e-Beam

Lesson 4

Science and Applications of Electron Beam Irradiation Technology

Lesson 4 of 4

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Complex Food Items using Electron Beam Technology."

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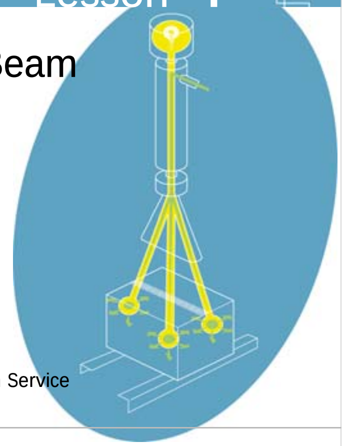

The National Center for Electron Beam Food Research

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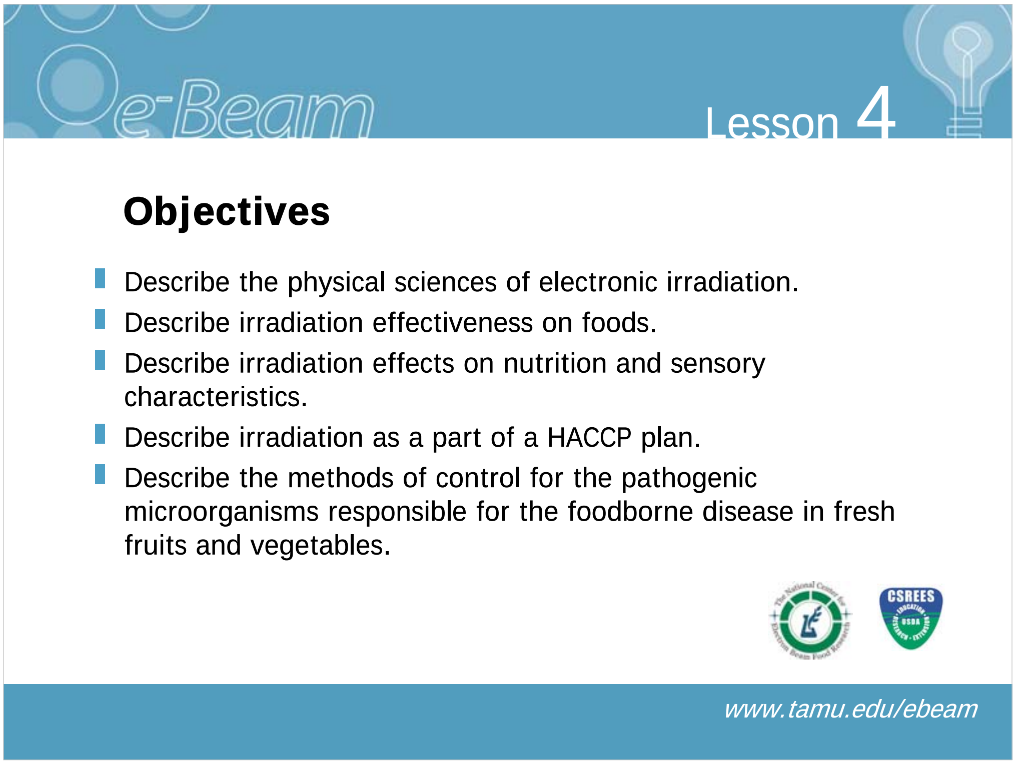
These slides contain notes which augment the actual slide presentation. You may view the notes by clicking on the "normal view" icon in the lower left-hand corner of your screen, or by selecting "Normal" in the "View" dropdown box from your toolbar's menu.

In this section, we will review the *Science and Applications of Electron Beam Irradiation Technology*. This lesson will share how we can further reduce the incidence of foodborne disease using the technology of irradiation as an additional intervention strategy.



Learners who complete this lesson will be able to…

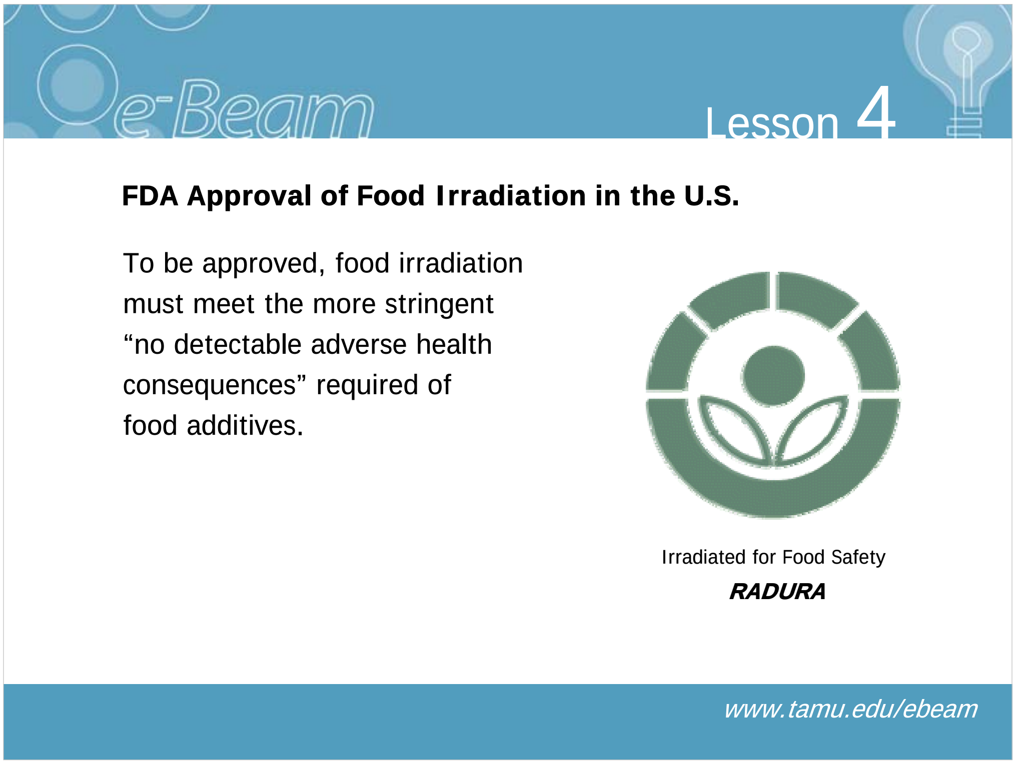
…describe the physical sciences of electronic irradiation.

…describe irradiation effectiveness on foods.

…describe irradiation effects on nutrition and sensory characteristics.

…describe irradiation as a part of a HACCP plan.

…and describe the methods of control for the pathogenic microorganisms responsible for the foodborne disease in fresh fruits and vegetables.



First and foremost, we recognize that neither producers, processors, nor consumers are aware of the intense level of scientific scrutiny placed on the safety and wholesomeness of irradiated foods. The US Food and Drug Administration (FDA) requires irradiated foods to meet the more stringent "no detectable adverse health consequences" required of food additives.

FDA also requires irradiated foods to carry an international label, the radura, which symbolizes that the product has been irradiated to eliminate harmful pathogenic organisms. Along with the radura, food processors must also include labeling terms that distinguish the products as having been treated by irradiation. All processors use the term irradiated and may add terms to inform consumers why the produce was irradiated such as "Irradiated for Food Safety," fulfilling the consumer's right to know. These labels allow consumer choice at the grocery shelf when consumers prefer a safer food product.

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Foods Currently Approved for Irradiation by USDA and FDA

Product	Approval Date	Max. Dose (kGy)
Wheat & wheat flour	1963	0.50
Dry enzyme preps	1985	10.0
Pork	1985	1.0
Fruits & Vegetables	1986	1.0
Spices & dry seasonings	1986	30.0
Poultry	1992	3.0
Red Meat (fresh/frozen)	2000	4.5/7.0
Shell eggs	2000	3.0
Seeds for sprouting	2000	8.0
Animal Feed & Pet Treats	2001	50.0

Irradiated for Food Safety

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The first U.S. food irradiation approval was for wheat and wheat flour in 1963. Other food irradiation applications have been approved and regulated by the U.S. Food and Drug Administration and Department of Agriculture since that time. Most pharmaceutical containers, gel caps, contact lenses, bandages, feminine products and other consumer products are also irradiated for elimination of pathogens.

