THE FOOD ZAPPERS

Do the advantages of food irradiation outweigh its potential risks?

BY JUDITH ANNE GUNTHER

The message to the Washington State Department of Health was the first sign that a serious health crisis was about to explode: In just three days, nearly a dozen patients had been admitted to Children's Hospital and Medical Center in Seattle with bloody diarrhea. Furthermore, several were suffering from hemolytic uremic syndrome, a dangerous condition that affects the kidneys and blood. Both symptoms are indicators of food poisoning caused by *Escherichia coli* 0157:H7, a toxin-producing bacterium.

That was the situation on Jan. 13. 1993. By Jan. 22, health officials had counted more than 100 cases of *E. coli* food poisoning and one death in Washington state as well as another death in Boise, Idaho. By Feb. 8, the numbers skyrocketed—officials had identified 400 confirmed cases in Washington state, even as they evaluated about 100 more reports. By the end of February, the outbreak was over; the casualties totaled more than 600 possible cases, 477 confirmed cases, 144 hospitalizations, and 3 deaths.

The source, the officials discovered, was bacteria-tainted, possibly undercooked beef patties sold by the Jack in the Box fast-food chain.

Ironically, the outbreak occurred exactly one year after the first sale of produce treated with a technique that might have avoided the hamburger havoc—irradiation. A year before, irradiated strawberries had appeared on the shelves of a grocery store in Florida—the first time irradiated food was sold commercially in the United States, except for a limited number of treated spices and a handful of test-market trials.

Irradiation, say experts, can destroy the bacteria, fungi, parasites, and insects that infest food products. Not only do some of these intruders cause food to spoil more quickly, but if consumed they can make people dangerously ill, as with *E. coli* and other pathogens. As the supervisor of one irradiation facility says succinctly: "Radiation kills living cells. That's what we use it for."

The procedure is simple: Expose food products to gamma rays from radioactive cobalt, to X rays, or to a beam of high-energy electrons. A small dose of radiation extends the shelf life of fruits and vegetables by a week or two. A slightly larger dose kills most disease-causing microorganisms in beef and poultry. And even larger doses will sterilize foods, giving them a shelf life of years (see "How Much Is Enough?").

The technique is not new; in fact, it has been applied to certain spices sold in the United States since the mid-1980s. In a few stores that are routinely supplied with irradiated products, the treated fruits and vegetables are advertised as such in supermarket circulars. Now, Vindicator Inc., a facili-

TOM WHITE

HOW MUCH IS ENOUGH?

The FDA [illegible] the amount of [illegible] of food can [illegible] [illegible] kGys). A dose of 0.01 kGy would be lethal to humans. A [illegible] of approximately 30 kGys, or [illegible] most food

SELECTED FDA APPROVALS

	Purpose of radiation	Dose (kGys)	Date of approval
Wheat, flour	Insect disinfestation	0.2-0.5	1963
Spices	Decontamination/Insect disinfestation	30.0	1983
Pork	Control of *Trichinella spiralis*	0.3-1.0	1985
Fresh fruits and vegetables	Delay of ripening	1.0	1986
Poultry	Bacterial decontamination and extended shelf life	1.5-3.0	1990

SOURCE: COUNCIL FOR AGRICULTURAL SCIENCE AND TECHNOLOGY

ty near Tampa, Fla., irradiates poultry. And many experts are advocating government approvals for irradiated beef, eggs, pork, seafood, and other products.

Not everyone agrees that the benefits of food irradiation outweigh the possible risks. Dr. Donald Louria of the University of Medicine and Dentistry of New Jersey in Newark warns that irradiation destroys important nutrients. Other experts worry that the irradiation process may form toxic, possibly carcinogenic, compounds in the food. And some people object to the possibility of more radioactive cobalt and related materials, used in the irradiation process, being transported on our highways.

The opponents say more studies need to be done to ensure the safety and wholesomeness of irradiated food. Boosters of the technique argue that the situation is little different from the efforts, decades ago, to pasteurize milk.

Before 10:00 a.m., the Florida sun already scorches the landscape, and laborers in the strawberry fields hurry to pick the fruit before the temperatures soar higher. If those berries are bound for a market in Chicago, later that day they will be trucked a few miles down Highway 60 to the Vindicator plant for a quick bath of gamma rays.

