the same. After the participants were given more information on irradiation, 71 percent purchased ground beef labeled as irradiated when priced the same as regular ground beef. (The ground beef labeled irradiated had not actually been irradiated, and the participants were informed of this after the experiment.)

Outlook for Ground Beef Irradiation Uncertain

The marketing of irradiated ground beef faces hurdles. Irradiation of ground beef awaits approval by FDA and FSIS. Although irradiating ground beef would likely reduce foodborne illness and extend shelf-life, there may be insufficient demand. To date, the market for irradiated pork has not developed, while the market for irradiated poultry is limited primarily to healthcare and foodservice establishments.

Irradiated ground beef may be more suited to fill these niche markets. Some consumers are at greater risk from foodborne illnesses because of their age or weak health, or because they do not have control over their own cooking, such as with nursing home residents and hospital patients. For example, Marriott, at the request of their clients, buys irradiated chicken from FOOD TECHnology Service, Inc., to use in their foodservice operations in hospitals and nursing homes in some Southeastern States. Some large fast-food chains serving hamburgers may also be interested in irradiation’s potential for preventing foodborne illness outbreaks that may be traced back to their restaurants.

The food industry needs more certainty of sufficient consumer acceptance of food irradiation before adopting the technology. Also, producers, retailers, and foodservice operators will consider the cost of irradiation compared with other technologies for reducing pathogen contamination of foods.

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