

FOOD IRRADIATION:

SETTING NEW STANDARDS OR A SLIPPERY SLOPE?

Cathie Deeley reviews the current situation

Since the US Department of Agriculture (USDA) gave final approval for the irradiation of red meat in February 2000¹ the USA has seen unparalleled growth in the adoption of food irradiation to help combat *E. coli*: O157-H7 in ground beef (minced beef). Irradiated fresh and frozen hamburgers are now available in 1,500 supermarkets throughout the USA. Meat producers have launched new brands for irradiated product that are reported to be selling strongly at up to 25 cents per pound more than the un-irradiated option. These new products are being marketed with a brand identity that targets safety and additional peace-of-mind for family households. Meat producers are keen to promote irradiation as just

one part of their hazard analysis critical control point (HACCP) strategies that still include multiple conventional hygiene interventions. Approval from the USDA for the irradiation of ready-to-eat meats to combat listeriosis is expected in the next twelve months.

In Europe, member states of the European Community are currently locked in dispute over agreement of a unified list of foods approved for irradiation^{2, 3}. National approvals for food irradiation range from only herbs and spices in Germany to widely applied, diverse lists of foods including frogs' legs, imported fresh water shrimp and mechanically de-boned chicken in Belgium and France. Until this dispute is resolved, national approvals may be maintained but they are closed

to new additions. Applications to irradiate a food that is not already on the national list must now be made to Europe for approval to add it to the unified list, currently comprising one entry: 'dried aromatic herbs, spices and vegetable seasonings'.

What is the need? Combat foodborne illness: In the USA, latest figures⁴ estimate that 76 million cases of food-borne illness occur every year and as many as 5,000 of these result in death. Statistics for England and Wales are similarly disturbing with more than 55,000 cases of *Campylobacter* and 23,000 cases of salmonellosis reported in 1998.⁵ *Listeria* is currently receiving attention from the Commission of the European Communities. A draft decision, issued for comment in July 2000, on the control of *Listeria monocytogenes* in ready-to-eat meat, milk and fish products requires manufacturers to control the presence to less than 100 colony forming units per gram during the shelf life of the product.⁶ If adopted this will have an impact on manufacturers in all Member States in the Community.

Spoilage: 25–50% of world food production is lost to spoilage from farm-to-table. Irradiation of fresh fruit, vegetables and grain at very low doses destroys pests, slows the ripening process and prevents sprouting; it increases shelf-life significantly. Fungi, which shorten shelf-life of high-value fresh fruit and vegetables, are treated with fumigants, chemical washes and pesticides. These are surface treatments that may leave chemical residues on the skins. Some importing countries, including the USA, Europe and Japan

	FOOD	PATHOGEN	IMPORTING COUNTRY
Table 2. Examples of outbreaks of food-borne illness (FBI) in the 1990s associated with international trade in food. Ironically 'healthy eating' is contributing to the problem of FBI. We eat more fresh fruit and vegetables from a wider market than ever before. Developing countries often have less advanced food hygiene and basic sanitation than the consumer expects. Polluted irrigation water and natural, untreated fertilizer are common.	Alfalfa sprouts	<i>Salmonella</i> spp.	Finland Sweden USA
	Raspberries	<i>Cyclospora</i> spp.	USA
	Crabs clams	<i>Vibrio cholera</i>	USA Japan
	Spices paprika-flavoured snacks	<i>Salmonella</i> spp.	Germany
	Infant dried milk	<i>Salmonella</i> spp.	UK Ireland



have banned the use of common fumigants, ethylene dibromide, ethylene dichloride and ethylene oxide, identified as health hazards. Methyl bromide, the remaining fumigant most widely used, is highly ozone depleting and legislation demands it to be phased-out in advanced countries by 2005 and in developing countries by 2015. The inability of countries to satisfy each other's quarantine and public health standards is potentially a major barrier to trade.

