Electron Beam

21st Century Food Technology

Texas A&M University

INSTITUTE OF food science AND engineering TEXAS A&M UNIVERSITY

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The Language of Food Irradiation

Prelude:
In 1904, Prescott at MIT discovered that irradiation could destroy bacteria in food and proposed its use to preserve foods.

Bacteria, Microbe, or Pathogen:
One-celled microorganism that can cause illness and spoil food, sometimes without changing the food's taste, smell, or appearance.

Cesium 137, Cobalt 60:
Metals that are produced by nuclear reaction and give off ionizing radiation as gamma rays.

Chemical Sprout Inhibitors:
Certain chemicals being used to inhibit sprouting of potatoes, onions, etc.

DNA (Deoxyribonucleic acid):
The essential building block of life in pathogens, human, plants, and animals.

Dosimeter:
A device for measuring the energy emitted by irradiation process.

Electrons:
Electrons, photons, and neutrons are natural parts of the compounds that make up living organisms, including humans. Chemically, an electron is a particle that has mass and has a negative (-) charge that forms a part of all elements (i.e., carbon, nitrogen, oxygen).

Electron Beam:
Stream of electrons accelerated to 99.9% the speed of light by using the energy of microwaves.

Effective Energy:
The measure of energy required to rid food of harmful bacteria and other pathogens. For example: 1.5 kilogray is the effective energy dose to rid most hamburger meat recipes of *E. coli* 0157:H7.

E-beam Food Irradiation:
Process in which energy-releasing electrons collide with the DNAof pathogens causing damage or destroying pathogens in food products.

Kilogray (KGy):
A measure of the effective energy as food passes through a radiation field. One kilogray equals ~1.5 athletic push-ups of energy absorbed per pound of product.

Fungal and Insect Control Fumigants:
Chemicals applied after harvest to control pests and insects inside or on the surface of plants, plant products, grains, seeds, nuts, etc.

Ionizing Radiation:
Rays of energy that move in short, fast wave patterns and can penetrate cells.

Irradiation:
The process of applying radiation.

Radiation:
Rays of energy (Examples of radiation emitting electronic products: Television, X-ray machine, microscope, tanning lamps, welding equipment, light bulbs, alarm systems, dryer, ovens, heaters, remote controls, vibrator, radio, etc) .

Radiation Dose:
The measure of effective energy as food passes through the radiation field during processing. Accelerated electrons release energy (ionization) until dissipated.

What is Food Irradiation?

Food **irradiation** is the treatment of food by a certain type of low energy **radiation**. The process destroys insects, molds, fungi, and **pathogens** that cause foodborne diseases or food spoilage. Food irradiation involves exposing the food to a carefully controlled amount of **ionizing radiation** for an effective period of time. Irradiation makes food safer and spoilage resistant without compromising taste, texture, aroma, or nutritional values.

Why are we interested in Food Irradiation?

1. Reduce high food losses from infestation, contamination, and spoilage.
2. Control foodborne diseases affecting people, pets and livestock.
3. Reduce transmittal of diseases, pests, and insects by international trade.
4. Lesson restrictful regulations and prohibition of food chemical treatments.
5. Extend shelf life.

How does irradiation work?

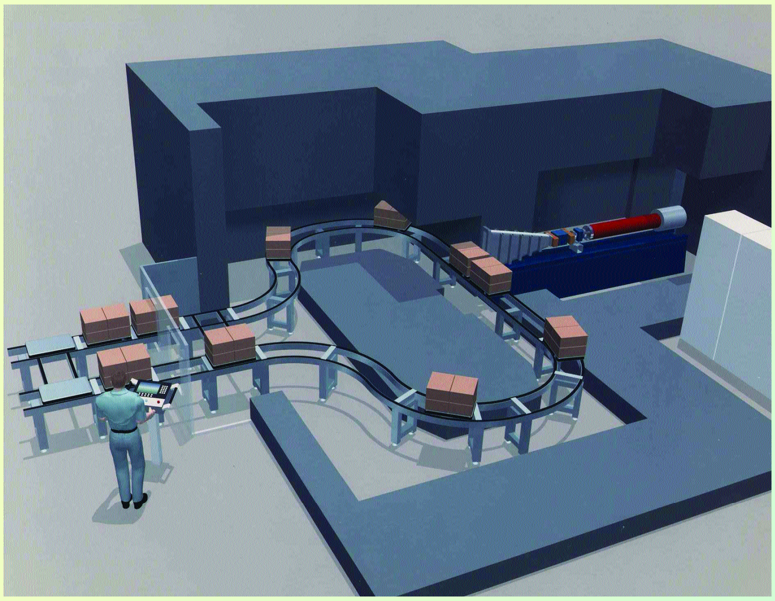
Packaged food is exposed to ionizing radiation in specially designed and shielded facilities. The food is exposed to effective amounts of ionizing radiation so that pathogens, pests, and spoilage organisms can be destroyed. The organisms are destroyed by the **electrons** breaking the bonds that hold the pathogen's **DNA** together. Damage to the DNA disables the organism's ability to grow or multiply. The **radiation dose** to which a food is exposed is based on extensive research to ensure the destruction of pests and pathogens while at the same time preserving the wholesomeness of foods.

