

ARS Continues Advances in Irradiation of Ready-To-Eat Foods

We are surrounded by radiation. It's a natural part of the electromagnetic spectrum, and we've harnessed its power for our benefit.

Ionizing radiation is widely used around the world today as a safe and effective nonthermal way to pasteurize fruits and vegetables, ground beef, poultry, and spices. Agricultural Research Service scientists in Wyndmoor, Pennsylvania, are discovering more about how this valuable technology can be used to improve food safety.

Whether from gamma rays, electron beams, or x-rays, irradiation inactivates bacteria such as *Escherichia coli* O157:H7, *Salmonella*, *Listeria*, and other microorganisms and parasites that cause some 250 types of foodborne illnesses. Symptoms of infection can include nausea, vomiting, abdominal cramps, and diarrhea.

Irradiation also inactivates food-spoilage organisms, including bacteria, molds, and yeasts. Irradiation modifies the genes and cell membranes of microorganisms, killing or severely injuring them. It can lengthen the shelf life of fresh fruits and vegetables by delaying ripening and inhibiting sprouting.

Irradiation's effectiveness against food-spoilage organisms was first shown in France in the 1920s. In the mid-1960s, the U.S. Food and Drug Administration (FDA) approved use of low-dose ionizing radiation for killing or sterilizing insects in wheat and wheat flour and for inhibiting sprouting in potatoes. In 1983, FDA approved using irradiation to sterilize spices.

In 1981, research programs for food irradiation were transferred from the U.S. Army to USDA's Eastern Regional Research Center (ERRC) in Wyndmoor. Since then, ERRC scientists have conducted genetic toxicology testing of irradiated foods and supervised completion of the Raltech Study, the most complete and comprehensive experiments ever conducted on the toxicological safety of irradiated foods. These studies found no increased risk of cancer, birth defects, or other harm from consumption of irradiated foods.

Thanks in part to ERRC research efforts, FDA approved irradiation of poultry in 1990 and of fresh and frozen red meats, including beef, lamb, and pork, in 1997. ERRC research also established that ionizing radiation could inactivate *E. coli* O157:H7 in red meat and poultry. Irradiated ground beef and poultry are now sold in more than 4,000 supermarkets across the United States.

The 2002 Farm Bill allowed, on a voluntary basis, irradiated ground beef into the National School Lunch Program, which USDA oversees. In 2003, Xuetong Fan, a food technologist at ERRC, led taste panels where participants were asked to evaluate various sensory characteristics of irradiated meats in comparison with untreated products. The project was started to

support two USDA agencies, the Food and Nutrition Service and the Agricultural Marketing Service, in their efforts to assure parents and school leaders of the continued quality of school lunches. States were permitted to offer school districts irradiated ground beef beginning in January 2004.

STEPHEN AUSMUS (K11710-1)



So that study panelists focus only on taste, flavor, and texture, food technologist Xuetong Fan presents samples in a specially lit room that helps mask visual differences between samples. This study evaluates sensory properties of irradiated ground beef for the National School Lunch Program.

Microbiologist Christopher H. Sommers is the lead scientist for food irradiation in ERRC's Food Safety Intervention Technologies Research Unit. His research is directed at improving the safety and shelf life of raw meat and ready-to-eat (RTE) meat products. Sommers has done extensive work

with ionizing radiation to eliminate *Listeria monocytogenes* from RTE meats.

“Although RTE meats are already cooked, FDA and the meat industry recommend reheating for some products, because they can become contaminated between cooking and packaging.



Pathogenic bacteria such as *L. monocytogenes*, if present on the product, can sometimes multiply during refrigerated storage,” Sommers says. FDA is reviewing, but has not yet approved, irradiation for RTE meats such as hotdogs, bologna, and deli turkey and ham.

Currently, the RTE industry uses thermal and other non-thermal techniques to inactivate, if not completely kill, microorganisms. But those treatments don’t always prevent subsequent growth of bacteria under refrigeration. At least 90 million pounds of RTE meat products have been recalled since 1998 due to *L. monocytogenes* contamination. Sommers believes that for ground meats and some RTE products, irradiation may be the only effective means of treatment, since it can be used after packaging.

The radiation resistance of *L. monocytogenes* and other pathogens depends on the product’s formulation and the genetic characteristics of the contaminating strain. Sommers has established the radiation doses needed to inactivate *L. monocytogenes* in a variety of RTE meat products, and he’s determined the radiation resistance of *L. monocytogenes* strains associated with foodborne illness.

