SAND2007-5099P

Introduction to Food Irradiation

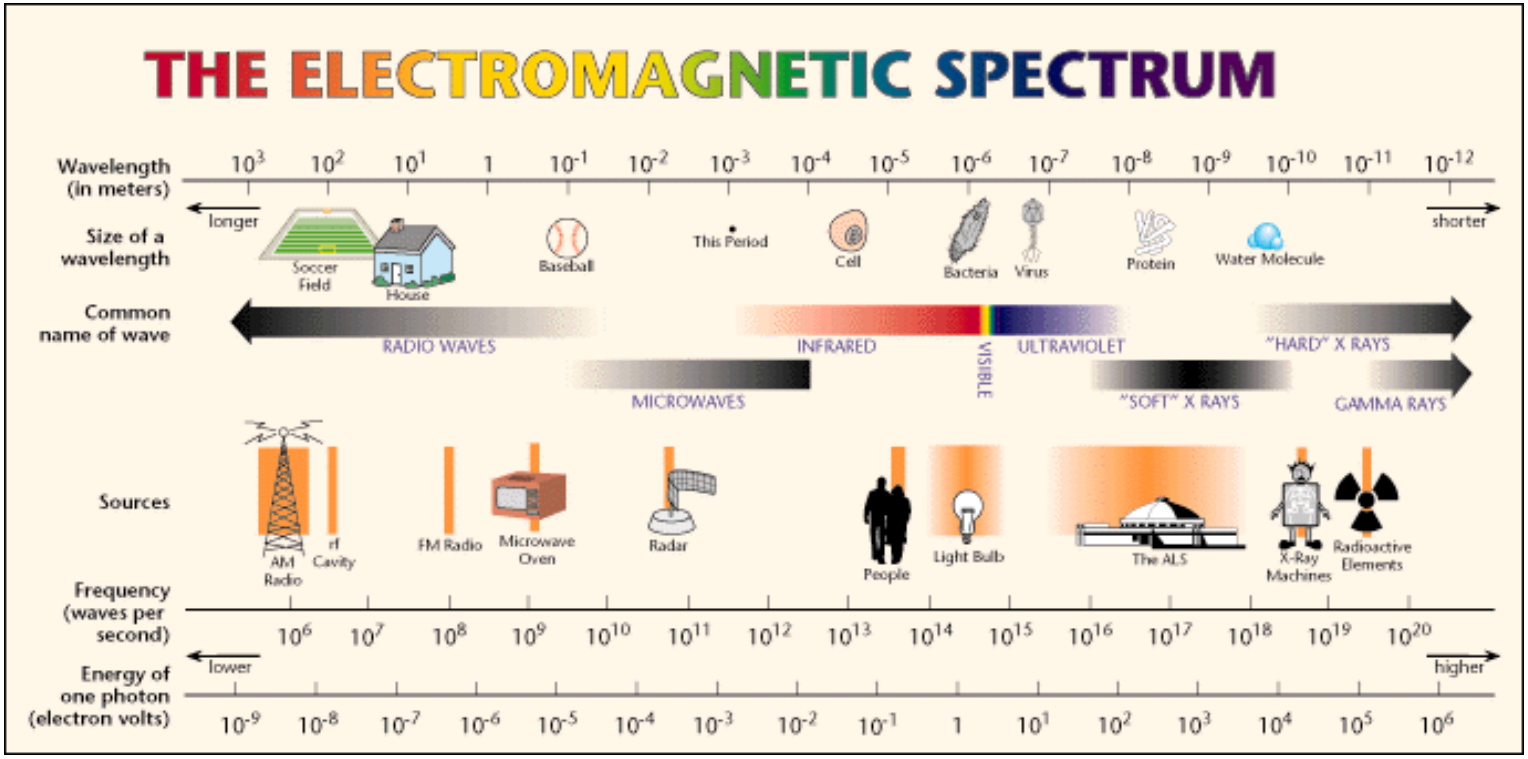
Sandia is a multiprogram laboratory operated by Sandia Corporation, a Lockheed Martin Company, for the United States Department of Energy's National Nuclear Security Administration under contract DE-AC04-94AL85000.