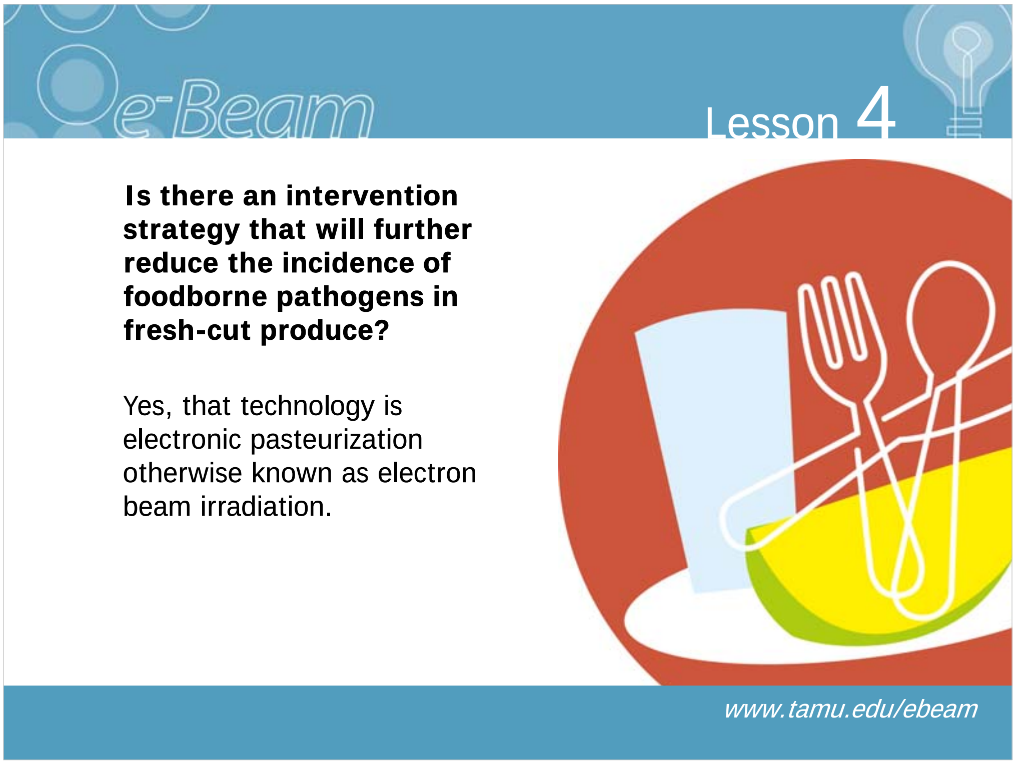
Since 1986, almost every American has been a consumer of irradiated spices and dry seasonings. Food pathogens in our spices and dry seasonings are prolific due to issues such as pathogen infested soil and irrigation water as well as farm fertilization practices in the countries of origin of many of these products. Another concern is the rapid population growth of pathogens along with the normal length of time and temperature at which a food establishment or consumer may store spices and dry seasonings.

From Project Apollo in 1972 to the Space Shuttle and the International Space Station in 2005, NASA has ensured health and safety of our astronauts in training and manned flight missions by sterilizing their foods with irradiation. For example, since 1993, NASA astronauts have consumed approximately 1500 irradiated entrees annually during 29 shuttle missions and four MIR missions.

Also, irradiated foods in elder care facilities and hospitals has increased in use during the past five years due to immuno-compromised residents and patients who dine at these facilities.

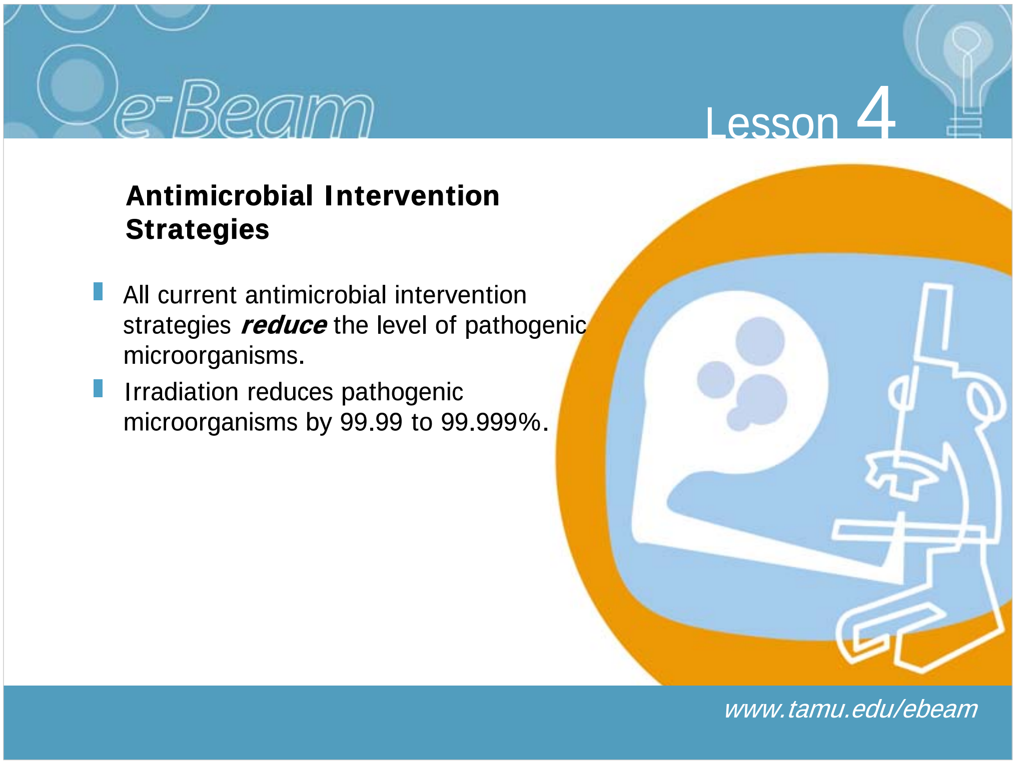
Let's review for a moment.

An intervention strategy is defined as any chemical or physical process or technology, that when applied effectively, reduces or eliminates pathogenic microorganisms from a product, process, or equipment surface.

