Food irradiation options for meat

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Results for today; Ideas for tomorrow

Radiation processing has been used for over forty years to sterilise medical devices such as syringes and gloves as well as cosmetic and pharmaceutical ingredients. One of the first food products to obtain irradiation approval was flour in the USA in 1963. There are now approximately 250 large-scale industrial irradiation facilities throughout the world and approximately 250 000 tonnes of food products and ingredients are irradiated in 40 countries worldwide (Deeley, 2002).

The Food and Drug Administration (FDA) in the USA approved the use of gamma irradiation for all raw meats in February 2000 and this regulation was amended in February 2001 to also allow the use of x-ray and e-beam irradiation.

Sources of irradiation

Gamma Irradiation

Gamma irradiation uses radiation emitted by radioactive isotopes such as Cobalt 60 or Cesium 137. Both give off high-energy photons, called gamma rays that are capable of penetrating food to a depth of one to two meters. These substances do not give off neutrons and therefore do not make anything around them radioactive. Because radioactive substances emit gamma rays continuously the radioactive 'source' is stored in a pool of water when not in use. To irradiate food the source is pulled out of the water into a concrete chamber with walls at least 1.8 meters thick, which prevents any rays from escaping. The food product is placed on a pallet in the chamber and exposed to the rays for a defined period of time, depending on the dose required. The process may take several hours for the dose level required for meat. The product is transported to an irradiation facility and is therefore treated off-site. This form of irradiation has been used for more than forty years to sterilise medical and dental products.

E-beam irradiation

E-beam irradiation is a stream of high-energy electrons propelled out of an electron generator. The electron beam generator can be switched on and off and does not involve radioactive substances. Some shielding is necessary to protect the operator from the electron beam but it is much smaller than the concrete chamber that is required for gamma irradiation. The electrons can penetrate food to a depth of approximately five centimeters. The food to be treated can be no thicker than the penetration depth if treatment is required all the way through, however, two opposing beams can be used for products that are twice as thick.

X-ray irradiation

The latest technology is X-ray irradiation, an expansion of e-beam irradiation. The X-rays are produced when a beam of electrons is directed at a thin plate of gold or other metal. The X-rays are capable of penetrating through the same depths as gamma irradiation and also require heavy shielding for safety. X-rays are, however, like e-beams in that they can be switched on and off and do not involve radioactive substances. Four commercial X-ray irradiation units have been built around the world since 1996.

The overseas cost for a commercial radiation plant is approximately $2.4 million to build and $75k per year to run.

In line irradiation

By its nature, gamma irradiation will probably never be installed in-line at a food processing facility. The food products will have to be transported to an irradiation facility. The e-beam and X-ray irradiation systems are capable of irradiating foods in-line. The concept of in-line irradiation involves a smaller system and placing it directly on the production line, so the product may be processed, packaged, irradiated and then distributed. Convenience and cost saving are the two basic reasons why companies may ultimately favour in-line irradiation rather than the off-site irradiation services. The compact unit stands approximately 1.8 meters tall and takes up about 7.8 m^2 of floor space.

A US based company, Mitek Advanced Technologies, has advanced the in-line electron beam system so that it is capable of delivering and measuring doses electronically, item by item. This enables processors to merge several products into one conveyer line passing through the irradiation system, giving individual doses for each product.

Mitek have also developed a separate system called DynaFlo for Ground Beef (DFG) – a technology specifically for ground beef. The ground beef is pumped under vacuum through a piping system in which the beef is irradiated. The irradiated beef exits the pipe and is packaged immediately, minimising the risk of contamination.

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Table 1. Comparison of the three different irradiation technologies

	Electron Beam	X-ray	Gamma Ray
Technology	Focused beam of electrons	Focused beam converted to x-ray	Photons created from decay of radioactive material
Processing Time (Dose Rate)	Seconds	Seconds	Minutes – hours
Power Source	Electricity	Electricity	Radioactive isotopes
Safety	Safe; on or off	Safe; on or off	Cannot be turned off; always emits radiation
Penetration	3 – 6 cm	1 – 2 meters	1 – 2 meters
In-line Processing	Yes	Yes	No
Chamber Temperature	Ambient or temperature controlled	Ambient or temperature controlled	Ambient or temperature controlled
Food Product Design	Variable	Variable	Variable

Effect of irradiation on bacteria

Food irradiation uses the process of passing ionising radiation through food to kill microorganisms. Ionisation denatures cell membranes and enzymes that are necessary for the survival and growth of living cells. The effects of the process depend on the amount of energy absorbed. It is well established that ionising radiations leave no residues and are effective means of reducing levels of both pathogenic and non-pathogenic bacteria alike. The threshold dose for most meat is 1.5 to 2.5 kilo Gray (kGy) whereas sheep meat can be treated at levels as high as 6kGy. The process causes minimal changes to the food and it is because of this absence of noticeable change that it is difficult to detect whether food has been irradiated or not.