Overview

- Applications of Radioactive Sources (Industrial, Medical, etc.)
- Application of Radioactive Sources for Food Irradiation
- Typical Food Irradiators
- Operational Aspects of Food Irradiators
- General Safety Aspects of Food Irradiators

Sources of Radiation

(Electromagnetic Radiation)



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Sources of Radiation

(Ionizing Radiation)

- Cosmic Radiation (the sun)
- Medical procedures
- Radon and other terrestrial sources
- Nuclear weapons fallout
- Power plants
- Fertilizers
- Smoke detectors
- Accelerators

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Sources of Radiation
(Examples)

Radioisotope	Half-life	Specific activity (Ci/g)	High energy alpha emissions	High energy beta emissions	High energy gamma emissions
Cobalt-60	5.3 years	1,100	N/A	Low energy	Yes
Cesium-137 (Barium-137m)	30 years (2.6 min)	88 (540 million)	N/A	Low energy (Low energy)	N/A (Yes)
Iridium-192	74 days	>450 (std) >1,000 (high)	N/A	Yes	Yes
Strontium-90 (Yttrium-90)	29 years (64 hours)	140 (550,000)	N/A	Yes (Yes)	N/A (Low energy)
Americum-241	433 years	3.4	Yes	No	Low energy
Californium-252	2.7 years	536	Yes	No	Low energy
Plutonium-238	88 years	17.2	Yes	No	Low energy

Sources of Radiation

(Applications)

Industrial

- Tracers (pipeline leaks, malfunctions, wear, and corrosion)
- Thickness gauges (sheet metal, paper, textiles)
- Imaging (weld inspection, non-destruction examination)
- Smoke detectors (unmatched reliability)

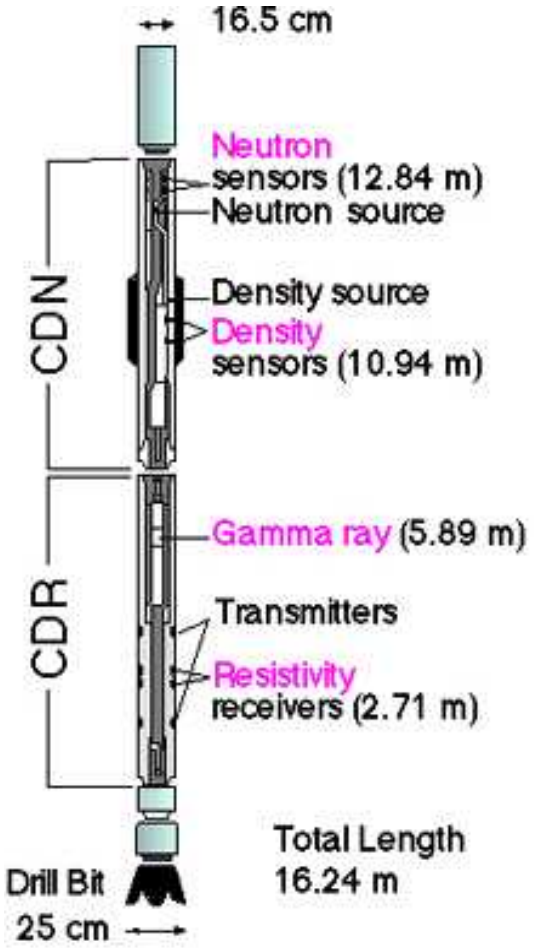
Sources of Radiation

(Applications)

Industrial

- Density gauges (oil and food industries)
- Lighting (airports, exit signs, traffic control)
- Tires (vulcanize rubber)
- Reduce static electricity printing process, paper making)

Well-Logging *Sonde*



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Sources of Radiation
(Applications)

Medical

- **Sterilization of medical products**
  - Surgical dressings, sutures, catheters, syringes
- **Diagnosis (12-14 million procedures each year in U.S.)**
  - Technetium-99 extensively used for bone cancer, prostate cancer
  - Imaging for heart, brain, lung disorders
  - Imaging for cancer tumors
  - Radioimmunoassay (determine levels of hormones, vitamins, enzymes, drugs)

Sources of Radiation
(Applications)

Medical

- New drug testing
  - Over 80% of all new drugs tested with radioactive tagging before approval
- Therapy
  - Decrease pain of bone cancer
  - Hyperthyroidism (20,000 patients/year)
  - Cancer (direct gamma, “smart bullets”)

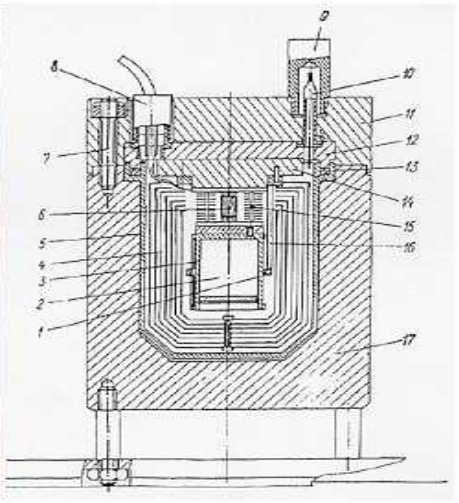
Cobalt-60 Teletherapy Machine from MDS Nordion