Three different ionizing irradiation technologies: The types of radiation used in irradiation processing are limited to **electron beams**, x-rays, and gamma rays:

Electron Beams: Electron beams are produced from machines capable of accelerating electrons to near the speed of light (~190,000 miles/second). This electron beam generator uses commercial electricity as an energy source and can be simply switched on or off. Compared with gamma rays or X-rays, the electron beam is limited to treating relatively thin packages because of the low penetrating power (< 2 inches) of electrons.

X-Rays: X-rays are produced using an electron beam accelerator whereas a beam of electrons strikes a metal target such as tungsten. X-rays have greater penetrating power and can pass through larger packages of foods. Like electron beams, the machine uses commercial electricity, so it can be switched on and off.

Gamma Rays: This technology has been used in food processing for four decades. Gammas are short wave length, high energy photons, and have deep penetrating power. Gamma rays come from spontaneous disintegration of radioactive nuclides (**Cobalt 60 or Cesium 137**) as their energy source. During irradiation, the radioactive nuclides are pulled out of storage (water pool) into a chamber with concrete walls that keep any gamma rays from escaping. Foods to be irradiated are brought into the chamber to be exposed to the gamma rays for a defined period of time required to destroy targeted pathogens.



What benefits are gained from irradiating foods?

Reduction of food-borne illnesses

Treating raw meat and poultry with irradiation at a food processing plant could eliminate **bacteria** commonly found on raw meat and poultry, such as *E. coli* O157:H7, *Salmonella*, and *Campylobacter*. These **microbes** currently cause millions of infections and thousands of hospitalizations in the United States every year. Irradiation could eliminate *Listeria* from ready-to-eat meat products. *Listeria* was the culprit that caused at least 120 illnesses, 20 deaths, and a poultry recall of 27.4 million pounds in October, 2002. Irradiation also eliminates parasites such as *Cyclospora* and bacteria such as *Shigella* and *Salmonella* from fresh produce.

Decontamination

Spices, herbs, and vegetable seasonings are often contaminated with microorganisms. Traditional treatment by certain chemicals can cause loss of flavor and aroma, and be potentially harmful to human health. Irradiation is ideal for decontamination purposes.

Extension of shelf-life

- Shelf life of certain fruits and vegetables, meat, poultry, fish and seafood can be extended by controlling spoilage microorganisms, such as *Pseudomonas spp* and *Botrytis cinerea*.

- Ripening of some fruits can be slowed down by irradiation treatment.

- Control of fungal rot in strawberries by 2 to 3 **kGy (kilo gray)** followed by storage at 10°C can result in a significant extension of shelf-life. Irradiation of mushrooms at 2 to 3 kGy inhibits cap opening and stem elongation.

- A very low radiation dose of 0.15 kGy or less inhibits sprouting of potatoes, yams, onions, garlic, ginger, and chestnuts. Irradiation could make these products available year around at a low cost and free from **chemical sprout inhibitors**. Though foods are currently treated with the chemicals, no labeling that discloses pretreatment is required for consumers.

Disinfestation

Application of 1 kGy or less can control insects in grains and fruits. Beetles, moths, weevils, and fruit flies cause extensive damage to stored grain, grain products, and fresh fruit. Irradiation makes the foods free from widely used and possibly dangerous **insect control fumigants** such as ethylene dibromide, methyl bromide, and phosphine.

Is irradiated food safe to eat?

Food irradiation is no more hazardous to achieve the same purpose than canning, drying, heat pasteurization, or cooling process. Irradiation is a 'cold pasteurization process'; it does not raise substantially the temperature of the food being processed. Nutrient losses are small and often significantly similar to losses from other methods of preservation. Much of the early work on irradiation examined foods treated at very high doses, but today, irradiation is very precise. In September 1997, an expert group organized by the World Health Organization (WHO), Food and Agriculture Organization (FAO), and International Atomic Energy Agency (IAEA) concluded that doses greater than 10 kGy "will not lead to changes in the composition of the food that, from a toxicological point of view, would have an adverse effect on human health." The United States Food and Drug Administration (FDA) has also evaluated the safety of this technology over the last 40 years and has found irradiation to be safe under a wide range of dose levels and has approved its use for many foods. Scientific studies have shown that precision dose-specific irradiation does not significantly reduce nutritional quality or significantly change food taste, texture, or appearance. Energies from gamma, X-ray, and electron beam sources are too low to induce radioactivity in any material, including foods.

How do I know if food has been irradiated?

Irradiated for Safer Food

FDA currently requires that irradiated foods include labeling that identifies the foods being treated with/by irradiation. These foods are also required to be labeled using the international symbol for irradiation, the radura.

Would irradiation replace other foodborne disease prevention efforts?

No. Irradiation is not a short cut to food safety. It is not an alternative to other important efforts, including those used to improve sanitation on the farm and in the food processing plant.

Are food irradiation facilities safe for workers and surrounding communities?

Yes. These facilities are built to strict standards and operations are under the jurisdiction of state and federal authorities.