This morning the cool, cavernous loading area of the Vindicator plant is nearly empty, save for a roving forklift that is moving wooden pallets. On one side are the receiving and shipping docks, flanked by refrigerated rooms where produce is arranged on pallets before being irradiated. Along the opposite wall, 24 huge, boxy metal carriers, each nearly 18 feet tall and capable of holding 8,000 pounds, hang motionless in a row, suspended from an overhead monorail system. When a shipment arrives, these carriers are loaded with pallets of fruit or vegetables, or frozen chicken. They're then conveyed on blue- and orange-painted beams by air cylinders through a metal gate, the entrance to the mazelike path that leads to the irradiation cell.

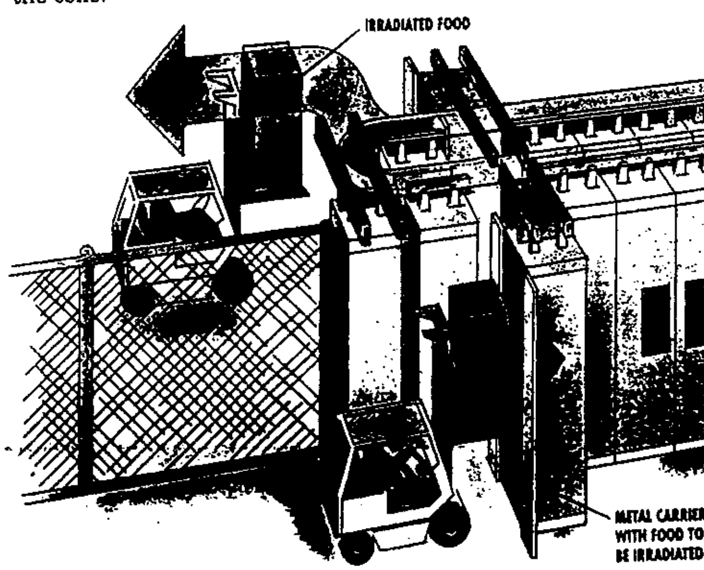
That irradiation cell, explains Vindicator supervisor Edward Sullivan, "is probably one of the safest rooms in the world." He is referring to the six-foot-thick, steel-reinforced concrete walls that fortify the 20-by-35-foot room like a modern-day citadel. The ceiling, pocked with emergency entrance portals, stands nearly 20 feet above our heads. The floor, also a thick slab of concrete, wraps around a square, stainless-steel-lined pool of water, 14 feet long on each side and 28 feet deep. Submerged in that pool is the source of radiation, the radioisotope cobalt-60.

Vindicator has 3.3 million curies of cobalt-60 packed into 400 17.7-inch-long, 0.5-inch-diameter stainless-steel pencils, or rods, which are bolted to a metal rack. The facility stores the radioactive material ten feet below the water's surface; the water acts as a shield against the intense flood of gamma rays. In the dark pool, the orderly rows of pencils glow a pure, neon-bright blue—the effect, called Cerenkov radiation, is caused by the passage of gamma rays as they speed through the water.

The rack of rods is suspended from hydraulically actuated cables; when the facility processes food, these cables pull the rack up out of the pool, drenching the entire cell in radiation. One by one, the food-laden carriers move in a slow waltz around the rack of cobalt-60, halting briefly at eight different positions along the route, exposing first one side, then the other to the radiation. If the carriers hold strawberries, each carrier stays in the room just eight minutes; if it holds frozen poultry, the treatment may last 20 minutes.

Cobalt-60 is derived from cobalt-59, a silvery white element that is shaped into one-inch-long slugs, then nickel-plated. Sixteen slugs fit into a 17.7-inch-long pencil. These are then placed in a nuclear reactor, where they are bombarded with neutrons. The cobalt-59 nuclei absorb an extra neutron each, thus changing to cobalt-60, an unstable radioisotope that emits gamma radiation. It has a half-life of about 5.3 years, meaning half of its nuclei will disintegrate to a stable state in every such period.