A number of pathogens have a low resistance to irradiation and *Campylobacter*, *Yersinia* and *Vibrio spp* are particularly susceptible. *E. coli* is reduced by approximately 99.9% at 1.5kGy whereas *Listeria* and some strains of *Salmonella* are less susceptible. A dose of 2.5kGy that is recommended for the elimination of *Salmonella* would also be sufficient to inactivate most other non-sporeforming pathogens.

Consumer acceptance

Foodborne illness remains an important cause of illness and death despite intensive efforts to keep food products from being contaminated by microbial pathogens. *E. coli* 0157:H7 is a particular public concern since it can cause serious illness or death at very low infectious doses, especially to young children, the elderly or the immuno-compromised. The number of illnesses could be reduced if consumers with an increased risk of foodborne illness substituted irradiated for non-irradiated products.

Food irradiation has been very extensively studied. This has enabled the meat industry to supply safer products to consumers. After the initial approval of food irradiation many consumers were opposed to the idea primarily due to lack of knowledge of the process. Many believed that irradiated foods could become radioactive or could be capable of causing cancer or birth defects.

Although both isotopic (gamma irradiation) and machine sources (E-beam and X-ray irradiation) have identical impacts on food, consumers react less favourably to isotope sources than machine sources because of the association of isotopes with the nuclear industry.

An American Meat Institute (AMI) study showed that the more knowledge consumers had about irradiation and the value it offers in destroying food pathogens, the more likely they were to accept the technology (Erickson, 2000). This survey also revealed that once fully informed, consumers would be prepared to pay more for the 'safer' products. Deeley (2002) indicates that consumer acceptance of irradiated food in the USA is being re-enforced by 3 key drivers:

- Growing public awareness of the risks from bacteria in meat products,
- Growing levels of educational media coverage on food irradiation, and
- Fear of bio-terrorism on centralised food production (since September 11th, the subsequent anthrax incidents have heightened consumer concerns for the potential impact of bio-terrorism on centralised food production)

Extensive marketing and numerous public surveys have been ongoing in the USA and they have revealed that irradiation is continuously gaining acceptance in the food industry as a key component in the fight against *Salmonella*, *Listeria*, *E. coli* and other food-borne pathogens (Frenzen et al, 2001).

Irradiation regulations

Since 1979 the maximum permitted dose for irradiating food products has been 10kGy. In July 2003 the UN Codex Alimentarius Commission (Codex) amended its recommendation

by removing the maximum; however, Codex states that countries wishing to use a higher dose will have to demonstrate that irradiating foods above 10kGy meets a legitimate technological purpose. Codex standards are enforceable through the World Trade Organisation, so member nations with food irradiation laws stricter than the new Codex standard could have their laws challenged and overruled.

Irradiation in Australia

Australia approved the standard for food irradiation in August 1999, which allows Food Standards Australia and New Zealand (FSANZ) to consider and approve applications to irradiate foods prior to entering the market. Currently the approval for food irradiation (Standard 1.5.3) is limited to herbs, spices and herbal infusions (fresh, dried or fermented leaves, flowers and other parts of plants used to make beverages, excluding tea) and tropical fruit (breadfruit, carambola, custard apple, litchi, longan, mango, mangosteen, papaya and rambutan). No one has yet submitted an application for the irradiation of meat or meat products.

International regulations

A list of currently approved items in various countries is summarized below.

	Current approved items
USA	Pre- processed meat and poultry Raw and pre-processed vegetables, fruits and other agricultural products of plant origin Certain multi-ingredient food products
Canada	Potatoes and onions Wheat, flour, whole wheat flour Whole or ground spices and dehydrated seasoning preparations
Japan	Potatoes
Korea	Dried meat Onions, mushrooms, potatoes and garlic Spices and selected seasonings
Taiwan	None

An application to irradiate fresh and frozen ground beef has been submitted to Health Canada and is awaiting approval.

An application has been submitted to the FDA in the US to approve the irradiation of ready-to-eat products. This includes deli meats, frozen foods, prepared fresh food and juices. This application was submitted in August 1999 and is still waiting for approval.

Multiple irradiation

It is feasible that foods and food ingredients in international trade could be irradiated more than once. For instance meat could be irradiated here in Australia, then again in the country of destiniation.

Codex states that the applied dose of ionising radiation should not be higher than is needed to achieve the desired affect. Irradiation of food should normally only be carried out once but the committee has agreed that repeated irradiation in certain circumstances may be justified provided that it remains within the maximum dose permitted and does not affect the nutritional or technological properties of the product.

References

Deeley C. (2002) Food irradiation: Setting new standards or a slippery slope? Food Science & Technology 16(2): 52-55.

Frenzen D., DeBess E., Hechemy K., Kassenborg H., Kennedy M., McCombs K., McNess A. and the Foodnet Working Group (2001) Consumer Acceptance of Irradiated Meat and Poultry in the United States. Journal of Food Protection 64(12): 2020-2026

Erickson Otto P. (2000) Where's the irradiated beef? Food Product Design 9(11): 14-16.

Mitchell G. E. (1994) Irradiation preservations of meats. Food Australia 46(11): 512-517.

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