Which other items are irradiated?

Other products that are commonly irradiated include animal feeds, enzymes, baby bottle nipples, pacifiers, bandages, sponges, gauze, baby powder, feminine products, potting soil, contact lens solution, medical disposables and hospital supplies, cosmetic ingredients, medical implants, wine bottle corks, petri dishes, labware, and food-packaging materials.

What does this added food safety cost?

Irradiated products sold to date cost slightly more than their conventional counterparts. Consumer prices for this added food safety value range from 5 cents to 25 cents per pound for ground beef (1.3 ~ 6.3 cents per hamburger).

Cost for product research and market testing at the Electron-Beam Food Research Facility at Texas A&M University will be customized to meet the expressed needs of the food processors, wholesalers, or retailers.

Levels of Food Irradiation and the Desired Effect

Benefit	Dose (kGy)	Products (* FDA Approved)
Low-dose (up to 1 kGy)		
(i) Inhibition of sprouting	0.05-0.15	Potatoes*, onions*, gallic*, root ginger*, yam, etc.
(ii) Insect and parasite disinfestation	0.15-0.5	Cereals* and pulses, fresh and dried fruits*, dried fish and meat*, fresh pork*, etc.
(iii) Delay of physiological process (e.g., ripening)	0.25-1.0	Fresh fruits and vegetables*
Medium-dose (1-10 kGy)		
(i) Extension of shelf life	1.0-3.0	Fresh fish, strawberries*, mushrooms, etc.
(ii) Elimination of spoilage and pathogenic microorganisms	1.0-7.0	Fresh and frozen seafood, raw and frozen poultry and meat*, shell eggs*, etc.
(iii) Improving technological properties of food	2.0-7.0	Grapes (increasing juice yield), dehydrated vegetables (reduced cooking time), etc.
High-dose (10-50 kGy)		
(i) Industrial sterilization (in combination with mild heat)	30-50	Meat*, poultry*, seafood, prepared foods, sterilized hospital diets, etc.
(ii) Decontamination of certain food additives and ingredients	10-50	Spices*, enzyme preparation*, natural gum, etc.

Source: Facts about Food Irradiation, International Consultative Group on Food Irradiation (ICGFI), 1999.

Texas A&M Electron Beam Food Research Facility

What Capabilities are at Texas A&M Electron-Beam Food Research Facility?

The Electron Beam Food Research Facility at Texas A&M University is a dual modality facility. There are 2 vertically mounted opposing 10 MeV (Million Electron Volt), 18 Kilowatt Electron Beam Linear Accelerators (LINAC) and a single horizontally mounted 5 MeV, 15 Kilowatt X-Ray Linear Accelerator. Energies from these radiation sources are too low to induce radioactivity in any material, including food.

In the **E-Beam Mode,** electrons are accelerated, to near the speed of light using microwaves, into the product breaking the DNA chain of pathogens in the product. Products receive radiant energy from both the upper and lower accelerators so that product flipping is not required and processing can be accomplished in seconds.

In the **X-Ray Mode,** electrons are accelerated to near the speed of light using microwaves into a dense metal which emits X-Rays that pass through the product breaking the DNA chain of pathogens in the product. The product will pass in front of the beam and then be rotated 180° to make a pass on it's opposite side. X-Ray is primarily used with bulky, non-uniform, high-density products.

The A&M research facility utilizes a single conveyance system to move the product in and out of the process chamber. All LINACs and conveyers are controlled with Allen Bradley Programmable Logic Control (PLC) software. This software, along with SureBeam's RS View Human Interface software, enables the electronic pasteurization process to be virtually automated and very tightly controlled with few staffing requirements.

The research facility, the result of a 10 year, 10 million dollar research contract between Texas A&M University and SureBeam Corporation of San Diego, California, is equipped with state of art SureBeam electron beam system components.

For further information about SureBeam's technology go to http://www.surebeam.com.

Which specific research projects will be invited?

- Food Security: Treatment of microbial pathogens in food (natural and intentional causes)
- Food Toxicology: Treatment to reduce toxic chemical additions to foods
- Food Quality Assessment & Improvement: Optimization processes for high quality foods
- Water Quality Assurance: Treatment of potable water to ensure virus & protozoan inactivation
- Water Detoxification: Use of E-Beams to detoxify chemically contaminated water sources
- Food Safety: Application to inactivate natural pathogens in meats, poultry, fish and shell fish
- Mycotoxins: Assessment of vulnerability of mycotoxins to E-Beam treatment of food
- Portability of System Designs: Explore mobile food treatment facility or rapid deployment system
- Shipboard Design Features: Explore scaling for on-board food use in carrier & support class ships
- Materials Handling Designs: Fluid beverage systems – streaming and packaged
- Discrete Food Handling Designs: Systems for handling discrete food and feed products.
- Phytosanitary applications for fruits and vegetables.

What dosimeter systems are used at the Facility?

- Alanine: Measures dose in foods and packaging
- TLD Thermoluminescent: Measures personnel exposure
- Chromatic Film: Measures machine function/efficiency
- Pocket Ionization Chamber: Measures personnel exposure

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