When gamma rays penetrate, say, a mushroom or a chicken leg, they temporarily increase the energy state of the food's atoms and molecules, making them more chemically reactive and thus more likely to damage a living cell. The rays may also rip electrons away from atoms' nuclei, leaving highly reactive molecular fragments in their wake. Sometimes, gamma rays may actually tear apart the genetic material of a cell, rendering it unable to replicate or produce life-sustaining proteins. They may even kill cells by changing nearby molecules, which then fatally react with the cells.



COBALT-60 IRRADIATION

Facilities that use the radioactive substance cobalt-60 maintain elaborate systems to ensure that, when food is irradiated, people aren't. The food, already packed onto pallets, is placed by forklifts into large metal carriers. These carriers enter the irradiation area through a maze of thick concrete walls; because gamma

"Many reactions to radiation are indirect," explains Donald Thayer, a research leader at the Eastern Regional Research Center for the U.S. Department of Agriculture in Philadelphia. The reason: Food products typically contain about 70 percent water, which absorbs much of the gamma rays' energy. As a result, the water molecules fragment into charged pieces—ions and free radicals—that then bond with other molecules. If those fragments react with a bacterium's outer membrane, continues Thayer, they may damage it irreparably.

Other things may be damaged as well. "The evidence is that nutrients are damaged by irradiation, and the higher the dose, the more the damage," says physician Donald Louria. "Before we put any irradiated food on the market, we should check its nutrient value—before irradiation, after irradiation, and after appropriate processing."

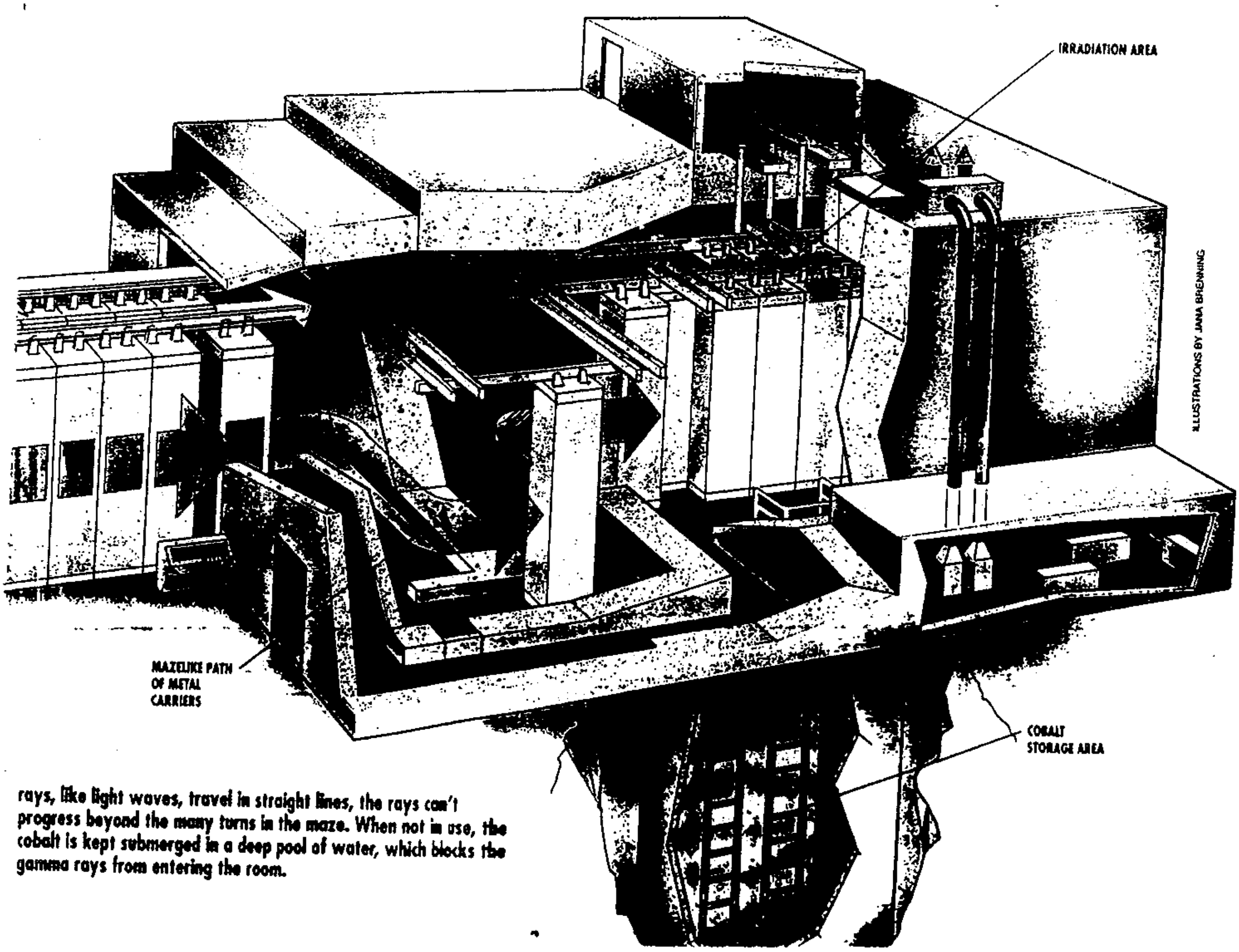
Whether or not irradiation could deprive consumers of significant sources of nutrients depends upon the nutrients at risk and the type of food. Studies performed by Thayer's laboratory indicate that, for example, chicken irradiated at FDA-approved levels loses less than 9 percent of its thiamine, an essential B vitamin. The same holds true for pork, although if the FDA dose regulations were upped to destroy dangerous salmonella bacteria, the loss of thiamine would be "significant," according to Thayer. As for citrus fruit, he says, the radiation changes the molecular structure of vitamin C, but this new structure can still can be absorbed by humans.