Quarantine: To avoid introduction of harmful agricultural pests such as fruit fly into non-infested areas bulk crops are chemically fumigated, often while in transit. MB is used most commonly. Although quarantine applications of methyl bromide are exempt from phasing out by 2005/15 the major producer of methyl bromide is the USA where there will be no production after 2005. Costs will rise and trade barriers to export of methyl bromide treated produce are almost certain. Hawaii now ships irradiated papaya to mainland USA.

What are the potential benefits?

For the consumer:

- Less risk of food-borne illness from cross contamination of foods eaten raw by high-risk staples such as chicken
- A choice of premium-quality brands – to ensure the safe consumption of rare cooked beef burgers and raw shellfish
- Longer shelf-life for fruit and vegetables using fewer pesticides and insecticides in production

For the wider environment:

- Reduction in the use of fumigation and resulting residual chemicals left on the skins of fresh produce
- Greater food supplies with less spoilage in transit – lower costs
- A bigger market available to developing countries leading to improved production standards
- Preservation of the ozone layer

How is radiation used to treat food?

Food irradiation describes the process of passing ionising radiation through food to kill harmful or spoilage microorganisms or to retard ripening, germination and sprouting in fresh produce and extend shelf-life. The radiation used can be gamma, x-ray or a stream of electrons travelling at almost the speed of light, an electron beam (E-beam). These are all sources of high energy that act in exactly the

	PATHOGEN	PRIMARY GLOBAL SOURCES	INCIDENCES IN USA PER 100,000 POPULATION 1998
Table 1. Most common sources of food-borne illness	<i>Campylobacter</i>	Poultry	21.7
	<i>Salmonella</i>	Meat Poultry Shell fish Frogs' legs Herbs/spices	12.4
	<i>E. coli: 0157-H7</i>	Ground beef Alfalfa sprouts	2.8
	<i>Yersinia enterocolitica</i>	Pork, raw sausage	1.0
	<i>Listeria monocytogenes</i>	Soft cheeses Ready-to-eat meats	0.5
	<i>Vibrio</i>	Oyster, shellfish	0.3

FOOD SAFETY



Top, labelling in the USA requires the radura to be displayed alongside a statement indicating 'Treated by irradiation'; above, labelling in Europe requires a statement indicating 'Treated by irradiation'

same way to destroy bacteria by ionisation. Ionisation denatures cell membranes and enzymes that are necessary for the survival and growth of living cells.

As with milk pasteurisation, the purpose of food irradiation is not to sterilise the product but to reduce the number of harmful bacteria to a level that is no longer a threat to the consumer. It is therefore sometimes referred to as 'Cold Pasteurisation' or 'Electronic Pasteurisation', when an E-beam is used as the energy source.

It is not possible to make bad food good using radiation processing. Toxins are unaffected and the use of high dose to combat a high bio-burden is likely to reduce the organoleptic

quality of the food. In addition, the cost increases significantly with dose. In this way food irradiation is a self-limiting process.

What dose of radiation is required? The amount of radiation used depends upon the application and type of organism being treated. A strictly regulated process of dosimetry is used to measure the exact dose of radiation absorbed by the product. This is achieved by the use of radiation monitors that are irradiated along with the product and measured against a national calibration standard to provide traceable proof that the appropriate dose has been delivered.

There have been significant technological challenges to overcome the development of off-flavours due to oxidation in products with high fat content. For ground beef this has been addressed using low oxygen packaging.

Labelling The chemical changes in irradiated foods are so small that they are detectable by only the most sensitive analytical techniques.⁷ Ironically opponents have cited this against the acceptance of food irradiation. In Europe, it is a legal requirement for irradiated food to show a written statement, 'Treated with Radiation', close to the name of the food. The USA requires the internationally recognised radura to be shown alongside. Consumer opinion in the USA is that labelling should better reflect the benefit: e.g. 'Treated with radiation to remove harmful bacteria'. This is currently under review by the US FDA.⁸ Labelling regulations

for food that contains small quantities of irradiated ingredients such as seasonings varies from country to country. In the UK all irradiated ingredients must be labelled.