Sources of Radiation
(Applications)

Other

Electrical generation
- Radio-Thermal Generators (RTG)
  - Pu-238 excellent heat source (87.7 year half-life)
  - Direct conversion to electricity (~7% efficiency)

Soviet-made RTGs



Space Exploration
- Deep Space missions >100 KW

Galileo

Sources of Radiation

(Applications)

Irradiation of blood & blood products

- A proven and safe method to inhibit T-Lymphocyte Proliferation
- Eliminates the risk of post transfusion graft versus host disease (T-GVHD).
- Gamma irradiation of cellular blood components is the best current technology to reduce the risk of T-GVHD
- Being widely practiced world over in hospitals and blood banks
- Blood is usually irradiated in standard blood bags in dedicated blood irradiators using cobalt-60 or caesium-137 radioactive source.
- The usual recommended radiation doses are 25 Gy to 35 Gy for this purposes.

Sources of Radiation -Applications

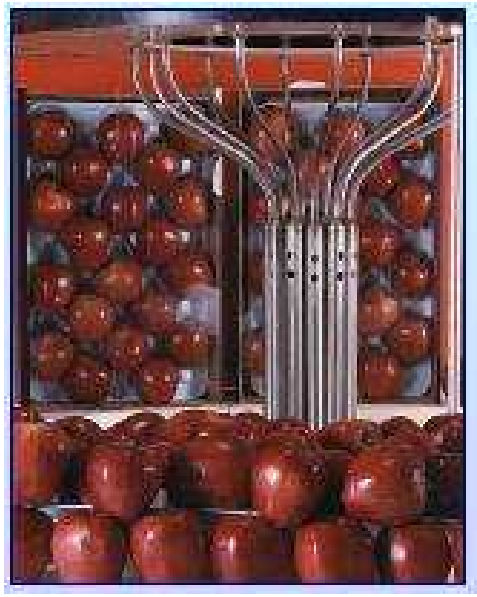
Agriculture

- Reduce needs for fertilizers and water
- Speed breeding of improved crops
  - 2,250 new crop varieties worldwide (89% radiation used)
  - Greater yield
  - Increased disease resistance
  - Better nutritional value
- Animal husbandry
  - Increase body weight
  - Vaccines to eliminate diseases
- Insect control
  - Sterilization (screw worm, Mediterranean fruit flies, gypsy moths)

Sources of Radiation -Applications

Agriculture

- **Food irradiation**
  - 76 million cases of food poisoning each year in U.S.)
  - Kill bacteria, molds, yeasts, parasites, insects
  - Extend shelf life



Co-60 Food Irradiator

Sources of Radiation -(Applications)

Practice or Application	Radioisotope	Typical Radioactivity (Ci)
Radioisotope thermoelectric generators (RTGs)	Strontium-90	20,000
	Plutonium-238	280
Sterilization and food irradiation	Cobalt-60	4,000,000
	Cesium-137	3,000,000
Self-contained and blood irradiators	Cobalt-60	2,400-25,000
	Cesium-137	7,000-15,000
Single beam teletherapy	Cobalt-60	4,000
	Cesium-137	500
Multi-beam teletherapy	Cobalt-60	7,000
Industrial radiography	Cobalt-60	60
	Iridium-192	100
Calibration	Cobalt-60	20
	Cesium-137	60
	Americium-241	100
High and medium dose rate brachytherapy	Cobalt-60	10
	Cesium-137	3
	Iridium-192	6
Well logging	Cesium-137	2
	Americium-241/beryllium	20
	Californium-252	0.03
Level and conveyor gauges	Cobalt-60	5
	Cesium-137	3-5

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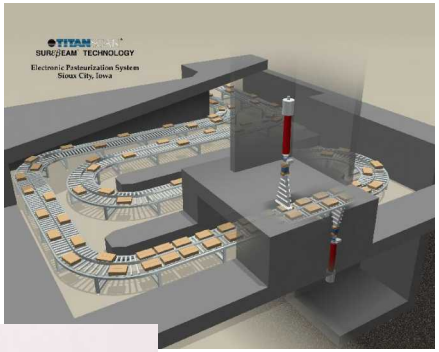
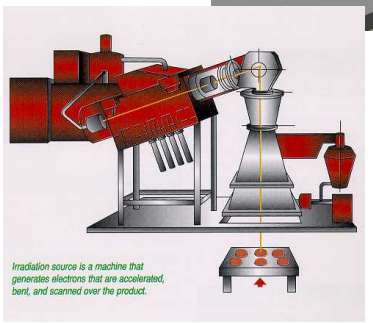
Typical Food Irradiator