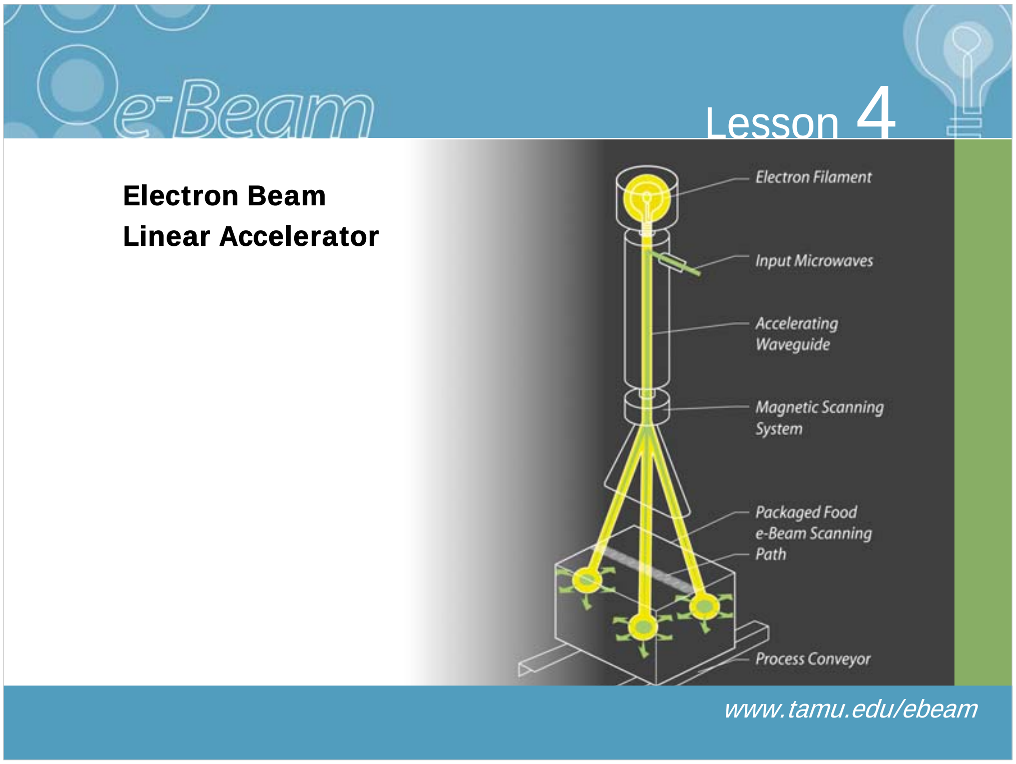


The U.S. Centers for Disease Control and Prevention record more than 5,000 die, 1 in 1000 people are hospitalized, and 1 in 4 people become sick annually due to illnesses caused by foodborne pathogens. Deaths from foodborne pathogens equate to approximately 14 per day in the USA. That is 1/8 of the 40,000 annual deaths from automobile accidents (110 per day). What's important to point out is that consumers recognize and accept the risk of driving an automobile, but when dining at home or eating out, the consumer's perception is that there should be no risk to themselves or their family. Most consumers believe they are in control and responsible when behind the steering wheel of an automobile. But when illness or injury comes from a foodborne pathogen, consumers feel as if they have no control and are not responsible.

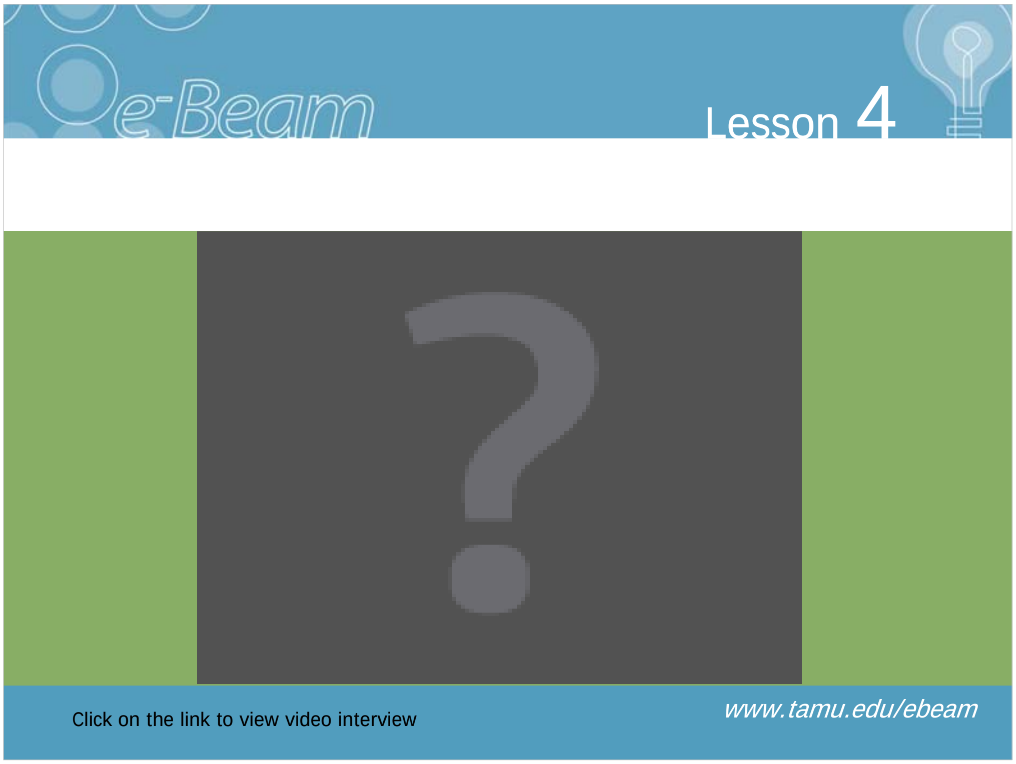
The associated annual costs of foodborne illnesses in the US are estimated at $7 billion due to medical expenses, hospitalizations, and loss of productivity. According to the USDA's school lunch program, the cost of e-Beam processing, including additional handling and shipping charges, is about $0.13-$0.20 per lb. of food. That's about 4 cents per ¼ pound hamburger, minimal compared to the liabilities and economic losses associated with foodborne illness.



Research reveals that irradiation is an extremely effective intervention strategy in which light waves leave no residue and sustain quality, nutritional value, and taste. It is a fact that irradiation only produces chemical changes in foods similar to those produced by conventional cooking or pasteurization.



Pre-packaged or bulk foods are exposed to a type of irradiation in the form of electron beam light waves traveling near the speed of light. The linear accelerator looks like a 9" x 24" flashlight that produces pulsating light waves of electrons which are capable of breaking the bonds in the DNA of harmful microorganisms in food, damaging or destroying the organisms. The dose of light waves is controlled to a level which eliminates the targeted pathogen without changing the food quality. All this is done with less that 2° F change in the temperature of the product, thus the term "cold pasteurization" was coined in the 2002 USDA Farm Bill .

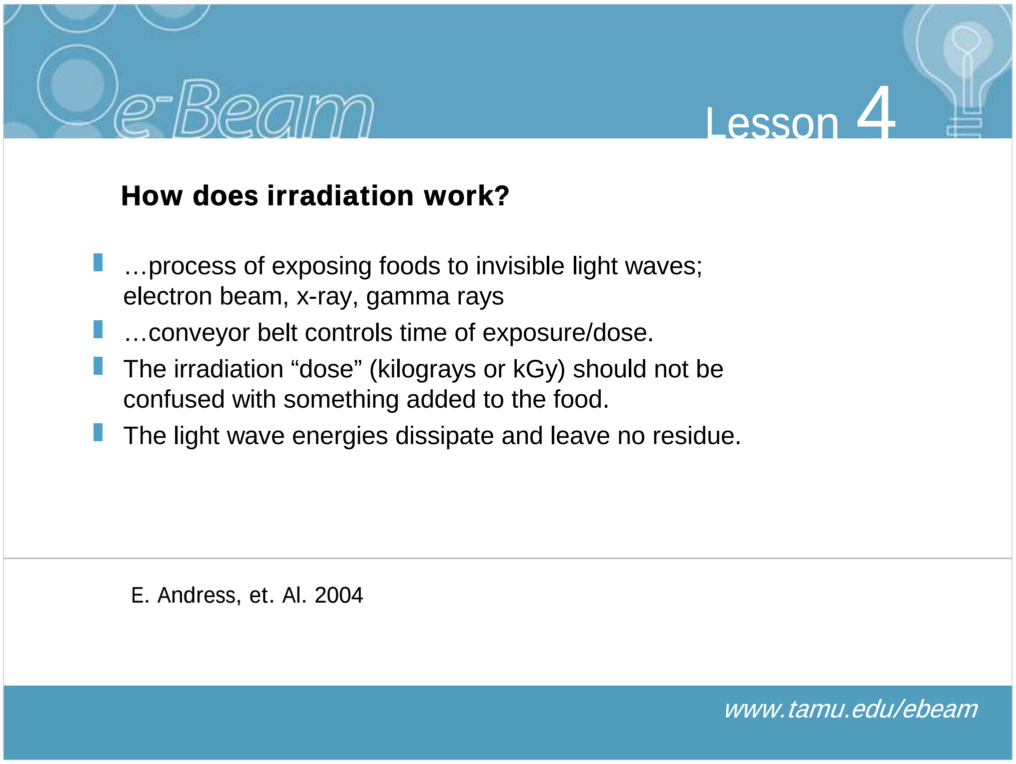


Click on the link in the slide presentation to view video interview.

NASA Scientist: That's the amazing thing about science, sometimes you are studying something and you may discover something else entirely different. For example, when NASA was looking for ways of preserving food for the astronauts, they came upon irradiation and it's a perfect way to preserve food. The last thing that NASA wants is to have somebody getting sick in a weightless environment. You can imagine what a mess that is. So they came up with these new techniques to be able to preserve foods and have them fresh and make sure that the astronauts wouldn't get sick. And now, we are finding that, even on Earth, some foods are very nicely made safer using irradiation.