What capacity exist to irradiate food?

Radiation processing is not new. It has been used safely and effectively for almost forty years, to sterilise medical devices such as artificial joints, syringes, gloves, and gowns, cosmetic and pharmaceutical ingredients and more recently, food packaging. There are approximately 250 large-scale industrial irradiation facilities throughout the world. Each year about 250,000 tonnes of food products and ingredients are irradiated in 40 countries worldwide.⁹ Facilities wishing to irradiate food must apply for a specific licence and comply with the code of practice set down by Codex Alimentarius.¹⁰ In the UK there is one facility licensed by the Food Standards Agency¹¹ to irradiate herbs and spices and, in Europe, 12 facilities licensed to irradiate food.

How commercial food irradiation works

The key functional difference between electron-beams and gamma or X-radiation is in the depth of penetration. Since electrons have both mass and charge the penetration depth into the product is approximately ten times less than gamma and X-radiation, e.g. 8cm compared with 80cm in typical use for radiation processing. This restricts E-beam to the treatment of individual shipping boxes while gamma and x-rays can treat palletised product in industry-standard shipping boxes.

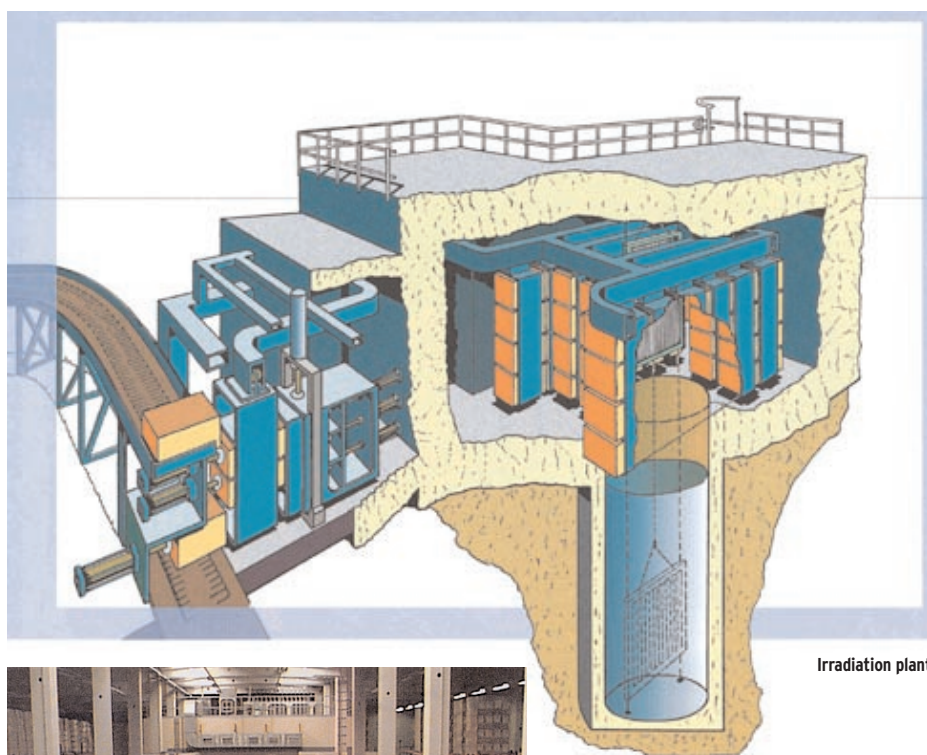
It is necessary to irradiate products in a shielded environment to prevent radiation from passing into the surroundings. This is usually a concrete room, called an irradiation cell, contained within a warehousing facility.

In a gamma irradiation cell cobalt-60 sealed radiation sources are kept in a source rack in a pool of water 6m deep. With the source rack in this position the water absorbs the gamma radiation and people can enter the cell wearing everyday clothing without risk of being irradiated. The water is pure enough to drink! When the cell is isolated and sealed the source rack is raised. The product is conveyed slowly past both sides of the raised source to ensure that it receives an even dose of radiation throughout. After an appropriate time (some hours) in the cell, the product leaves to be shipped out of the warehouse for use.