- **Suitable Ionizing Radiation**
  - **Only Certain Energy Sources Can Be Used**
  - **Gamma rays from Radioisotopes**
  - **Machine generated beta or x-rays**
    - **Produces no waste outside of the machine used to produce the radiation Electrons**





- **Permitted Sources**
  - **Cobalt-60 and Cesium-137**
    - **Emit gamma rays**
    - **Sealed in container - *never touches food***
    - **Can be recycled**

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Basic Food Irradiator

- **Suitable Ionizing Radiation**
  - **Only Certain Energy Sources Can Be Used**
  - **Gamma rays from Radioisotopes**
  - **Machine generated beta or x-rays**
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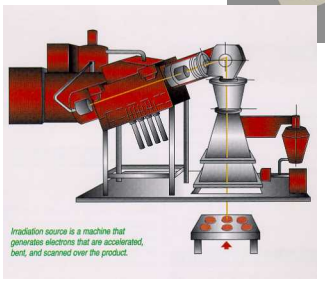

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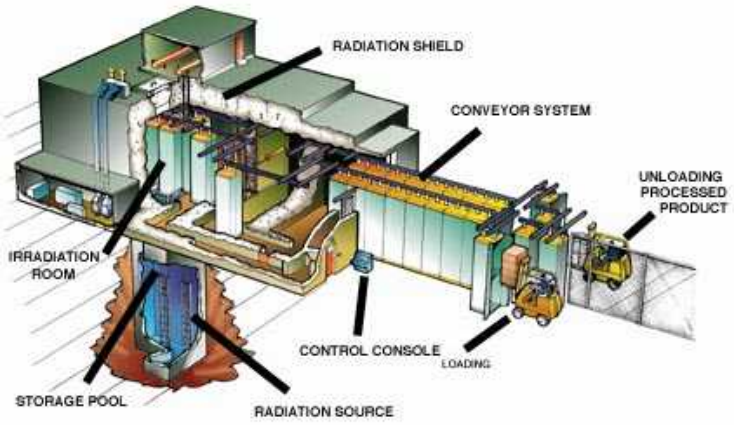

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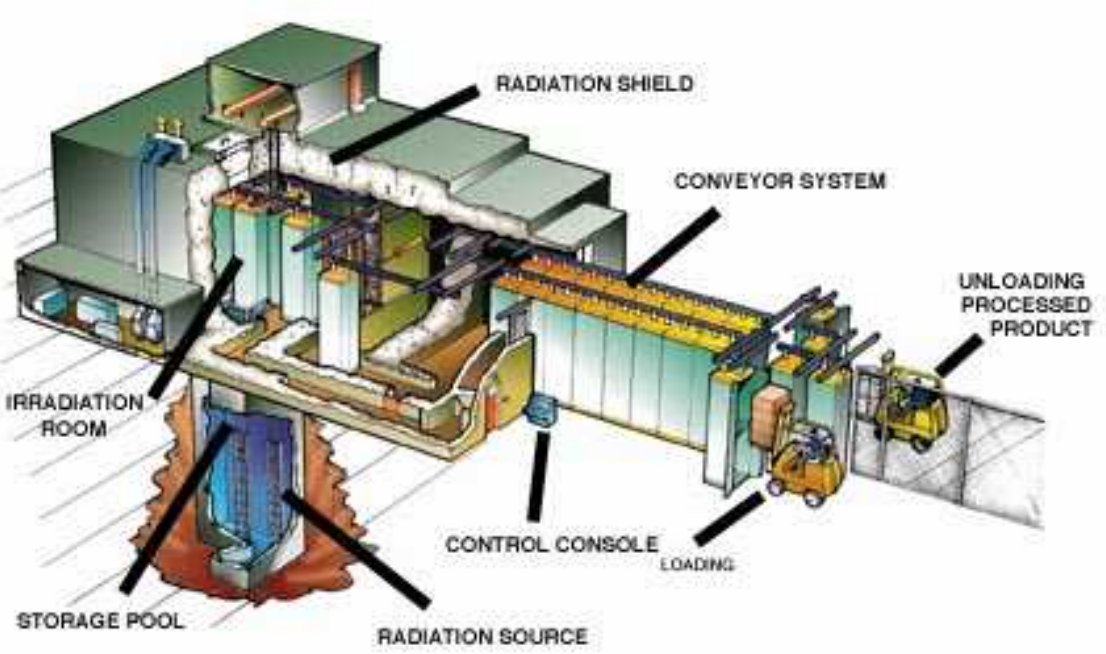
A Typical Food Irradiator

- An Industrial irradiator consists of:
  - A room with concrete walls 2 meters thick which contain the radiation source (cobalt-60).
  - A conveyor system automatically moves the product into the room for irradiation, and then removes it.