Occasionally, gamma rays may split protein, carbohydrate, or fat molecules; when the unstable fragments bond anew, they create different compounds altogether. "Generally, these compounds are breakdown products of the original food," says Edward Josephson, an adjunct professor at the University of Rhode Island who has been researching food irradiation for 37 years. He adds that these compounds, called radiolytic products, are formed in minute amounts and are the same as those found in foods processed by other methods, such as heating.

In fact, it is the lack of unique compounds formed by irradiation that some scientists find a handicap. If unusual new compounds were formed, they might serve as reliable chemical tags that inspectors could use to verify that food labeled as irradiated actually had been treated. "The scientific community has been working to identify unique radiolytic products for 40 years," Thayer remarks, "and we've yet to find anything we can really lay our hands on. These products are produced in tiny amounts, and almost all are not unique to irradiated foods."

Only recently, Thayer continues, have researchers at his lab come closer to establishing a reliable method for identifying irradiated meats. The tactic is to measure different products formed by the oxidation of cholesterol; irradiation alters the ratio of these products slightly. "But," he adds, "those products are present in parts per billion," so it's still like looking for a needle in a haystack.

Not all food irradiation is performed with cobalt-60. At an Iowa State University facility, named, with Midwestern bluntness, the Meat Laboratory, scientist Dennis Olson uses a linear accelerator to blast beef and



ILLUSTRATIONS BY JANA BRENNING

rays, like light waves, travel in straight lines, the rays can't progress beyond the many turns in the maze. When not in use, the cobalt is kept submerged in a deep pool of water, which blocks the gamma rays from entering the room.

pork with a powerful electron beam. Like gamma radiation, electron beams can tear apart molecules as they penetrate foods. There is, however, one drawback: Electron beams do not penetrate foods as deeply as gamma rays, and so cannot handle thicker cuts of meat, for example.

Still, some researchers, like Olson, prefer to use a linear accelerator rather than a radioactive isotope. One reason has to do with the dosages of radiation the researchers want to apply. These doses are measured by the amount of energy that is absorbed by the food, in units called grays. Where gamma rays and electron beams differ is in the time it takes to deliver a typical dose, which may be as large as kilograys.

The rate at which a linear accelerator can treat a product with a given dose of radiation is thousands of times faster than with a gamma ray source. "The question is," says Olson, "does the higher rate of dosage cause greater destruction of bacteria, or less? We know, for example, that if you cook a product slowly, organisms can adapt to the heat and survive at temperatures higher than if you were to heat the product very quickly. Likewise, can we destroy salmonella at lower dose levels if we use a higher rate of dosage?"