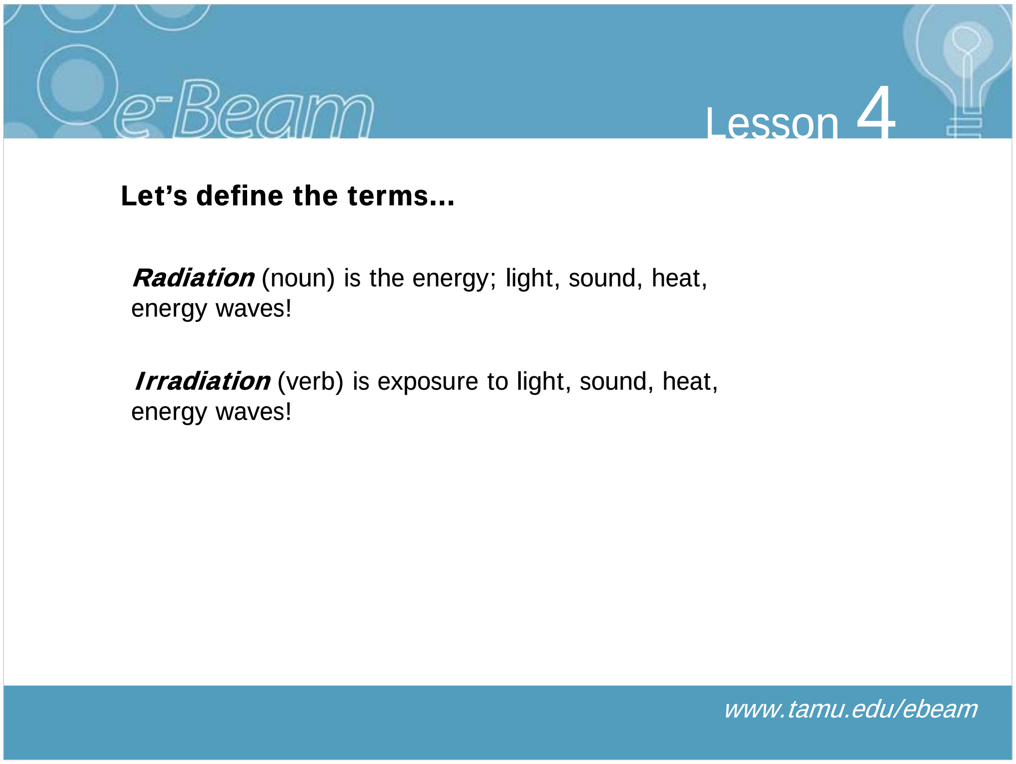
Student: How does irradiation kill the bacteria?

NASA Scientist: The irradiation process works by passing high energy electrons or gamma rays through the food. If there is bacteria in the food, they also get subjected to the same irradiation. And the radiation breaks the DNA inside the cells and prevents the bacteria from replicating. Which inactivates them or kills them.



Like the NASA scientist explained in the previous slide, irradiation is a process of exposing foods to invisible light waves called electron beams or gamma rays. You may also add x-ray to this list of light waves. Contemporary electron beam technology enables us to create x-rays for food irradiation, much like your dentist turns electron beams into x-rays to make an image of your teeth, but with more electrical intensity.

The irradiation source, in this case an electron beam linear accelerator, is stationary. Food processors simply engineer a conveyor belt designed to carry packaged food products through the field of light wave energies at a predetermined rate of speed (i.e., 40 feet per second). The rate of speed of the conveyor controls the precise amount of energy exposure received by the food product. In other words, the duration of exposure determines the dose rate of energy (dose per unit of time). A science-based level of energy necessary to destroy a certain pathogen (i.e., *E. coli* O157:H7) and maintain the sensory and nutritional qualities of the food is predetermined by replicating and validating dosimetry required of each food item.



Sometimes we need to gain an understanding of the basic terminology used in a new food science technique. In this case one needs to understand that irradiation is the verb form of the noun radiation.

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The Language of *e-Beam* Food Irradiation

Electron *(noun)* **–** electrons, along with protons and neutrons, are natural parts of the compounds that make up living organisms and organic compounds, including humans.

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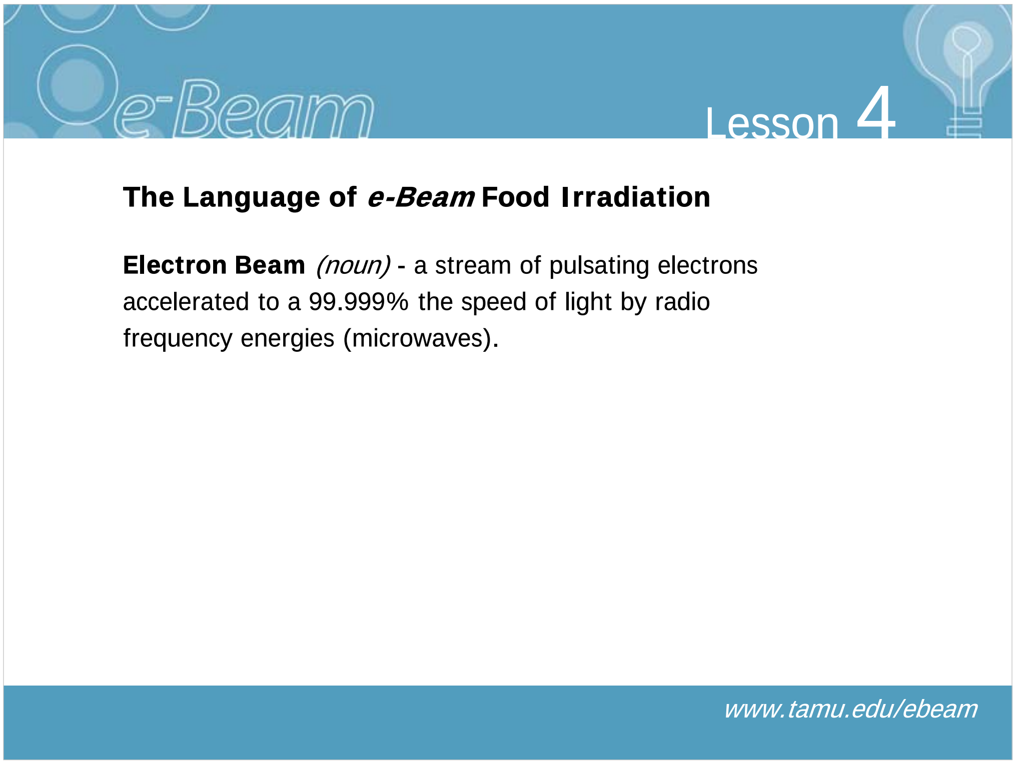
Electrons are the negatively charged particles associated with almost every order of mass on the earth, including living plant and animal cells. An electron is not very powerful. For example, if you were to drag your feet along the carpet in your living room, this action would create static electricity, basically an additional electron encircling your body searching for a positive (+) charged particle in order to balance its negative charge. If you touch a sibling, or a door knob, the electron passes and the electron's little power is transferred.



You may ask: If the electron is not very powerful, then what gives electrons the power to penetrate into foods with energies capable of breaking DNA of food pathogens? Well, the electrons themselves, as we have demonstrated with the static electricity example, don't have the power to penetrate or break DNA. The electron beam linear accelerator injects radio waves into the accelerator cylinder along with the electrons. The electrons ride the radio waves, like a surfer rides a wave to shore, at near the speed of light. This velocity energy enables the electrons to penetrate nearly 2 inches into foods with the power to break DNA and disable or destroy pathogens in foods.