Sommers has also completed studies on the roles of food additives in inhibiting growth of injured pathogens in food products during long-term refrigerated storage.

Food additives are commonly used to extend the shelf life of meat products. Sommers says certain ones make *Listeria* more sensitive to radiation. For instance, he determined that a mixture of salts of acetic acid (vinegar) and lactic acid in bologna formulations decreased the radiation dose needed to inactivate 99.999 percent of *L. monocytogenes* inoculated onto the meat from 3.0 to 2.5 kiloGrays (kGy). The combined treatments also prevented growth of spoilage microorganisms for 2 months. “Ionizing radiation, when combined with common food additives, has the potential to significantly reduce the incidence of listeriosis associated with consumption of RTE meats in the United States,” Sommers says.

Fan and colleagues demonstrated that irradiation promoted production of several volatile sulfur compounds associated with unpleasant odors that can sometimes occur in irradiated or overcooked RTE turkey meat. Adding antioxidants to RTE formulations had a very limited effect in preventing production of the compounds. In additional work with Fan and A.P. Handel from Drexel University in Philadelphia, Sommers found that the combination of common additives and mild heating reduced levels of sulfur compounds in RTE turkey meat by more than 50 percent compared to irradiation alone.

Sommers collaborates with colleagues at ERRC in related research, including irradiation of foodborne pathogens in fruits, vegetables, and juices. He’s also examining ways to control other major pathogens, such as *E. coli*, *Salmonella*, and *Yersinia*, in other meat products. *Yersinia* infection most often occurs from eating raw or undercooked pork products, such as chitterlings. *Y. enterocolitica* is of great concern to researchers

Research on Fruits and Vegetables Improves Safety and Quality

Brendan A. Niemira, a microbiologist and plant pathologist at ERRC, focuses on methods to irradiate fruits, vegetables, juices, and meat substitutes of vegetable origin, such as soy. He is interested in finding the ideal dose of irradiation that increases safety but does not affect a given product's quality.

Since late 2002, government regulations have permitted use of irradiation on imported fruits and vegetables to meet phytosanitary quarantine requirements, which refers to controlling organisms that affect plant health. Higher radiation doses could be used to inactivate foodborne pathogenic bacteria as well. The National Food Processors Association has petitioned FDA to allow the higher doses on fruits and vegetables. FDA is currently evaluating the petition.

Grapes, for instance, have recently been suspected in *Salmonella* outbreaks. Niemira and Fan tested red and white whole grapes and their juices after purposely inoculating them with the pathogen. The textures of both grapes were not significantly affected by irradiation doses of up to 1 kGy—the maximum dose approved for fresh fruits and vegetables. Although the color of red grapes and red grape juice was influenced by treatments, white grapes and white grape juice held up very well.

“These results demonstrate that each product responds differently to irradiation and has to be treated differently to ensure it remains appealing to the consumer,” Niemira says.

Niemira also recently studied the effectiveness of gamma irradiation in inactivating *Listeria* and *Salmonella* placed on the surface of lettuce. He studied four closely related but distinct types of lettuce: Boston (butterhead), iceberg (crisphead), green leaf, and red leaf (variants of looseleaf). The studies showed that the radiation sensitivity of *L. monocytogenes* was similar on the four lettuce types, but the sensitivity of *Salmonella* was slightly different. Complexity of the leaf surface was the underlying factor. Although irradiation was effective at reducing pathogen numbers, subtle differences between lettuce types influenced the sensitivity of bacteria present on their surfaces. Niemira says radiation doses would have to be tailored for each type of lettuce to be effective.

The key to using irradiation is to eliminate foodborne pathogens without affecting product quality. Fan wants to assess the extent of irradiation's effect on product quality and to develop novel ways to minimize any adverse effects. He examines factors such as chemical composition, nutritional qualities, aroma, flavor, and texture in a variety of foods.

Major quality changes in some vegetables appeared to be tissue browning and decreased shelf life from loss of tissue integrity, which, in some instances, gives a soggy appearance. Because fruits and vegetables contain so much water, they are especially susceptible to the effects of irradiation and other non-thermal treatments.