On the other hand, the faster the radiation is applied, the faster the resulting molecular reactions may occur. According to Thayer, that may not leave much time for the free radicals to diffuse to the surrounding molecules. And that may prevent some compounds, including beneficial ones like vitamins, from being destroyed.

This morning in Iowa, the sky and the streets reflect the same dark, icy gray. Olson arrives at the laboratory at an hour when many people are just waking up. He wrote the proposal for this laboratory in 1986; it was funded by the Department of Energy, he explains as he unlocks the door to the irradiation cell. The equipment is located in a cluster of

IT'S A GLOBAL TREND

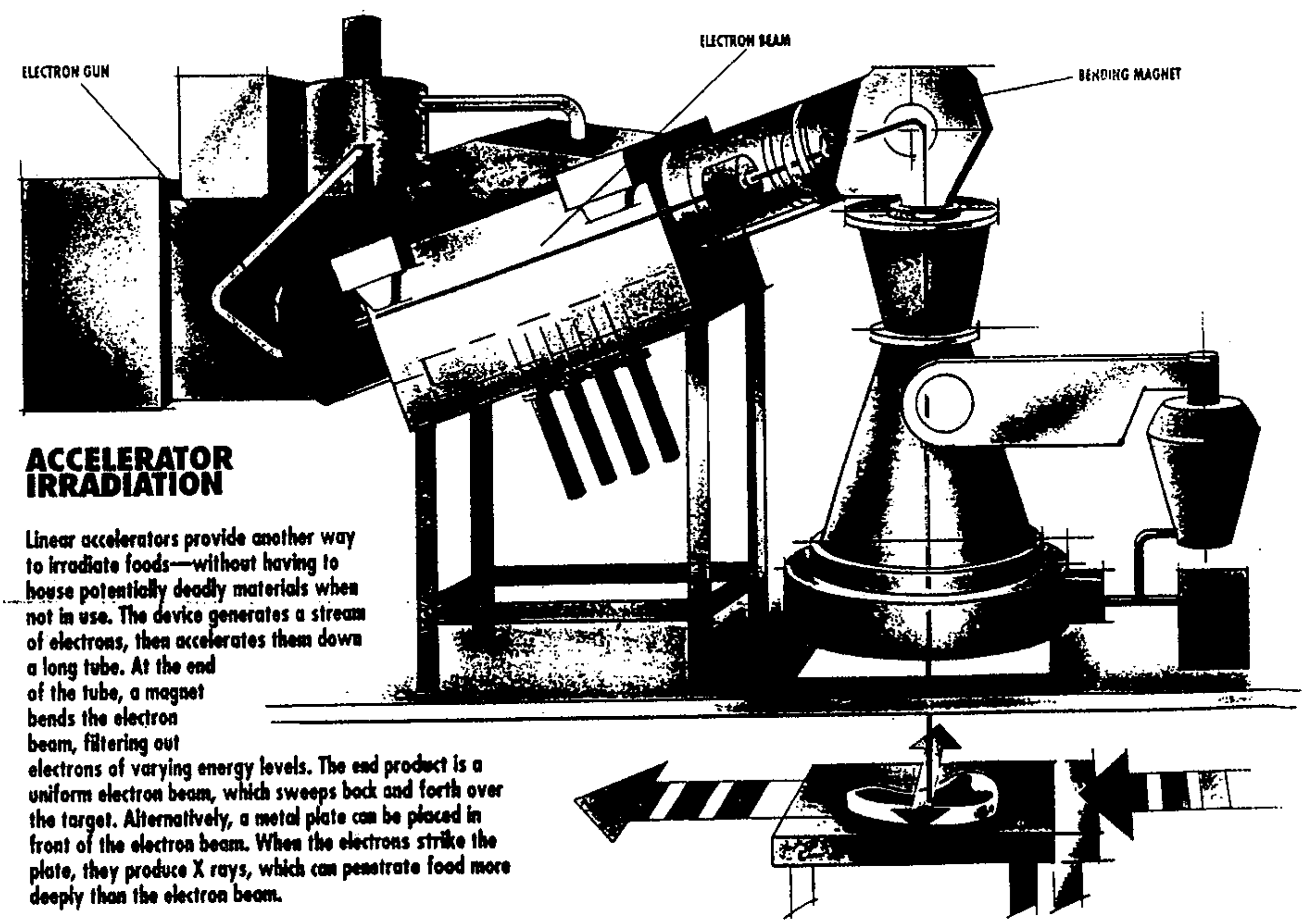
While irradiated foods are only now trickling into supermarkets around the United States, many have been available for years in other countries. Worldwide, some 35 countries have—or will soon have—facilities to irradiate food items on a commercial scale. That adds up to roughly 160 commercial irradiators, and 20 more are being built.