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The Language of ***e-Beam*** Irradiation

Radiation Dose *(noun)* - the measure of effective energy absorbed by the food as food passes through the field of energy during processing. (1 kGy = 1 kJ/kg of product)

E. coli 0157:H7	1.50 kGy
Salmonella	2.50 kGy
Listeria	2.00 kGy
Fruit Fly	0.25 kGy

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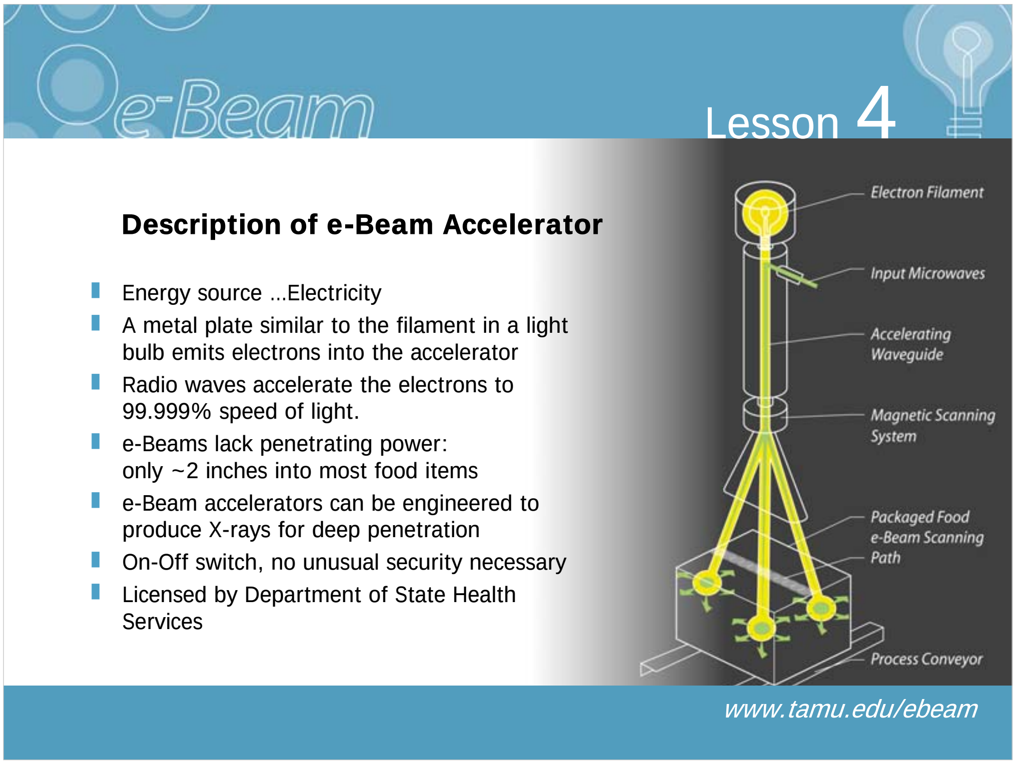
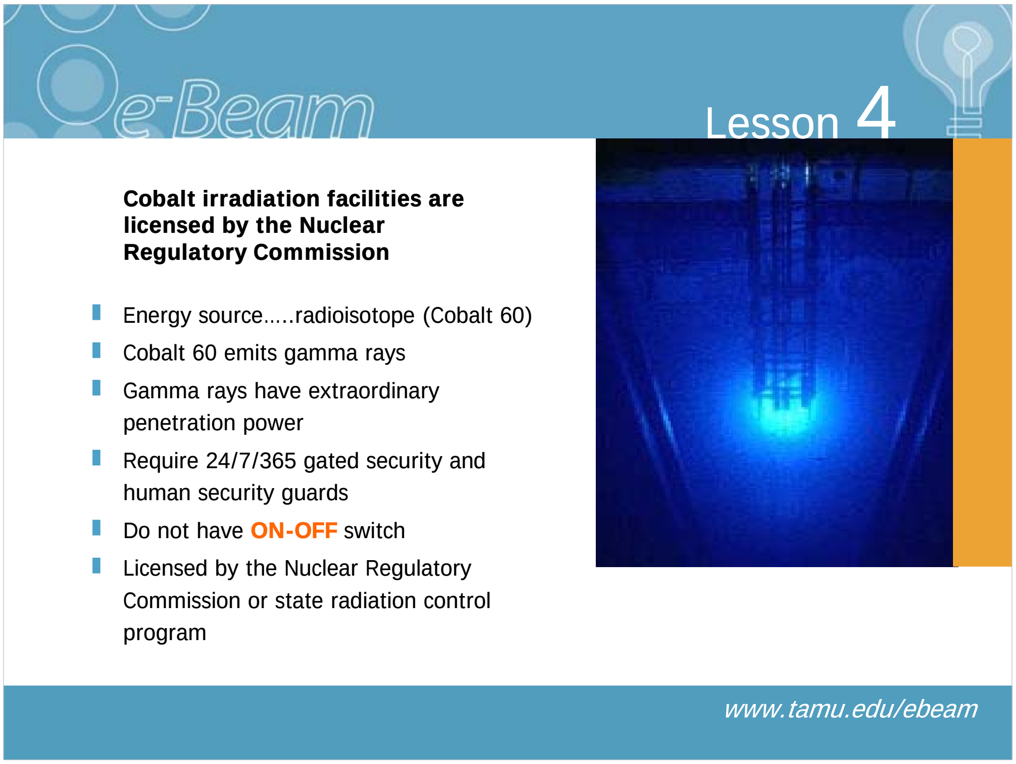
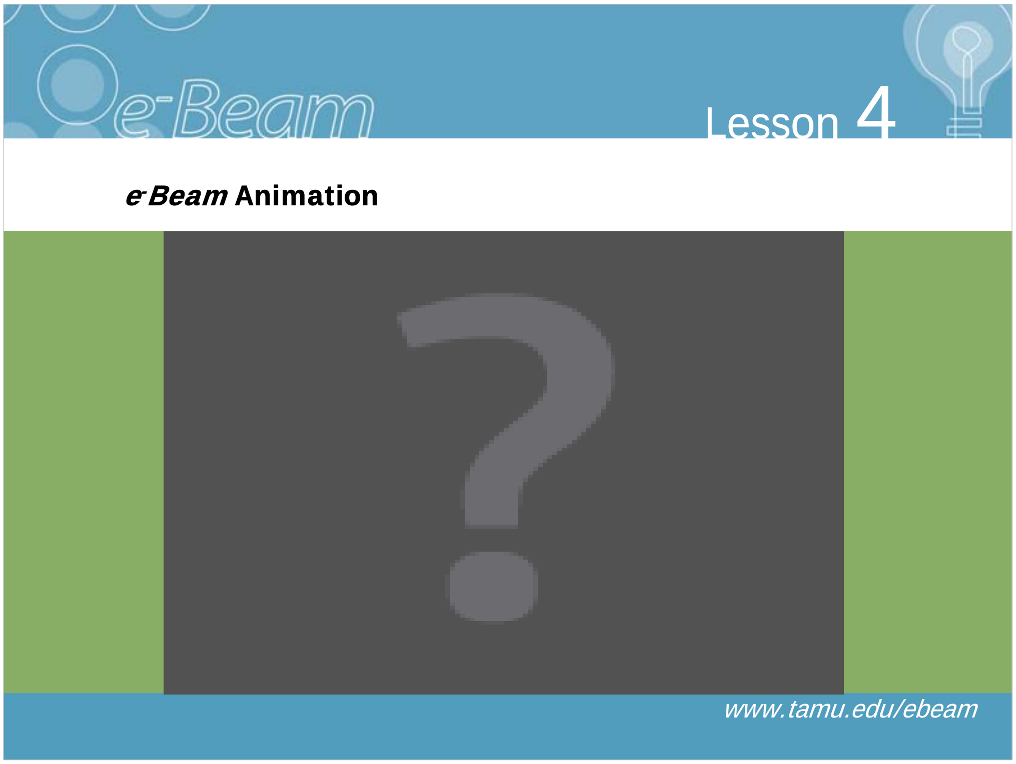
The amount of energy the food is exposed to is measured in kilograys (kGy), a unit of measurement of energy exposure. For example, the energy necessary to destroy *E. Coli* 0157:H7 bacteria at a rate of 6-logs or 99.9999% kill is 1.50kGy.



One reason we will experience more irradiated foods in our future is the fact that electron irradiation technology came of age with the opening of the first commercial electron beam food processing facilities in the early 2000's. Many food companies appreciate that electron beam technology uses commercial electricity as an energy source, can be engineered to produce x-rays for deeper penetration for larger food items or packages, has an On-Off switch like other food processing equipment and is licensed by the Department of State Health Services.

