Produce Irradiation – The not-so-silver-bullet

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From: The Packer, April 3, 2000. “Irradiation can’t guarantee bacteria-free food.”

The word irradiation conjures up different images for different people. And, in fact, irradiation can do many different things. It is irradiation, in the form of radio waves, which allows a trucker to listen to country music as he drives across the country. It is irradiation, as ultraviolet light, that gives a tan line at the beach. Irradiation runs metal detectors in food processing facilities. And irradiation can kill pathogenic bacteria. Is irradiation good or bad? As with all technologies it is both, depending on how it is used.

Armed with an understanding of the different types of irradiation that can be used to improve produce safety and quality, and of the capabilities and limitations of each form of irradiation, it becomes clear that there has been a certain amount of “irrational exuberance” as well as unfounded fears concerning the use of irradiation in the produce industry.

A simple view of irradiation is that it is simply energy in wave form. It can be very high energy and penetrating, such as x-rays, or relatively low energy and reflecting, such as radio waves. Irradiation can be generated by electrical energy, light energy, magnetic energy, chemical energy or atomic energy. Each type has its specific characteristics and uses.

The use of penetrating irradiation to promote the safety of foods takes three forms: gamma rays, electron beams and x-rays. Research is under way on a variety of other promising approaches, including pulsed energy, bright light, high pressure, and other non-thermal technologies, but few are ready for immediate application.

Gamma rays are given off by a radioactive substance, in this case either Cobalt 60 or Cesium 137. These substances give off very high-energy bursts of light (or photons), which can easily penetrate foods to a depth of several feet. Gamma irradiation is measured in a unit called the Gray. The Gray is a measure of the amount of energy transmitted to the food and is usually found in the form of kilo-Gray (kGy) or thousand Grays. The energy dosages approved for use on chicken or red meat are millions of times greater than those used for medical x-rays.

While this form of irradiation has very strong effects on living things, including fruits and vegetables, it does not make them radioactive or change them in obvious ways. This kind of irradiation has been used for more than thirty years to sterilize medical devices and household products, as well as in the treatment of cancer.

Cobalt 60 and Cesium 137 emit gamma rays constantly. They cannot be turned off and on and gamma rays are harmful to people. Consequently, these radioactive sources are stored under water because the water absorbs the gamma rays. Food to be irradiated is placed inside thick concrete walls around a pool of water and the gamma “source” is raised out of the water to expose the food to the gamma rays. After an appropriate amount of time the source is lowered back into the water and people can then enter the chamber to get the food without fear of irradiation.

After some years these sources lose their ability to produce gamma rays and they decay into non-radioactive substances. Cesium 137 loses half of its radioactivity in 31 years and so has to be replaced at some point. Cobalt 60 loses half of its radioactivity in 5 years and so has to be replaced more often. While the byproducts of some nuclear reactors may take millennia to become harmless, these substances will become harmless within decades, a time frame that can be reasonably managed. Thus, management of the nuclear waste from these facilities may be difficult, but it is certainly tractable. Fears of such waste from food irradiation facilities have been greatly exaggerated by some groups and should not be cause for excessive concerns.

Electron beams, or e-beams, are a stream of high-energy electrons, powered by an electron gun. The process is not dissimilar to what happens in a television, though the energies involved are greater. Electron beam and x-ray energies are measured in millions of electron volts (MeV).

Because the beam is powered by electricity, it can be shut on and off. There is no radioactive material involved. While the beam is on, some shielding is necessary to protect workers from the high-energy electrons, though not nearly as much shielding as is necessary with gamma irradiation. This is because electron beams are not as penetrating as gamma and herein lays one of its chief limitations. Electron beams will only penetrate food up to about three centimeters, or a bit more than an inch. This would make electron beam irradiation unsuitable for applications where penetration of fruits was necessary, for example. Electron beam devices have been used to sterilize medical devices for many years.

X-rays can also be used to kill microorganisms on food. These machines are similar, though more powerful, than those that are used for medical and dental x-rays. A beam of electrons is directed at gold or another metal that then emits a beam of x-rays. Like gamma rays, x-rays can penetrate thick foods and they also require heavy shielding. Unlike gamma, x-ray machines are driven by electricity and can be turned on and off. There is no radioactive material involved.

X-ray technology for food irradiation is relatively new and there are only a few facilities worldwide. However, interest in this technology is growing and we may expect to see more facilities built in the coming years.

Killing microbes with irradiation occurs when the irradiated energy interacts with water in the microbial cells. Reactive chemicals are created that damage the cells genetic material, or DNA. The ability of irradiation to kill a particular microbe is measured as the "D-value" or the amount of energy to kill 90% of the cells of the microbe. Thus, a dosage of 2D would kill 99% of the cells, 3D kills 99.9% and so on. Of course, the D-value will differ for different microorganisms.

Insects pests and some parasites (*Cyclospora*, *Cryptosporidium*, etc) have a relatively large amount of water and DNA in their cells, and so are easily killed by irradiation. D-values for gamma irradiation of 0.1 kGy are typical. Thus, a dosage of 0.5 kGy would give a five-log reduction. Bacteria (*E. coli*, *Salmonella*, *Listeria*, etc.) have smaller DNA and so are more resistant to irradiation. D-values of 0.3 to 0.7 kGy are typical, depending on the bacterium. Thus, it would require 1.5 to 3.5 kGy to achieve a 5-log reduction of bacteria. Unfortunately, at this time, the maximum allowable dosage for treating fruits and vegetables is 1.0 kGy. The implication is that gamma irradiation is not approved for use at dosages high enough to effectively eliminate pathogenic bacteria from fresh produce. There is a petition in to the FDA to increase the allowable dosage to that used for red meat, which is 4.5 kGy.

Spore forming bacteria (*Clostridium, Bacillus*, etc) are even more resistant to irradiation, and viruses (Hepatitis, Norwalk, etc.) are impossible to kill even with the dosages allowable for meat. Compared with the amount of radiation used on medical devices, the dosages approved for food are extremely low. Allowable doses of irradiation don't make food sterile. They don't always kill all the bad microorganisms if there are lots of them to begin with. Also, an irradiated food can be re-contaminated if mishandled. Consequently, while irradiation may have a future role in fruit and vegetable sanitation, it will never effectively guarantee pathogen-free produce, nor will it ever be a substitute for proper sanitation and food safety preventative programs.

There are also effects of irradiation on fruits and vegetables to consider. Plant tissues contain water and DNA, which will be damaged by irradiation. The extent and nature of the damage will vary with different products, the condition of the products and the dosage of irradiation. For some products there may be dosages that will kill some pathogens without causing noticeable damage to the product itself. For other products it may not be possible to use irradiation to promote food safety because the product would suffer unacceptable damage in the process. Damage in the form of fruit softening, wilting of leafy vegetables, irregular ripening and increased susceptibility to plant pathogens may occur subsequent to treatment with irradiation.

Some studies of bacteria on irradiated fruits and vegetables have shown an initial reduction in bacterial levels but that within days the bacterial numbers become similar to un-irradiated controls. One explanation is that the plant tissues are damaged by the irradiation and in their weakened state are less able to resist growth of microorganisms.

Irradiation shows some promise as another tool available to help insure the safety of fresh fruits and vegetables. Irradiation by itself will never be a silver bullet. It will, in itself, never be a food safety program. There is much yet to learn about the effects of moderate dosage irradiation on fruit and vegetable microbiology and physiology before we get too enthusiastic about its promise. Until we learn more, we would do well to continue to rely on strong food safety programs to prevent contamination of our products rather than to believe that we can fix the problem after it has happened.