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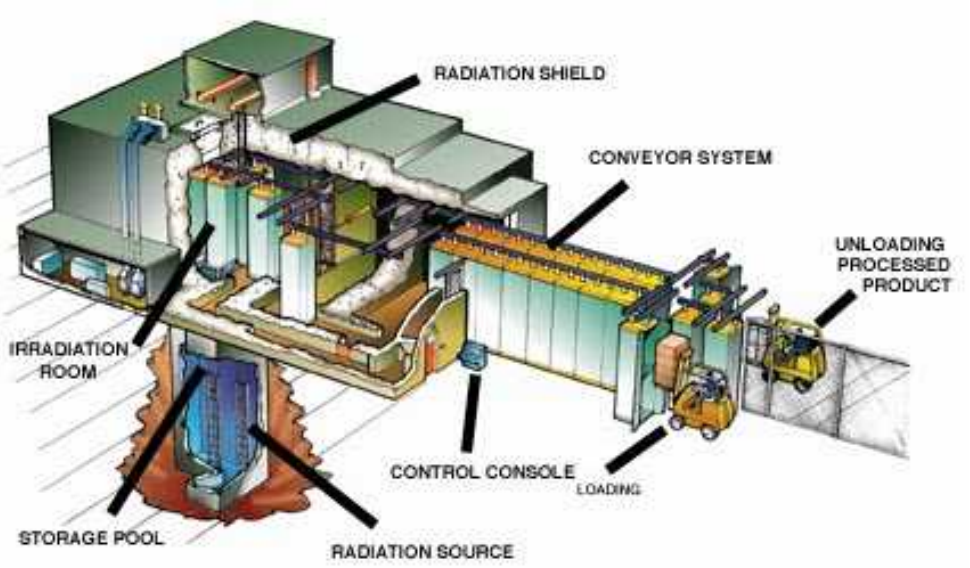
Typical Food Irradiator

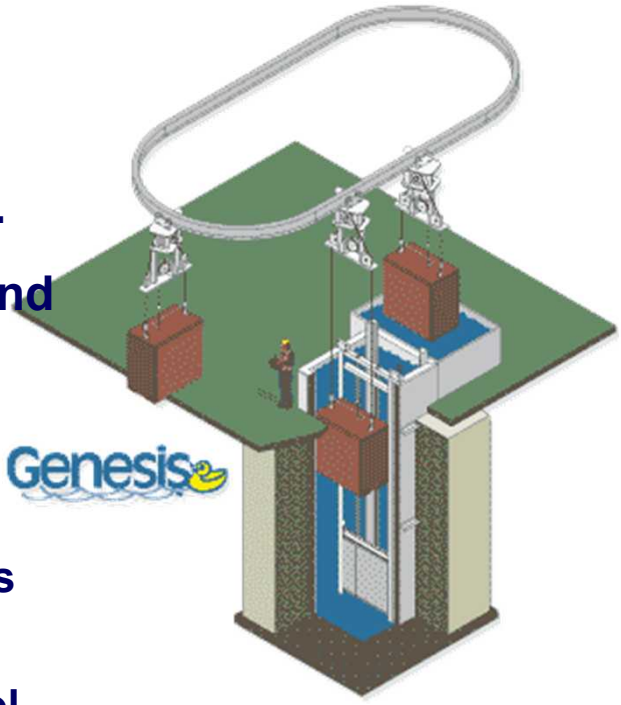
- When personnel must enter the room, the source is lowered to the bottom of a pool, where water absorbs the radiation energy and protects the workers.
- The gamma radiation source consists of cobalt-60 rods in stainless steel tubes.
  - The tubes are stored in water and raised into a concrete irradiation chamber to treat the food.



New Irradiators

General Description

- Self-contained, gamma irradiator specifically designed to process food.
- Does not require massive above-ground shielding,
- Does not require complex electrical interlock systems
  - Cobalt-60 radiation source never leaves the shielded pool
  - Instead product is lowered into the pool adjacent to the source



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New Irradiators

RADIATION SOURCE

- Cobalt-60; 1,000,000 curies per unit (Maximum); half-life - 5.3 years;
- 705 source positions available;
- Dry helium storage of sources shielded by water.