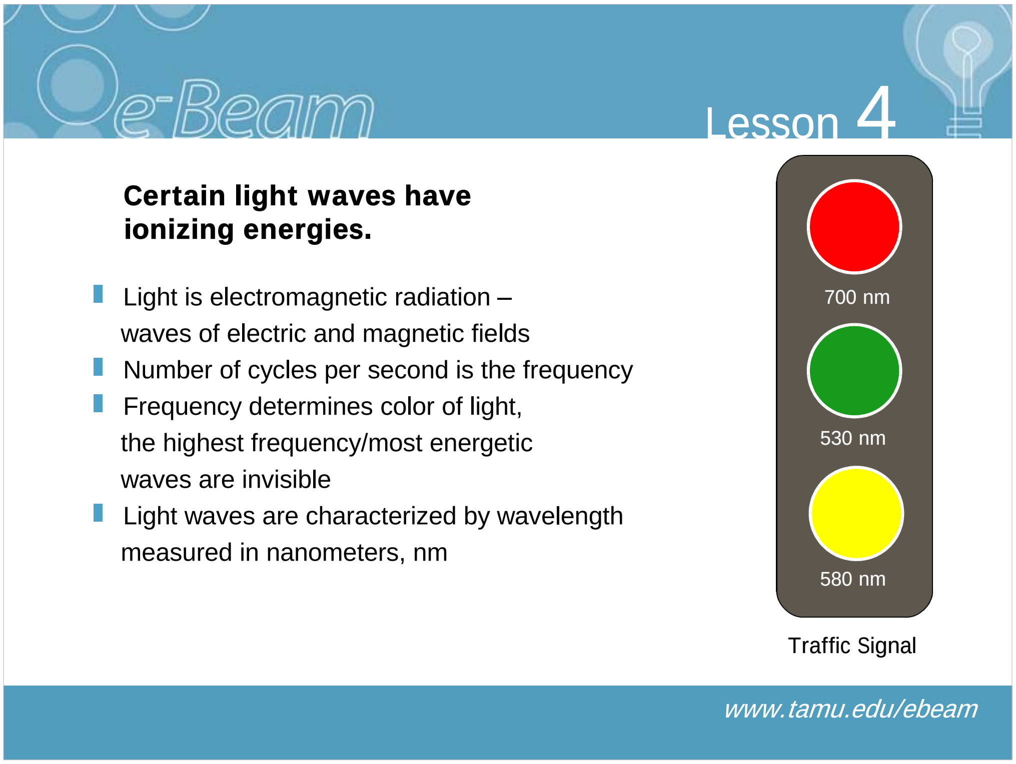


Gamma ray food irradiation facilities differ in that their energy source is a radioactive isotope, requires 24/7/365 security, has no On-Off switch, and is licensed by the Nuclear Regulatory Commission or state radiation control program. Although both gamma and electron beam irradiation are proven safe and effective for controlling food pathogens, some food processors and consumers hold negative perceptions of radioisotope-based irradiation.

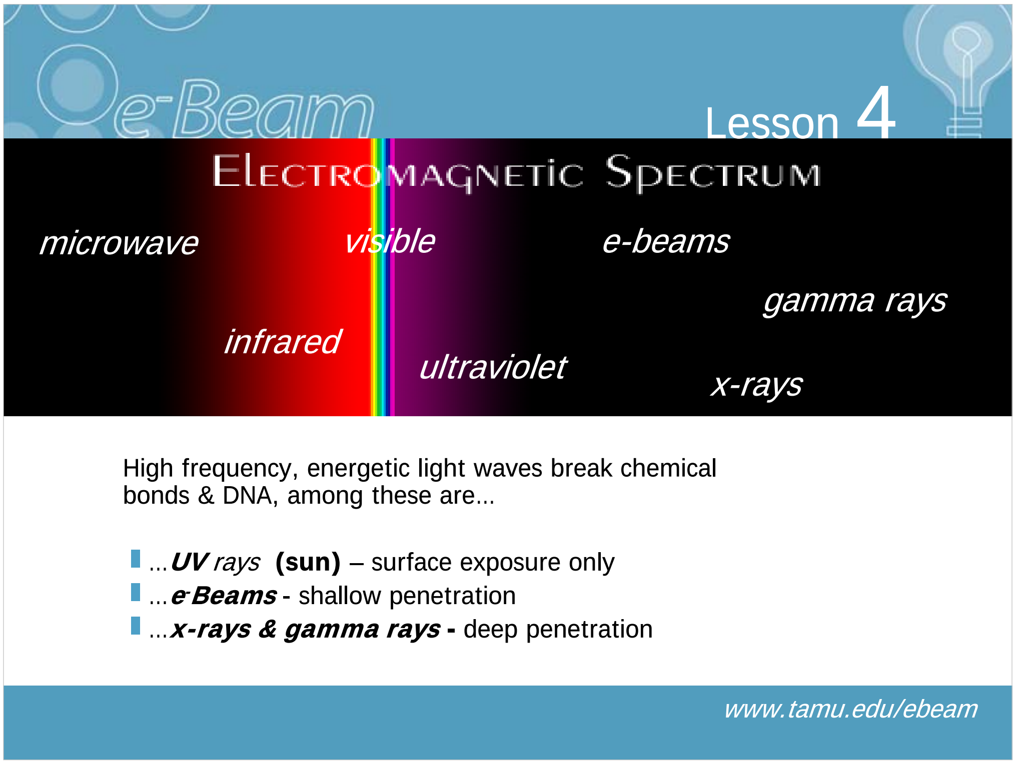


At this electron beam irradiation facility, notice first that the concrete shielding is minimized so that we can see the rest of the engineering. Next notice the presence of two electron beam linear accelerators, above and below the conveyor belt carrying the consumer-ready packaged food products. The light waves easily penetrate through FDA and USDA approved packaging to deliver the appropriate dose of light wave energy to destroy the target pathogens.

You may ask why an electron beam irradiation facility has 2’ to 4’ thick walls of concrete surrounding the electron beam cell. This is a good question because we already know that penetration into, say, ground beef, is limited to less than 2”. It’s all about the physics of electrons. Notice that most of our conveyor belt equipment in the cell is constructed of stainless steel. Some electrons, less than 10%, turn into x-rays when they pass through certain metals. The extensive use of concrete shielding is a precautionary measure protecting workers at the facility from potential x-rays that may be produced while processing foods.