South Africa, the first country to irradiate food for public consumption, treated onions and potatoes in 1968. But it was Japan that built the world's first dedicated commercial food irradiator, which was in operation by 1973. The application: potatoes that were treated to ensure their supply for fast-food restaurants.

Now, a total of 37 countries allow irradiation of one or more food items; eight are western European countries, including France, Great Britain, and The Netherlands. But seven countries—Austria, Germany, New Zealand, Singapore, Sudan, Sweden, and Switzerland—have laws banning irradiation and the importation of irradiated foods.

What food items are most often treated with radiation? Across Europe, frozen frog legs, shrimp, onions, and vegetable seasonings as well as wine corks are all irradiated commercially. Spices make up the single most important irradiated item in terms of quantity, economic value, and worldwide acceptance. In addition, Belgium and The Netherlands now treat de-shelled and powdered eggs, poultry, rice, and packaging material. And recently, French researchers demonstrated that soft, creamy Camembert cheese—which is made from the raw milk of goats and could be a carrier of *Listeria monocytogenes*—can be irradiated without imparting unappetizing flavors.

Nearly all irradiation plants around the globe use cobalt-60. The electron linear accelerator is less popular because it cannot treat bulkier items. However, it is used in Russia to irradiate grain because it is less costly than cobalt.—*Wordservice International*



ACCELERATOR IRRADIATION

Linear accelerators provide another way to irradiate foods—without having to house potentially deadly materials when not in use. The device generates a stream of electrons, then accelerates them down a long tube. At the end of the tube, a magnet bends the electron beam, filtering out electrons of varying energy levels. The end product is a uniform electron beam, which sweeps back and forth over the target. Alternatively, a metal plate can be placed in front of the electron beam. When the electrons strike the plate, they produce X rays, which can penetrate food more deeply than the electron beam.

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fident that consumers will reach for packages of irradiated poultry rather than nonirradiated. But for many consumers, the biggest question is how irradiated food tastes. The answer: just like nonirradiated foods, if FDA-prescribed doses are applied. "At higher doses, the irradiation forms more free radicals," explains Olson. "The fat oxidizes and produces byproducts that create the off flavors and odors. The same thing happens when you keep meat in the freezer too long—it acquires a funny flavor."

Some day, irradiation may even lead to better-tasting fruits and vegetables. Irradiation alters the respiration rate of fruit, which controls the ripening process. "Today, many products are picked green, then gassed to stay green," explains Edward Sullivan. "Then they're shipped and regassed to stimulate maturation. But with irradiation, you can pick the fruit after it has begun to ripen, and you obtain the flavors consumers want."

Olson predicts irradiated meat products will be most popular with hospitals, nursing homes, restaurants, and other institutions that are concerned—or liable—for the safety of the food they serve. Consumers may remain a hard sell. "If irradiated poultry looks the same and tastes the same as untreated poultry," he says, "consumers may not be convinced that they should buy it. A consumer might say, 'I know how to cook and handle poultry correctly, so why should I pay more for it?' "

The other side of the coin is that consumers may erroneously assume irradiated products are unequivocally free of microorganisms. "Modest doses of irradiation, such as have been approved for poultry, greatly reduce the amount of pathogens on treated products," says Thayer. "But those products are not sterile, by any means. All normal food-handling techniques apply —this food is just a lot safer."

