Part four of a four-part series

Irradiation promises new era in preservation

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For centuries, mankind has been developing methods of food preservation. Perhaps the greatest development was the discovery of canning.

Nicholas F. Appert, a French confectioner and cook, found by heating food in a metal container and sealing it from air, food could be preserved for an indefinite period of time while still remaining wholesome and nutritious. At the same time, Napoleon Bonaparte was having difficulty feeding his armies scattered throughout Europe. To help solve the problem, he offered a large cash prize to anyone who could discover a process preserving French produce while it was being sent to his armies. Appert developed canning and earned the prize.

Canning is just one of many food preservation techniques available today. Refrigeration is essential for red meats, poultry, and fish while foods such as grains, are dried to preserve them. The most controversial methods available today include irradiation, developed to help extend present day preservation beyond that previously possible.

If you were to discuss the applications of radiation with a group of average Americans, they would probably express their fear of nuclear war, mention Three Mile Island, and vow never to get another medical x-ray. Radiation suffers from a negative public image.

However, radiation can be a very safe, effective, and economical method of preserving foods. Foods preserved by radiation could have less microbial contamination and a longer shelf life leading to better health and lower food costs for American consumers.

Research in the U.S. and from throughout the world has shown proper doses of ionizing radiation reduce microbial contamination of spices, delay ripening of fruits and vegetables, inhibit sprouting of vegetables, destroy insects in grains, fruits and vegetables, eliminate pathogens in meats, and give a variety of foods extended shelf life.

It's not microwaving

Approximately one-third of the worlds food harvest is lost every year because of spoilage, pests, and waste. Irradiation could help alleviate world hunger and extend food supplies via the destruction of insects, larvae, and microorganisms thereby delaying food decay for up to several weeks longer than normal and reducing losses significantly. Also by destroying or slowing the growth of microorganisms in food, irradiation could reduce the incidence of many food-borne diseases in both industrial and Third World countries. Utilizing irradiation to control insects in spices and grains would provide an alternative to certain chemical fumigants presently used for preservation. Without a doubt, irradiation would contribute to the wholesomeness and abundance of food throughout the world.

Irradiation is a process where foods are exposed to various kinds of ionizing radiation in order to inactivate food-borne pathogens (such as Salmonellae), inactivate food spoilage microorganisms, inhibit sprouting of vegetables, and disinfect grains of destructive insects.

Foods can be irradiated by gamma rays, x-rays, or high velocity electrons. Gamma rays emanate from decaying radioactive isotopes. Two isotope sources proposed for food irradiation are cobalt-60 and cesium-137. Cesium-137 is a by-product of plutonium production for defense programs. Rather than storing the cesium in a pool of spent fuel, the federal government is looking for a safe and economical way to use it. Irradiation may serve that purpose. Electrons and x-rays are produced by an electron beam accelerator powered by electricity. A food irradiation facility consists of (1) the radiation source, which is housed in (2) a cell-like structure, usually made of thick concrete walls that confine the radiation and protect personnel involved in the facility operation and provides (3) the means to move foods into and out of the cell so as to expose them to the radiation in a controlled manner. Most designs for industrial food irradiation show pallet loads of food moving down conveyor belts to the cell where the food is exposed to radiation. Food can also be irradiated in its final packaging, which helps avoid recontamination.

The "dose" is the amount of radiation applied to a food to obtain the desired effect. Determining the correct dosage is a critical requirement for the successful application of irradiation. Two units commonly used to express dosage are: (1) the rad, which is enough energy to lift a mosquito 100 centimeters, and (2) the gray (GY) which is equal to 100 rad.

It's obvious that both the rad and Gy are very small quantities of energy. Dosage levels and their subsequent effects are listed in Table 1. *Radurization* refers to low doses, up to one kilogray (kGy), which suppresses ripening of fruits and vegetables and sprouting of root crops, kills insects, and causes some reductions of microbial populations.