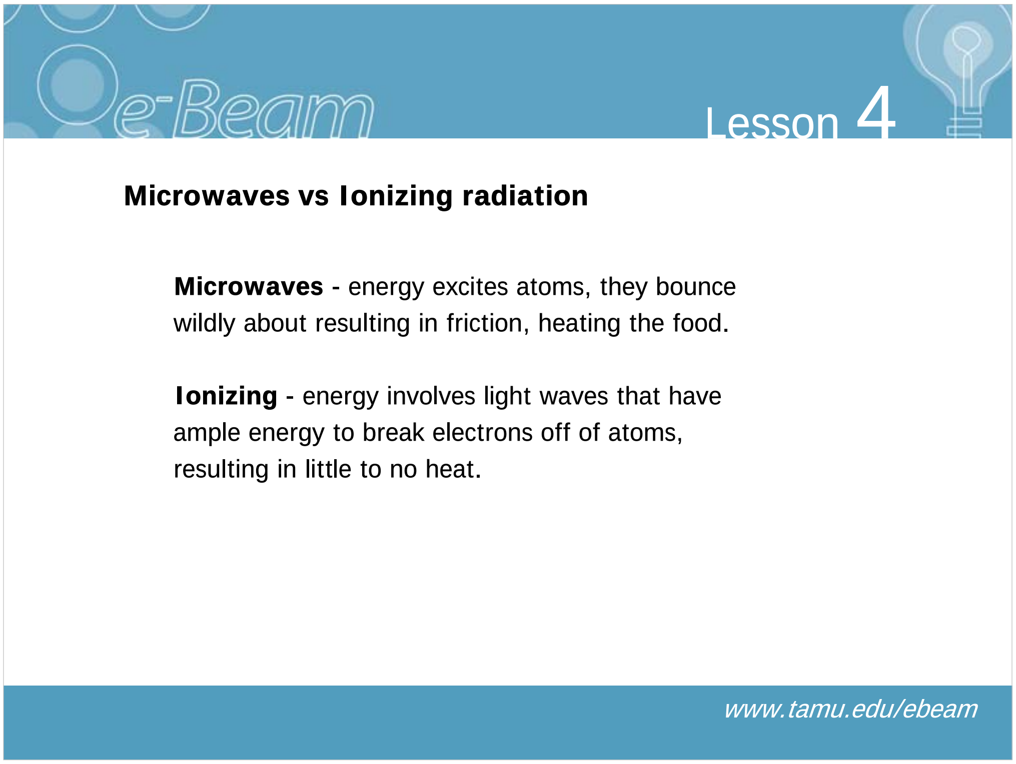


Lets contrast light wave frequencies with those of ocean waves. When wind speed is high, ocean waves are more energetic and more frequently crash into the beach. Similar to ocean waves, light waves are measured by their frequency. Less frequent light waves, for example those with frequencies of 700nm in length, are less energetic and are easily seen as red. More frequent and energetic light waves have shorter wave lengths, such as the color green at 530 nm. The most energetic light waves are shorter in length and are very energetic, so frequent that they are invisible to our eyes. These light waves begin with ultraviolet light emitted by the sun. The shortest wave length (or most energetic frequency) light waves are called electron beams, x-rays, and gamma rays.



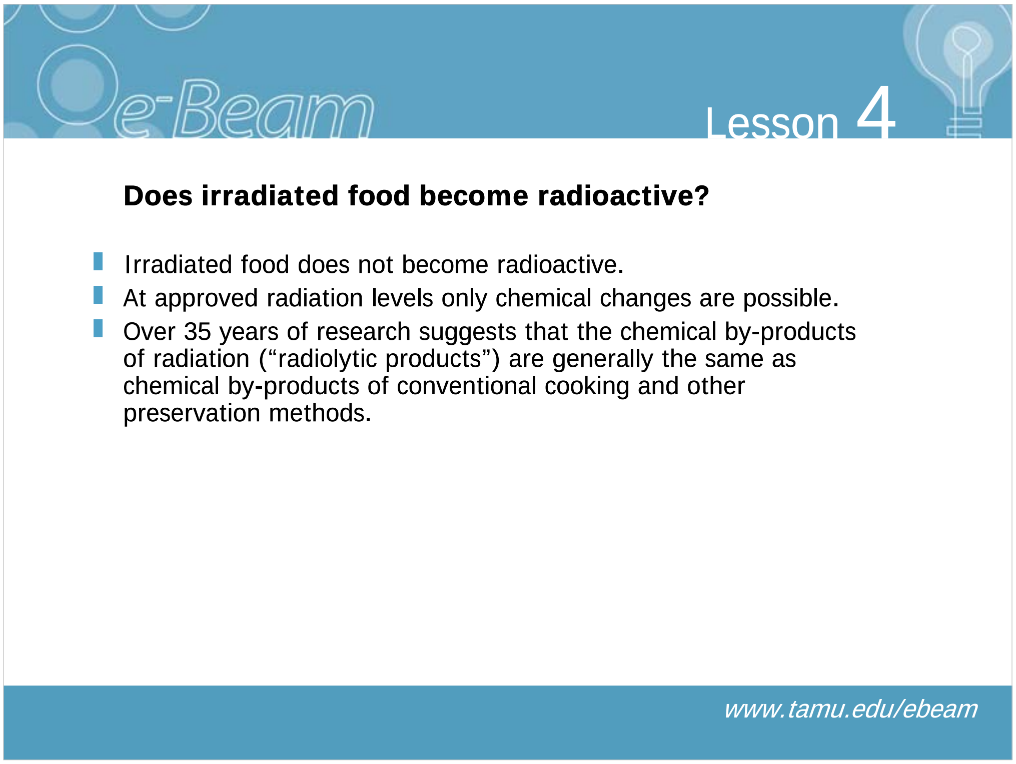
Again, the most energetic light waves are shorter in length and are so energetic, so frequent, that they are invisible to our eyes. These light waves begin with ultraviolet (UV) light emitted by the sun. UV light waves are powerful enough to break chemical bonds and DNA, for example sunburn, but do not have penetrating energies, thus they cause damage at the skin surface only. The shorter wave length, more energetic frequency light waves called electron beams when accelerated (velocity energy added) to near the speed of light using a linear accelerator, have shallow penetration energies and can penetrate into most food items about 2 inches. An electron has a negative charge and has mass, therefore; electrons collide and try to adhere to other matter causing rapid energy dissipation.

X-rays and gamma rays are the most energetic forms of light waves. They are highly energetic, have no mass, thus they have extraordinary penetration energies.



When foods are exposed to the radio wave energies of a microwave oven, atoms become excited causing them to bounce wildly about, resulting in friction induced heat, in other words cooking.

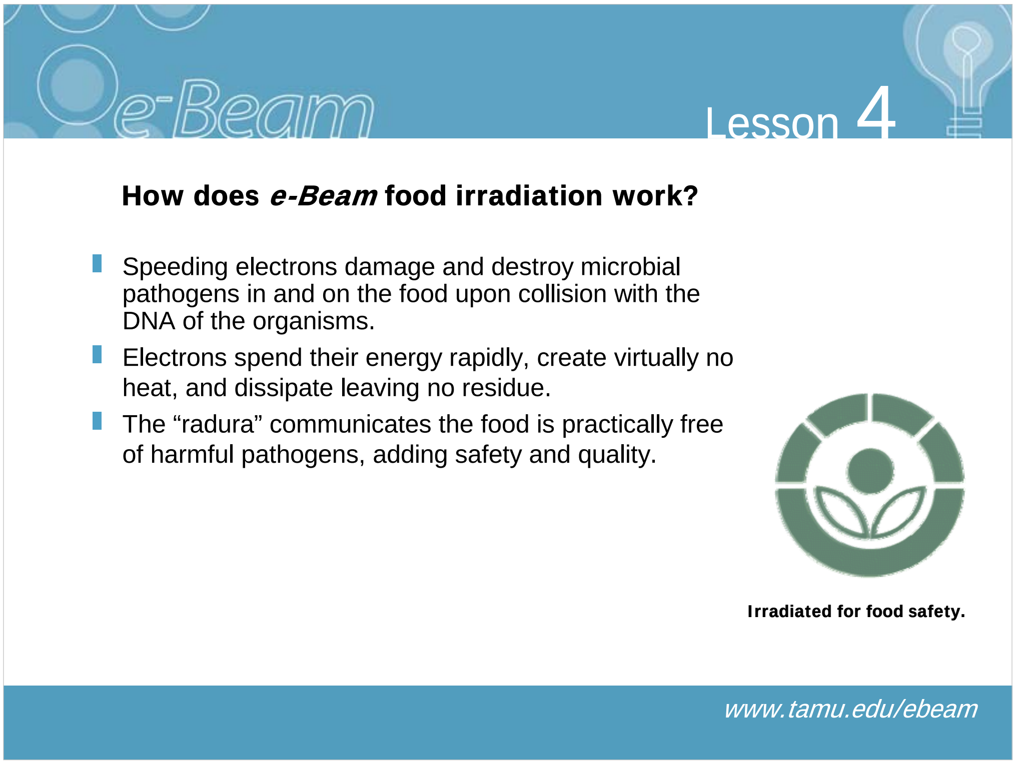
When foods are exposed to the light wave energies of gamma rays, x-rays, or accelerated electrons, ionization takes place causing fracturing of molecular bonds. These energies do not cause friction; therefore, the food is not heated.



Irradiated food does not become radioactive.

At approved radiation levels only chemical changes are possible.