Dr. John Kobayashi, Washington state's chief epidemiologist, agrees. "Irradiation is only one of many ways that we can prevent food-borne illnesses," he says. "To a certain extent, people have to be aware that there is an inherent risk in handling raw meat products. I think there's a tendency for people to look upon technology as the answer to everything. But it's not a substitute for good handwashing, thorough cooking, and refrigeration."

To be sure, there are a few microorganisms that FDA-approved doses of irradiation won't affect. For instance, it cannot destroy *Clostridium botulinum* spores, which produce the deadly toxin botulin if the product is packaged under anaerobic conditions. Likewise, irradiation can kill staphylococcus bacteria, but it won't necessarily break down the toxin it makes.

These are some of the concerns, says George Pauli of the FDA, that the government considered when it set the dosage guidelines for poultry. "We were looking for good, solid data to show that there is a margin of safety . . . that irradiation at certain levels wouldn't result in a product that is less safe than what we started with." Theoretically, such a situation could happen if some resistant strains of bacteria were not destroyed. Because the product would be labeled as having a longer shelf life, these bacteria would have a longer period of time to grow.

How will irradiation treatment change food stores and supermarkets around the country? Subtly, say the experts, at least for a while. For irradiated foods to reach store shelves, says Pauli, three things are required: "somebody to do the irradiation processing, somebody to supply the food and somebody to buy the product." Much of what suppliers decide to do depends on the initial reactions of consumers. While Carrot Top, a supermarket in Northbrook, Ill., reports that its irradiated strawberries outsell nonirradiated ones, some experts like Olson forecast less enthusiasm for poultry.

Other meats—beef, lamb, pork—as well as seafood and eggs likely remain still years away from irradiation en masse. Currently, the FDA is evaluating two petitions that propose to include seafood as safe for irradiation. Meanwhile, the American Meat Institute is spending $200,000 to study the effects of irradiation on five bacteria commonly linked with beef products, including *E. coli* 0157:H7, the deadly strain that plagued the Pacific Northwest a year ago. In the future, the institute may use the data to petition the FDA for the approval of irradiated beef.

Ultimately, the real gain of food irradiation may come when it is used in concert with other techniques. Thayer plans to explore modified-atmosphere packaging; irradiated meat products stored in nitrogen or carbon dioxide gas might remain fresh for long periods of time. Olson envisions food products that are exposed to low doses of irradiation to destroy some organisms, heated slightly to destroy others, and chilled to kill yet more. Such steps should bring products that blend the best of taste, safety, and storage capacity. PS small rooms, one full of computer banks, another with electrical transformers, a third with water pumps used to cool some of the machinery. The loading area, shielding walls, and irradiation room are on the ground floor and the linear accelerator is one story up; the machine, which nearly fills a 12-by-15-foot room, sends the electron beam through a window in the floor to the irradiation area below.

The system is in many ways analogous to a television set, Olson explains. Both technologies use a heated filament in a vacuum to generate electrons. Electrical fields are then employed to focus the electrons into a beam and accelerate them down a tube. In a television, the electrons are accelerated to several thousand volts: in this machine, they are accelerated to millions of volts.

This accelerator is an assemblage of finely tuned machinery that, Olson admits, the laboratory struggled for a year and a half to perfect; the first food samples were run under the beam in early 1993. He shows me long strips of polypropylene streaked with a coffee-colored smear. The researchers exposed the strips to the beam, then used the streaks to adjust and readjust the beam until it was accurately centered and focused.

The linear accelerator is capable of producing a beam of three different energies: five-, seven-, and ten-million electron volts. These energy levels control the depth to which the beam can penetrate food. To vary the dose of irradiation, Olson can adjust the kilowatts of electricity consumed. The machine has a conversion rate of about ten percent; in other words, "to generate ten kilowatts of power," says Olson, "we need about 100 kilowatts of electricity." When the machine is operating, so is a powerful ventilation system. As the electrons move through the air toward a carton of food, he explains, they react with the oxygen, forming ozone that must be pumped out. "It's like a hurricane in here," he says. "We remove approximately 17,000 cubic feet of air per minute."

Unlike the Vindicator facility, the Iowa lab is devoted to research, not commercial irradiation. Instead of using pallet-laden carriers, here they manually load small metal carts that run on a variable-speed track. To alter the dose, the researchers usually just change the speed of the cart.