Similar to pasteurization, radicidation refers to doses of 1-10 kGy which will inactivate all non-sporeforming pathogens (i.e. Salmonella) which would lead to an increase in the refrigerated shelf life of fresh red meats. *Radappertization* refers to doses of 10-50 kGy which destroy all organisms of concern to public health. These high doses, in combination with heat, sterilize food so it can be stored in sealed containers at non-refrigerated temperatures for many years.

Irradiation is not a recent scientific development. It was first patented as a food preservation process in France in 1930. Research in the U.S. originated in the early 1940s where it was observed that military rations could be improved by exposing the food to ionizing radiation. Additional testing occurred following World War II by government, industry, and academia. The U.S. Atomic Energy Commission and the Army began broad-scale food irradiation research and development programs in the 1950s. The Army's Natick Laboratory conducted tests on sterilization of foods with ionizing radiation in the early 1960s. Studies conducted to determine the wholesomeness and safety of irradiated foods continued to 1980. At this time the USDA assumed responsibility from the Army for testing of food irradiation. Presently research is being conducted by the USDA, the Department of Energy, universities, irradiation companies, and food processors.

The gamma rays used to irradiate food are essentially little bundles of energy called photons that pass through a substance destroying the living cells in their paths. The higher the level of radiation, the more photons applied. The more photons, the smaller the target they can destroy. Thus, low-dose radiation can efficiently kill only relatively large "targets" such as insects and trichinae, in contrast to higher irradiation doses to kill smaller microorganisms.

Table 1.
Radiation dose required for potential food preservation

LOW DOSE (kGy*, 100 krad*)—"Radizuration"
- Sprout Inhibition
- Insect Disinfestation
- Delay of Ripening

MEDIUM DOSE (1-10 kGy, 100-1000 krad)—"Radicidation"
- Reduction of microbial load
- Extension of food shelf life (i.e. refrigerated meats)

HIGH DOSE (10-50 kGy, 1000-5000 krad)—"Radappertization"
- Commercial sterilization

* 1 kGy= 1000 Gy= 100,000 rad
* 1krad= 1000 rad

Irradiation destroys organisms in two ways. First, the energy in the photon of gamma radiation may interact directly with a sensitive site in the organism. This site is usually the nucleic acid (DNA) that directs cellular reproduction and synthesis of cell components. This type of irradiation damage is termed a "direct effect" of ionizing radiation.

In addition, the energy in the gamma photon can be deposited in molecules of the organism, causing the formation of toxic products which subsequently damage the microorganism. This damage is termed an "indirect effect" of irradiation. It should be remembered at specific doses, irradiation disrupts the molecules in bacteria and other food, spoilage organisms without significantly damaging the structure of the food itself.

It *must be emphasized that irradiation is not the same as microwaving.* Irradiation does not raise the temperature of a product. Energy is released within cells of the target organism, which destroys them. Microwaving, on the other hand, raises the temperature of water molecules, creating heat.

Research to date indicates that radappertization prior to non-refrigerated storage and distribution of processed meats is useful and economical if used with other existing processes.

Energy requirements for radappertization of red meats, with subsequent storage at room temperature, are lower than those for canning or those for freezing with storage at freezing temperatures. The production scheme for this type of product (i.e. beef roast) would be as follows: (1) Preparing the roast with an addition of one percent salt along with 0.3 percent

On the hazards...

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"There is a sharp distinction between exposing food to ionizing energy in a food processing facility and producing nuclear energy in a nuclear reactor. In a food processing facility, there is no uranium or other fissionable material and no source of neutrons to produce fission or a chain reaction. The energy levels involved in processing food with ionizing energy are far less than those used in cooking food. They produce little heat and create no detectable radio-activity in the food. The energy emanates from solid materials (cobalt-60 or cesium-137) or from special apparatus (electron-beam or x-ray generators) that emits energy only when it is turned on. The safety requirement is that of sufficient shielding of the sources to prevent undue exposure of people employed in the food processing facility. Food facilities are similar to those in which ionizing energy is used to sterilize medical products such as surgeons' gloves and sutures. There are almost 200 such plants inoperation worldwide. The U.S. has about 60 of these lants of which about 20 are machine sources.

condensed phosphates for improving flavor and juiciness; (2) Precooking the roast to an internal temperature of 150-160° F to destroy enzymes, whose action could cause undesirable changes during storage; (3) Vacuum package the roast prior to irradiation; (4) lrradiaiton of the product which will ready the roast for non-refrigerated storage.