New Irradiators

POOL DIMENSIONS

- 7' x 8' x 22' (3.5' above ground; 18.5' below)

RADIATION SHIELD

- De-ionized water. Minimum depth above source is 12.5 feet.

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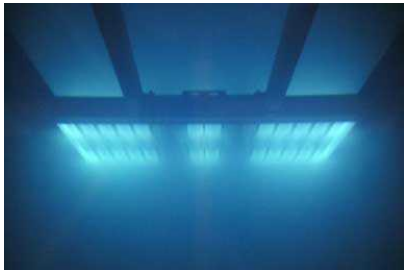
New Irradiators

- No Above-Ground Concrete Shielding, Interlock or Fire Suppression Systems Required
- Rapid and Inexpensive On-Site Installation (Full operation about six months from purchase)
- Small Footprint (1,600 sq. ft., including dosimetry lab and administrative office)
- Realistic Processing Capacities (Typically, 200,000 pounds of product per day)
- Gamma Radiation Penetration (Up to 24 inches of package thickness)

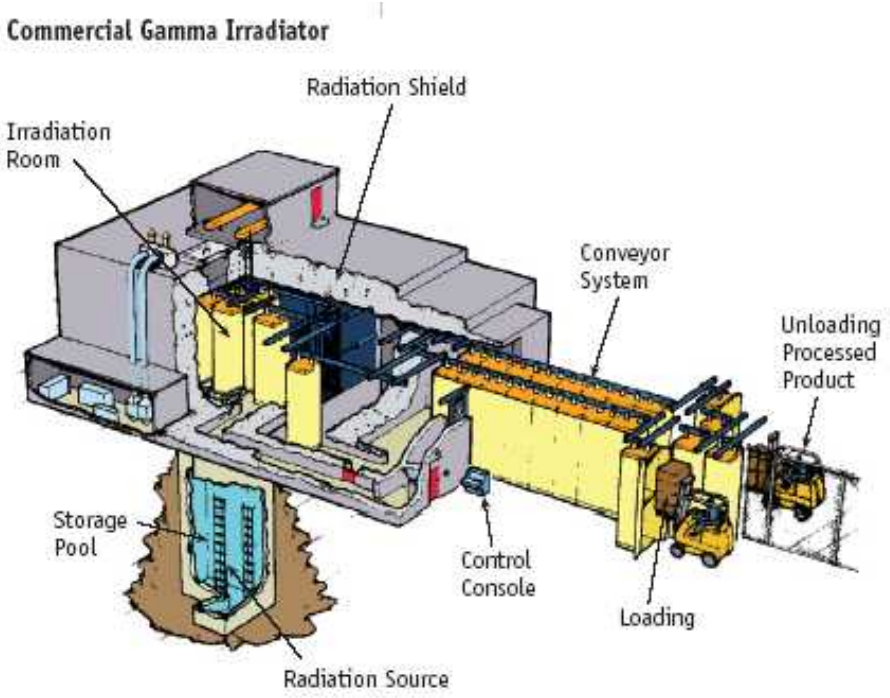


Operational Aspects of Food Irradiators

- **Products are irradiated in a shielded environment**
  - Concrete room, called an Irradiation Cell, 6 ft (2 m) Thick
  - Prevent radiation from passing into the surroundings
- **Sealed radiation sources are kept in a source rack in a pool of water 6m deep;**
  - People can enter the cell wearing everyday clothing without risk of being irradiated or contaminated
  - The source rack is only raised when the cell is isolated and sealed

Operational Aspects of Food Irradiators

- Product to be treated is loaded into carriers on a conveyor that passes into the cell through a labyrinth:
  - Passes slowly by both sides of the raised source to ensure that the product receives an even dose of radiation throughout
  - After an appropriated time in the cell the product leaves via the labyrinth to be removed from the carriers and shipped out of the warehouse for use.



General Safety of Irradiated Food

- Irradiated foods have been found to be safe and wholesome, while maintaining flavor, aroma, and texture (mouthfeel).
- More than 40 years of scientific research has shown that irradiated foods do not cause cancer, genetic mutations, or tumors.
- NASA to provides irradiated foods for astronauts to consume during space flights

Irradiation is a unique method to ensure microbial safety in raw foods.