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At ERRC, microbiologist Glenn Boyd places a batch of hotdogs into the gamma radiation source to rid them of foodborne pathogens.

and the meat industry because, like *L. monocytogenes*, it is capable of growing at refrigeration temperatures and in high-salt environments.

To determine the radiation resistance of *Y. enterocolitica* in different commercial practices, Sommers and co-researchers studied the pathogen in ground pork at different temperatures. They were particularly interested in the radiation dose needed to control *Y. enterocolitica* in subfreezing temperatures. There are fewer undesirable effects on some physical characteristics, such as texture and color, of meat products at subfreezing temperatures than those irradiated at refrigeration temperatures at the same dose. But it takes a larger dose to pasteurize frozen meat than nonfrozen meat. They were able to determine the range of radiation doses required to treat the same product at different temperatures—as commercial processors do.

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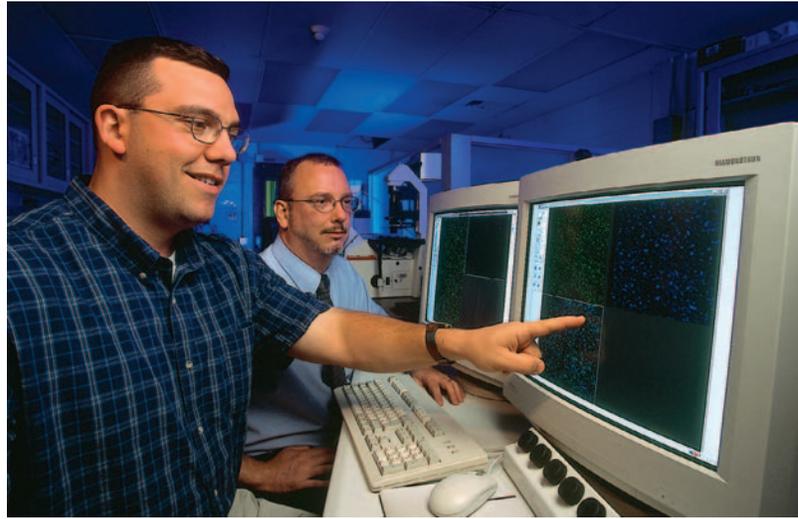
Molecular biologist Chris Sommers (left) and microbiologist Glenn Boyd vacuum-seal hotdogs to get them ready for irradiation.

Fan found that irradiation and heat pasteurization of apple and orange juice led to increased levels of several volatile sulfur compounds and aldehydes. Studies have shown that compounds such as aldehydes might contribute to off-odors in heated and irradiated foods. Fan believes conducting the treatments at lower temperatures, adding antioxidants, and combining irradiation with other treatments could help reduce undesirable quality effects on juices.

Fan teamed up with collaborators to develop a method to treat sliced apples used in fruit salads. They were interested in reducing tissue browning, which happens when plant tissue is cut during processing. They found that dipping apple slices into a calcium ascorbate (a form of vitamin C) solution before exposure to a low-dose gamma radiation treatment improved microbiological safety and inhibited tissue browning.

Fruits and vegetables are rich in antioxidants, which help protect us against cancer and heart disease. These beneficial effects are partially due to high amounts of phenolic compounds. Fresh and fresh-cut fruits and vegetables are living organisms, capable of synthesizing novel antioxidants in response to stresses even after they are picked and processed. Fan showed that irradiated iceberg and romaine

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Food technologist Ethan Solomon (left) and Chris Sommers examine fluorescent micrographs of bacteria suspended in biofilms exposed to ionizing radiation.

lettuce and endive developed a higher antioxidant capacity than nonirradiated vegetables during a postirradiation cold-storage period. The higher antioxidant capacity was mostly due to the increased content of phenolic compounds. Vitamin C content in the fresh-cut vegetables, however, was not significantly affected by irradiation doses as high as 1 kGy.

“In addition to the beneficial effect of foodborne pathogen inactivation, irradiation of fresh-cut fruits and vegetables may result in a product with enhanced antioxidant capacity,” Fan says.—By **Jim Core**, ARS.

This research is part of Food Safety (Animal and Plant Products), an ARS National Program (#108) described on the World Wide Web at www.nps.ars.usda.gov.

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Using a texture analyzer, food technologist Xuetong Fan and chemist Kimberly Sokorai evaluate an apple before processing and irradiation treatments to ensure initial product quality.