Additional research indicates that cured meats such as bacon, ham, corned beef, and frankfurters can be radappertized to provide protection against Clostridium botulinum while significantly reducing the requirement of added nitrite. Because nitrites have been shown to produce nitrosamines (which are proven carcinogens in laboratory animals) during cooking, reduction of the added nitrite would be desirable. Research shows that irradiation of vacuum packaged bacon at a dose of 10-15 kGy at 5° C will provide protection against Clostridium botulinum. In order to maintain the characteristic cured color and flavor of bacon, 20-40 ppm nitrite (vs. 120 ppm, the current commercial practice) is added. However, following irradiation, the bacon has little residual nitrite and undetectable or only trace levels of nitrosamines after frying.

Research shows that radurization of fresh meats prior to refrigerated storage can reduce the numbers of spoilage microorganisms present on the meat. Combined with refrigeration, this reduction in spoilage-causing bacteria created by irradiation can extend the market life of retail cuts of fresh meats from the current average of approximately three days to three weeks! This could improve the distribution of these perishable foods and decrease retail loss due to spoilage.

Current research indicates that irradiation at a dose of two kGy can extend the shelf life of vacuum packaged beef from five weeks (at 32°F) to 10 weeks (at 40°F). This extra shelf life of vacuum packaged beef could have a very positive effect on beef exports abroad to countries who desire a longer shelf life than the U.S. can now provide.

Another benefit for fresh red meats from the use of irradiation is that pathogens such as Salmonella bacteria which can be present on red meat are inactiviated by radurization. Professor of Animal Science Dennis Olson at Iowa State University says low dose irradiation (100 krads) can make pork carcassed trichina-safe. The ISU professor states irradiation dosage as low as 20 kilorads will render the trichina larvae incapable of reproducing. This effectively eliminates any possibility of a person contracting trichinosis from eating the meat.

In an ISU study, pork carcasses were irradiated with 100 krads to see if the additional dosage would increase the shelf life and affect taste. Results indicate bacterial numbers, at 14 days postmortem, were lower for the irradiated pork suggesting the irradiated pork might have an extended shelf life. Taste panel results indicate that panelists liked or even preferred the flavor of the irradiated pork. lt is apparent from research completed to date there are red meat products which would greatly benefit from the use of irradiation at each of the three dosage levels.

Four important areas should be considered when discussing the wholesomeness of irradiated foods.

1. Does the food become radioactive \ following exposure to ionizing radiation?
2. Do the bacteria that survive irradiation become resistant to radiation? Also, are any dangerous mutations formed?
3. Are toxic products produced in the food due to ionizing radiation?
4. Is there a significant loss in nutritive value of the irradiated food?

These are all good questions that need to be answered if consumer acceptance of irradiated meat products is to be achieved.

The question, “Are irradiated foods radioactive?” The answer is, “No.” It is a physical impossibility. Ionizing radiation is simply radiant energy. It disappears when the source is removed. The irradiated food is not radioactive and there is no radiation hazard in consuming it.

The second concern is that irradiation may create new strains of irradiation resistant, harmful organisms. Scientists consider the likelihood of developing radiation-resistant strains of bacteria to be negligible. Research indicates that repeated exposure over a long period of time would be required to develop a radiation-resistant bacterial strain. In addition, University of Wisconsin-Madison food virologist Dean Cliver studied viruses and other living organisms that survived irradiation and found no evidence of dangerous mutations formed as a result of irradiation.