Olson favors the accelerator over cobalt-60 because it can be turned off with the flick of a switch—there's no ever-present source of radioactivity to keep submerged in a tank of water. In addition, Olson can use the accelerator to experiment with yet another means of radiating food: X rays.

In some ways, X rays are better than either electron beams or radioactive cobalt. There's still no radioactive isotope to deal with, and X rays can penetrate food more deeply than electron beams. But X rays are more costly to generate.

To produce X rays from the electron beam, explains Olson, a metal target is positioned at the accelerator window. As the electrons penetrate the sheet of metal, they decelerate and some of their kinetic energy is converted to electromagnetic radiation in the form of X rays. The process is called *bremsstrahlung*, German for "braking radiation." Some metals are better targets than others. Although the lab now uses stainless steel, Olson would prefer tungsten. "Tungsten is a good plate for producing X rays. But it is so dense that it is very difficult to cool, and we were burning holes in it."

Sam Whitney sits at a bare table in Vindicator's brightly lit conference room, sipping coffee, chain-smoking, and pointing to framed photographs of the facility on the wall behind him. The firm's president, he is a spirited Southern businessman who spearheaded the plans to build the facility. Although the plant was originally conceived to process fruit, it was built to accommodate more profitable poultry products. Vindicator now irradiates poultry as well as fruits and vegetables.

DESTROYING MICROORGANISMS

Just how common is food po[illegible]? Unfortunately, few statistics exist that reveal the extent of food-borne [illegible]. Tom Skinner, a spokesman for the Centers for Disease Control in Atlanta, says states are not required to report [illegible] or [illegible] poisoning to the CDC. And the [illegible] that do [illegible]. Back in the early 1980s, [illegible] the CDC estimated that there may be anywhere from [illegible] cases of infectious food-borne diseases in the country each year. But that ranges from mild cases [illegible].

Moreover, the prevalence of [illegible] does not necessarily [illegible] predictable number of persons [illegible]. Many people, for example, know that pork products should be thoroughly cooked. In the same way, says Skinner, [illegible]try and eggs infected with salmonella bacteria may or may not be a health hazard. The CDC estimates that about one in every 50 consumers may be exposed to one contaminated egg over the course of a year [illegible]. But if that egg is properly cooked, the salmonella is destroyed.

Below is a list of [illegible] common microorganisms that [illegible] foods and can make humans ill.

Name	Effective dosages of radiation	Pathogenic effects in humans
Toxoplasma gondii (parasitic protozoa)	Neutralized at 0.1 kGy; killed at 0.3 kGy	Damages the central nervous system in infants
Trichinella spiralis (nematode)	inhibited effects at 0.009 to 0.3 kGy; killed at 2.3 to 7.9kGy	Parasite bores into host's muscles; symptoms include muscle pain, fever, edema
Salmonella (bacteria)	90 percent destroyed at 0.31 to 1.3 kGy	Abdominal cramps, diarrhea, fever, nausea, vomiting
Staphylococcus	90 percent destroyed at 0.34 kGy	Abdominal cramps, dehydration, nausea, sweating
Campylobacter	90 percent destroyed at 0.08 to 0.16 kGy	Cramps, diarrhea

SOURCE: COUNCIL FOR AGRICULTURAL SCIENCE AND TECHNOLOGY

Sometimes, says Whitney, the irradiation works spectacularly. "Our strawberries last 20 to 30 days longer," he says, "and irradiated mushrooms keep as long as 31 days." Other times, the treatment turns the food to mush. Two different varieties of tomatoes, he adds, can yield dramatically different results.

One reason has to do with the food's water content. Edward Josephson, the Rhode Island University professor, conducted food irradiation research for the Army during the Vietnam War. He describes the struggle to irradiate lettuce; at that time, half of the Army's shipments of the vegetable would spoil before they reached Southeast Asia. "What I found was that irradiation accelerated the rotting process, instead of retarding it," he says. "It broke the cell walls, releasing enzymes that promoted self-digestion." Some fruits failed too. Out of the 27 the laboratory tried, only nine worked well.

Because of the reduced levels of bacteria, Whitney is con-

[Continued on page 86]