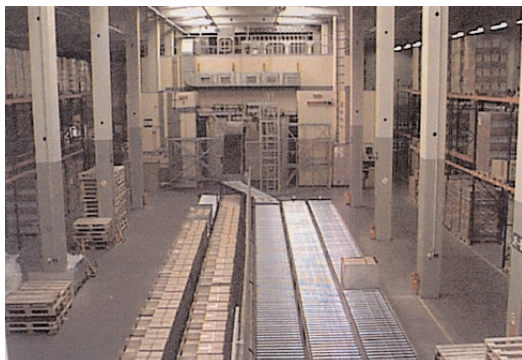
In an E-beam or X-ray facility a conveyor carries packaged product sequentially through the radiation beam. In the latest designs two beams irradiate both sides of the package at once. Dose is delivered in minutes to each package in turn. The source of radiation is electronic and can be switched off to gain access to the irradiation cell.

A commercial irradiation plant will cost approximately £1 million to build and £150–200k per year to run. Typical processing

	APPLICATION	FOOD PRODUCT	TYPICAL DOSE/kGy
Table 3. Typical radiation doses for various food applications. The necessary radiation dose depends on the application and the bacteria being treated. Moisture reduces the necessary dose. Absorbed dose is measured in Gray (Gy). 1 Gray is 1 Joule of energy absorbed per kilogram of food irradiated.	Reduction or elimination of microbial population in dry foods ingredients	Spices Starch Enzyme preparations	3-10
	Pasteurisation	Meat Poultry Shell fish Frogs' legs Herbs/spices	2-7
	Increase shelf-life	Fruits Vegetables Meat, poultry Fish	0.5-5
	Parasite disinfection	Meat Pork Fish	0.1-3
	Insect de-infestation	Grain Flour Dried fruits, etc.	0.2-0.8
	Inhibition of sprouting	Onions Garlic Potatoes	0.03-0.14



Irradiation plant



Gamma radiation processing has been used safely and effectively for over forty years on the industrial estates we drive past every day. Product is loaded into carriers ready to pass through the shielded irradiation cell at the end of the warehouse

throughput for a 15kW (1MCi) source is 3–4 tonnes per hour at a product density of 0.5 gcm^{-3} and a minimum dose of 4 kGy.

Consumer acceptance There is no doubt 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
- Fear of bio-terrorism on centralised food production

Over the past five years there have been several high profile outbreaks of foodborne illness, notably in 1998. *Listeria* in hot dogs from Sara Lee resulted in 15 deaths, 6 miscarriages and 100 illnesses with costs of millions of dollars in compensation. In Florida the state health authority has made statements on TV and radio in strong support of food irradiation to combat food borne illness. Even so, surveys typically find that only 30–40% of consumers are willing to buy irradiated food.

Since September 11th, the subsequent anthrax incidents have heightened consumer concerns for the potential impact of bio-terrorism on centralised food production. A news survey¹²

conducted in early November 2001 among 1,008 US adults reported that 64% of American consumers are concerned about contamination of the US food supply. More than 52% strongly support the use of food irradiation saying that, 'the government should *require* irradiation to help ensure a safe food supply'.

Consumers in Europe and the USA are generically concerned about food standards.¹³ Top of the list of concerns are:

- Bacterial contamination
- Surface residues (e.g. pesticides)
- Handling in supermarkets
- Antibiotics and hormones
- Additives and preservatives

Food irradiation is capable of improving four out of five of these issues with negligible negative impact on nutritional values.¹⁴ From experience in the USA, the key to consumer acceptance is to address a specific perceived need by the provision of information and education ahead of implementation and choice ever after. However, while consumer groups and the food industry in Europe continue to resist the adoption of food irradiation¹⁵ it seems unlikely, in the short term, that European consumers will be given the chance to make an informed choice for themselves. ■

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