A considerable body of scientific knowledge on chemical products which irradiation may have formed in treated foods has been developed in recent years. It has not been proven that the effects of ionizing radiation on the chemical composition of foods are more dangerous than those of other common forms of radiant energy such as heat or microwaves, used in food preparation. According to the Council For Agricultural Science and Technology, none of the compounds found to be produced by ionizing radiation are unique products of the irradiation. Rather, they are identical with naturally occurring substances, and they are found in smaller quantities than are produced when foods are cooked. The absence of toxic products resulting from food irradiation has been established on scientifically firm ground.

The nutritional properties of foods are not affected by the use of ionizing radiation as a food preservation process. **Too little energy is** involved to make significant changes in the nutritional quality of the protein, lipid, carbohydrate, and mineral constituents of foods. However, there can be losses of certain vitamins. These losses can be reduced when proper radiation dosages are used. At worst these losses are comparable to losses of vitamins obtained with other kinds of food preservation processes. In general, vitamin losses resulting from irradiation are regarded as not significant nutritionally.

The United States is one of the last industrialized countries to adopt the widespread use of irradiation as a food preservation process. Approximately 30 countries have approved the commercial use of irradiation for foods. Products include chicken, strawberries, onions, papayas, rye bread, garlic, mushrooms, bananas, and rice. In South Africa, irradiated foods command premium prices. In the U.S. astronauts and servicemen and persons with immune system disorders have eaten irradiated foods. Endorsed by the American Medical Association, irradiation is being used to sterilize about 35 percent of all medical and surgical instruments and equipment. These uses of irradiation, both abroad and in the U.S., have demonstrated the benefits and wholesomeness of food irradiation.

On July 22, 1985, the FDA approved the use of gamma radiation to control Trichinella spiralis in fresh pork. The dosage permitted ranges from a minimum of 30 kilorads to a maximum dose of 100 kilorads. This is good news for pork producers who have set 1987 as the target year for a trichinosis-safe pork supply. However, it remains to be seen if any major pork processor will implement the technology of irradiation.

On April 18, 1986, the FDA approved new regulations allowing the irradiation of fruits and vegetables to retard growth and ripening and also to control microorganisms. The maximum dosage is 100 kilorads (1 kilogray). This new regulation requires all irradiated foods sold at the retail level must state on their label that they were “treated with radiation” or “treated by irradiation.”

Scientific research has overwhelmingly proven the usefulness and safety of irradiation as a food preservation process. There is tremendous opportunity for its use in the red meat industry. Trichina-safe pork along with fresh meats with significantly longer shelf life are just two of the potential uses for irradiation. Certainlv. the ultimate factor deciding the future of irradiated food products including meats, is consumer acceptance. If consumers can be educated to and convinced of the benefits provided by irradiation, the process may become as popular in the U.S., as it is many other countries.

Irradiation demonstration and research facility to be established in Iowa.

The U.S. Congress has selected Iowa State University as a prospective participant in a cooperative demonstration of irradiation of pork and other meat products, according to Gordon P. Eaton, president of ISU.

Under the terms of the proposed cooperative agreement, the Department of Energy, *ISU*, and *ISU's* contractors would construct and operate a meat irradiation facility as an addition to the existing ISU Meat Laboratory. The preliminary cost estimate for the design and construction of the irradiator is $6.0 million DOE will provide partial funding for construction of the facility and funding for up to three years of operation.

The facility would use radioactive material (Cesium-137) to irradiate fresh pork and other meat and poultry products. It will be large enough to demonstrate commercial application of irradiation in the meat industry. Facilities for meat handling and storage, laboratories, and offices also will be constructed.

C.R. DeLannoy, program engineer for the DOE's Richland, Wash., Operations Office, said ISU was selected for several reasons, including its location within an area where approximately 80 percent of the nation's pork is produced, its internationally recognized Meat Laboratory, and its extensive trichina research program.

The proposed irradiator at ISU would be one of six *U.S.* irradiation facilities. Congress has identified Alaska, Oklahoma, Florida, Washington, and Hawaii as prospective sites for the other facilities, each of which would irradiate a different type of food.

Operation of the irradiators would be part of a DOE program to aid in the transfer of government-developed technology to the private sector. The irradiators would be used for research, development, market testing, operator training, and demonstration of the feasibility of irradiating food and other agricultural products.