Irradiation is an effective residue free method for microbial decontamination of spices

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General Safety of Irradiated Food

- Many immuno-suppressed hospital patients on sterile diets have been fed irradiated dairy products, breads, pastry products, cereals, dry beverages, snacks, and condiments.
- According to the International Consultative Group on Food Irradiation (ICGFI), the by-products produced in foods treated with irradiation are naturally present in foods and formed by heat processing.
- The Joint Expert Committee on Food Irradiation (JECFI) of the World Health Organization (WHO), Food and Agriculture Organization (FAO) and the International Atomic Energy Agency (IAEA) concluded that irradiated foods were safe and wholesome at irradiation levels up to 10 kGy.

Sprouting losses in stored potatoes can be prevented by irradiation

General Safety of Irradiated Food

- The FDA Bureau of Foods Irradiated Food Committee (BFIFC) found that more than 90 percent of all these compounds in irradiated foods are similar to those foods treated by other preservation methods such as freezing, drying, or heating.
- The BFIFC concluded that a diet consisting of food irradiated at 1 kGy (the approved level for fruits, vegetables, pork, and grains in the United States) would not contain a significant amount of these compounds.
- The irradiation process produces very small changes in the chemical composition of foods. These changes have not been found to be harmful or dangerous.

General Safety of Irradiated Food

Foods Currently Being Irradiated

- Internationally, foods such as apples, strawberries, bananas, mangoes, onions, potatoes, spices, seasonings, meat, poultry, fish, and grains have been irradiated for many years.
- Since 1991, Japan has irradiated more than 20,000 pounds of potatoes each year to prevent sprouting.
- In the Netherlands, more than 18,000 pounds of foods such as strawberries, spices, poultry, and dehydrated vegetables are irradiated daily.
- Belgium irradiates more than 8,000 tons of food per year. Canada irradiates potatoes, onions, wheat flour, fish fillets, spices, and seasonings. More than 35 countries have approved irradiation of some 40 different food products.

Food Irradiation Applications

Benefit	Dose (kGy)	Products
Low-dose (up to 1 kGy)		
(i) Inhibition of sprouting	0.05 - 0.15	Potatoes, onions, garlic, root ginger, yam etc.
(ii) Insect disinfestation and parasite disinfection	0.15 - 0.5	Cereals and pulses, fresh and dried fruits, dried fish and meat, fresh pork, etc.
(iii) Delay of physiological processes (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 or frozen poultry and meat, 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.
(ii) Decontamination of certain food additives and ingredients	10 - 50	Spices, enzyme preparations, natural gum, etc

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General Safety of Irradiated Food

Foods Currently Being Irradiated

- In 1986, the United States Food and Drug Administration (FDA) approved irradiation of spices and seasonings up to 30 kGy to reduce microorganisms and insects
- Fruits such as avocados, mangoes, and papayas imported into the U.S. have been approved to receive irradiation treatments
- Potatoes and onions have been approved for to inhibit sprouting
- Grains, such as wheat and oats are irradiated to prevent insect infestation

- In 1990, FDA approved the irradiation of poultry to eliminate harmful bacteria such as *Salmonella* spp., *Escherichia coli* O157:H7, *Campylobacter jejuni*, and *Listeria monocytogenes*.
- In September of 1992, USDA Food Safety and Inspection Service (FSIS) approved facilities to irradiate raw, packaged poultry.
- In December of 1997, FDA approved the irradiation of red meats for the elimination of food poisoning bacteria such as *Escherichia coli* O157:H7.

Most commonly used food packaging materials are suitable for irradiated foods

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General Safety of Irradiated Food

Nutritional Quality of Irradiated Foods

- Food proteins, carbohydrates, and fats have been found to be relatively stable to irradiation up to 10 kGy.
- Minerals have also been reported to be stable to irradiation.
- Vitamins A, C, E, and B1 (thiamin) tend to be susceptible to irradiation at doses of 1 kGy or above
  - But, are also sensitive to heat processing
  - Reduction of these vitamins in foods is minimal and would not create a risk of deficiency in the diet.
- Low-dose irradiation does not cause a significant decrease in the nutritional quality of foods.