Will FDA approve beef irradiation?

In the future consumers may be able to buy beef products that have a longer shelf-life if the Food and Drug Administration (FDA) approves the use of irradiation for beef products as it has for pork, fruit, and vegetable products.

After a spurt of interest and then a halting of research in the 1950s, interest in irradiation has resurfaced in recent years. Beef products could be next on the approval list.

Dennis Olson, professor of animal science at Iowa State University and coordinator of the Meat Export Research Center (MERC), says gamma irradiation results from the decay of a radioactive element. Gamma rays have short wavelengths compared to microwaves and light rays and cause almost no increase in the temperature of the meat.

Because the energy absorbed in meat is low, gamma rays will not cook the meat but will disrupt the ability of organisms to reproduce or produce proteins. Therefore, low-dose gamma irradiation of food products will harm dangerous microorganisms in meat but not the meat itself. For example, pork exposed to gamma rays will be made trichinosis-safe without changing the meat's flavor, texture, or juiciness.

Consumers, who may question the safety of irradiated products, should know that meat is irradiated with cesium-137 or cobalt-60 sources. Olson says these energy levels are so low that no radioactivity is retained in irradiated products. They are completely safe.

The International Joint Expert Committee on Food Irradiation examined all documents of research conducted on irradiated foods and concluded in 1980 that foods irradiated at doses of up to 10 KGy present no hazard. The 10-KGy dose level has been adopted into the International General Standards for Irradiation by the Codex Alimentarius Commission. Canada proposed approving a 10-KGy dose for food products in June, 1986. Many other countries have approved dosage levels up to 10 KGy for food products.

Costly foodborne illnesses challenged by irradiation

By Tanya Roberts
United States Department of Agriculture

Irradiation offers several potential benefits to the food supply. But, according to Tanya Roberts, an economist with USDA's Economic Research Service, one of the most important benefits of irradiation may involve its use to destroy microbial pathogens in food.

Several million Americans are afflicted by foodborne illnesses each year. In a recent issue of the Agriculture Department's *National Food Review* magazine, Roberts analyzed the costs of five foodborne illnesses associated with red meat and poultry-trichinosis, toxoplasmosis, salmonellosis, campylobacteriosis, and tapeworm. Roberts then looked at how irradiation could be one solution to these problems.

The costs of medical treatment, lost wages, and, in some cases, the. financial losses associated with death due to foodborne illness run into millions of dollars. Roberts cited the costs as follows:

- Trichinosis from pork, $1.5-$2.8 million.
- Congential toxoplasmosis from pork, $215-$323 million.
- Salmonellosis from chicken, $64-$115 million.
- Salmonellosis from beef, $209-$374 million.
- Campylobacteriosis from chicken, $362-$699 million.
- Tapeworm from beef, $100,000.

Irradiating red meats and poultry could significantly reduce the occurrence of these five food-related illnesses, says Roberts. In July, 1985, the Food and Drug Administration (FDA) approved the treatment of pork carcasses and fresh cuts of pork with irradiation at doses between 30 and 100 krads. Irradiating pork carcasses within this range is sufficient to prevent toxoplasmosis and trichinosis.

A dose of 200 krads would essentially eliminate campylobacter in chicken, and 250 krads would destroy about 93 percent of the salmonella in chicken carcasses. Neither of these dose levels has yet been approved by FDA, but FDA is currently reviewing the scientific literature on safety at these higher doses. A radiation dose as little as 40 krads would destroy tapeworm in beef, but FDA hasn't approved irradiation of beef at this time.

According to Roberts, irradiating chicken to kill salmonella and camphlobacter could save $341-$653 million annually-money that would otherwise be lost due to foodborne illness. Irradiating pork could save $186-$280 million.

"On the other hand, other options may have even higher net benefits," Roberts says. "For example, educating consumers on methods to prevent contamination or sterilizing animal feed to destroy pathogenic organisms, such as salmonella, may be the most cost effective. In any case, further economic analysis is needed before we can say conclusively."

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