Irradiation does not induce radioactivity in food just as fruit exposed to sun energy does not emit sunlight

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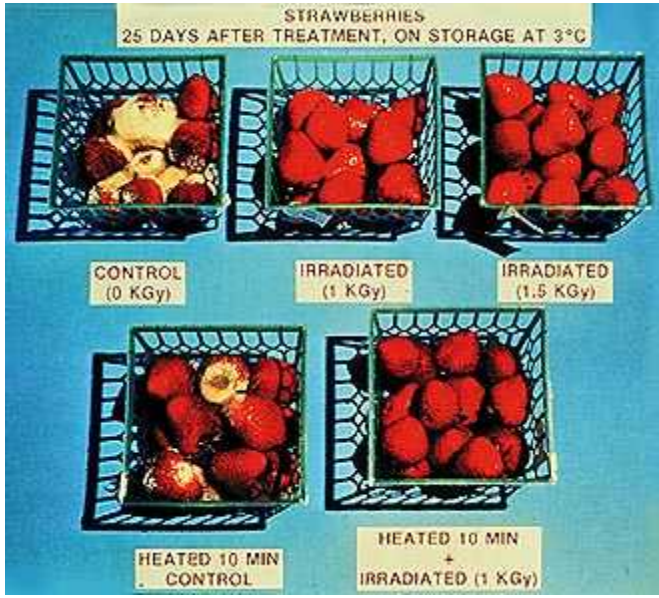
General Safety of Irradiated Food

Consumer Response To Irradiated Foods

- Consumer response to irradiated foods has been positive:
  - In March 1987, test markets of irradiated Hawaiian papayas
  - During the first quarter of 1993, irradiated strawberries outsold non-irradiated berries by a ratio of 20 to 1
  - In July 1993, Laurenzo's Market and Italian Grocery in Miami, Florida, reported selling their first shipment of irradiated poultry
- Results indicate that informed consumers like and will buy irradiated foods.
  - Safety from food poisoning bacteria,
  - Superior product quality.
    - For instance, strawberries stored in the refrigerator normally mold after 5 days. However, strawberries treated with 1 kGy of irradiation have been found to be free of mold after 25 days in the refrigerator
- To date, no single test market of irradiated foods has been unfavorable when the consumer has been provided information about food irradiation.



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General Safety of Irradiated Food

Summary

- Food irradiation can be used to combat foodborne diseases,
- Food irradiation could be used in place of harmful fumigants used to kill mold and insects on produce and grain.
- Food irradiation has been studied more extensively than any other food additive.
- Food irradiation has been endorsed by FAO, WHO, USDA, the American Medical Association (AMA), and the Institute of Food Technologists (IFT) as a safe and practical method for preserving a variety of foods and reducing the risk of foodborne disease.
- Food irradiation provides safer food, improves quality, and extends shelf life.

Limits to Irradiation

- Irradiation cannot
  - Replace basic food safety
  - Prevent recontamination
  - Deter bacteria introduced after irradiation
  - Kill all viruses at approved rad levels
  - Kill all bacteria at approved rad levels
    - Particularly in Shrimp
- Irradiation can alter the appearance of food
- Determining minimal effects is very difficult
  - Can only measure effects that are higher than background.

Next

- **We will examine different Aspects of Irradiators and Irradiated Foods in more details**
  - **Health Physics Aspects of Food Irradiators**
  - **Irradiator Source Storage & Security**
  - **Safety of Irradiated Food**
  - **Past History, Current Status, and Potential for Future of Irradiated Foods**

Supplement Summary

Final Summary

Irradiation Processes

- Sterilization
- Pasteurization
- Disinfestation
- Sprout Inhibition
- Delay of Ripening
- Physical Improvements

Final Summary

Irradiation Sterilization

- Very high dose used to kill all organisms
- Sterilization of > 50% disposable medical instruments
- Food sterilization - NASA, military, transplant patients

Irradiation Pasteurization

- Reduces remaining number of living organisms
- Prevent growth of mold
- Kill bacteria and parasites

Final Summary

Irradiation Disinfestation

- Kills insects and parasites in grains and other stored foods
- Fewer chemical residues on fruits and vegetables
- Does not prevent against re-infestation

Physical Improvements

- Inhibit sprouting of potatoes, onions, and garlic
- Delay of ripening for strawberries, mangoes, bananas, tomatoes, etc.
- Incidental improvement in fruit texture and meat color

Final Summary

How does irradiation do so many different things?

- High doses damage or kills cells
  - Kills microorganisms or insects
- Lower doses alter chemical reactions and interfere with cell division
  - Delay fruit ripening
  - Prevent sprouting or parasite reproduction

Final Summary

Are irradiated foods safe to eat?

- Foods cannot become radioactive at energies used in irradiation
- Below 10 kGy there are no known toxicological, microbiological, or nutritional problems

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Final Summary

Foods Approved for Irradiation in the United States:

- Fresh fruits and vegetables
- Herbs and spices
- Pork
- Potatoes
- Poultry

Radura: Official symbol or logo indicating that food has been irradiated

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