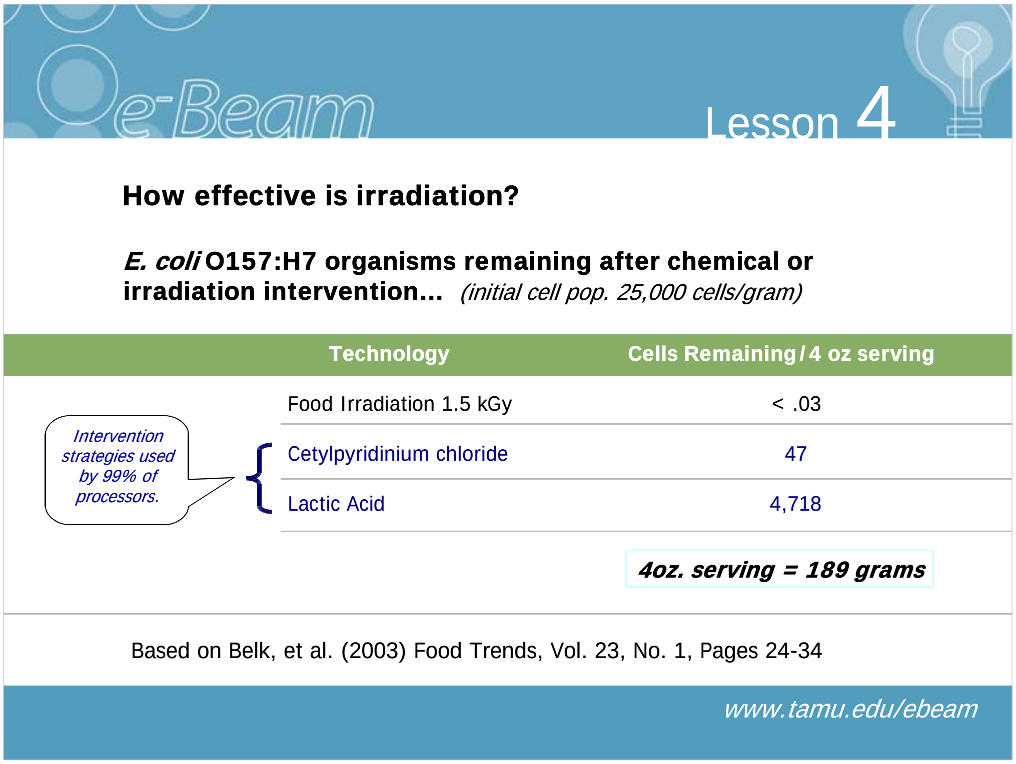
Over 35 years of research suggests that the chemical by-products of radiation (“radiolytic products”) are generally the same as chemical by-products of conventional cooking and other preservation methods.



Speeding electrons damage and destroy bacteria in and on the food upon colliding with the DNA of the organisms.

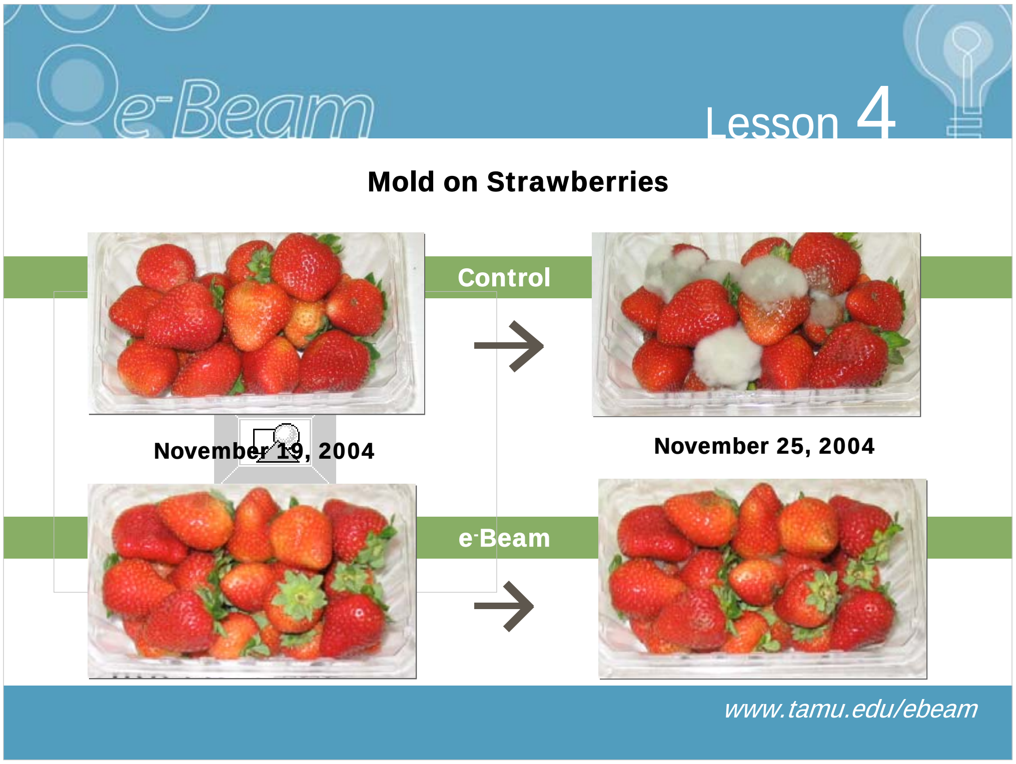
Electrons spend their energy rapidly, create virtually no heat, and dissipate leaving no residue.

The “radura” communicates the food is freed of harmful pathogens adding safety and quality.

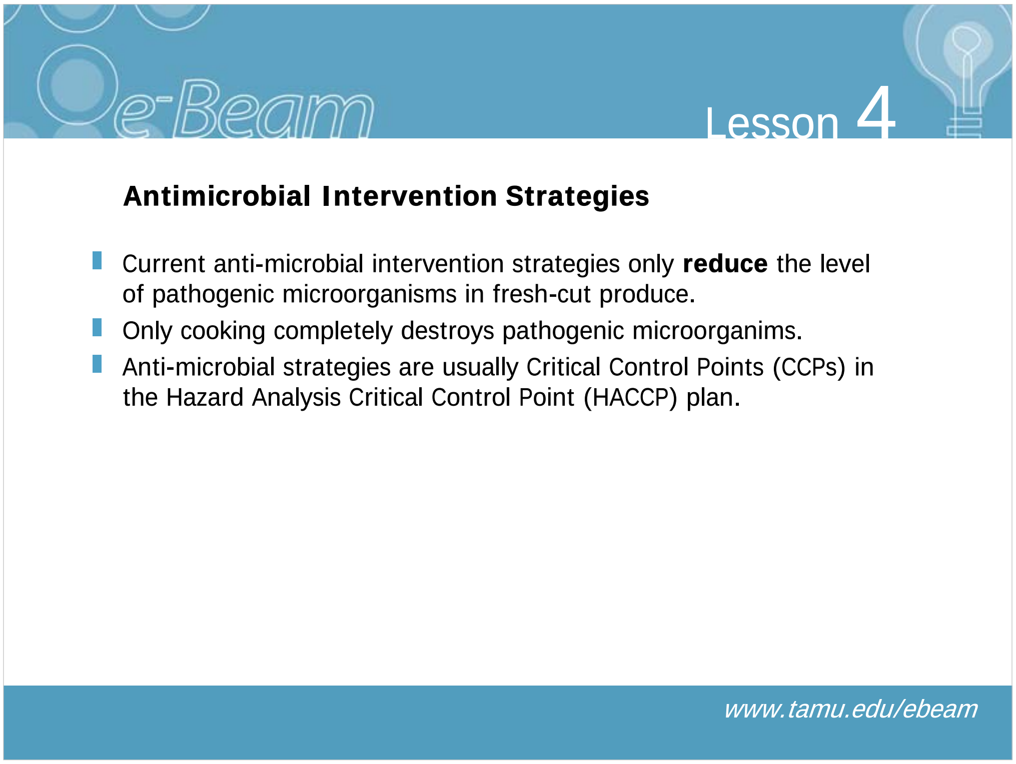


Lets consider the question - “How effective is irradiation?”

This example illustrates the remaining live cells after three separate intervention strategies, given the initial population of 25,000 cells of *E. coli O157:H7* per gram of hamburger meat. According to the CDC, *E. Coli* populations of less than 10 live cells may be a high enough population concentration to cause HUS. Irradiation is used by less than 1% of beef processors in the US. The other strategies, although effective in reducing microbial load in food, do not meet the reduction of microbial load necessary to avoid consumption of an infectious population of *E. coli O157:H7*. The application of 1.5 kilograys to hamburger equates to a 99.9999% (6-log) microbial kill.



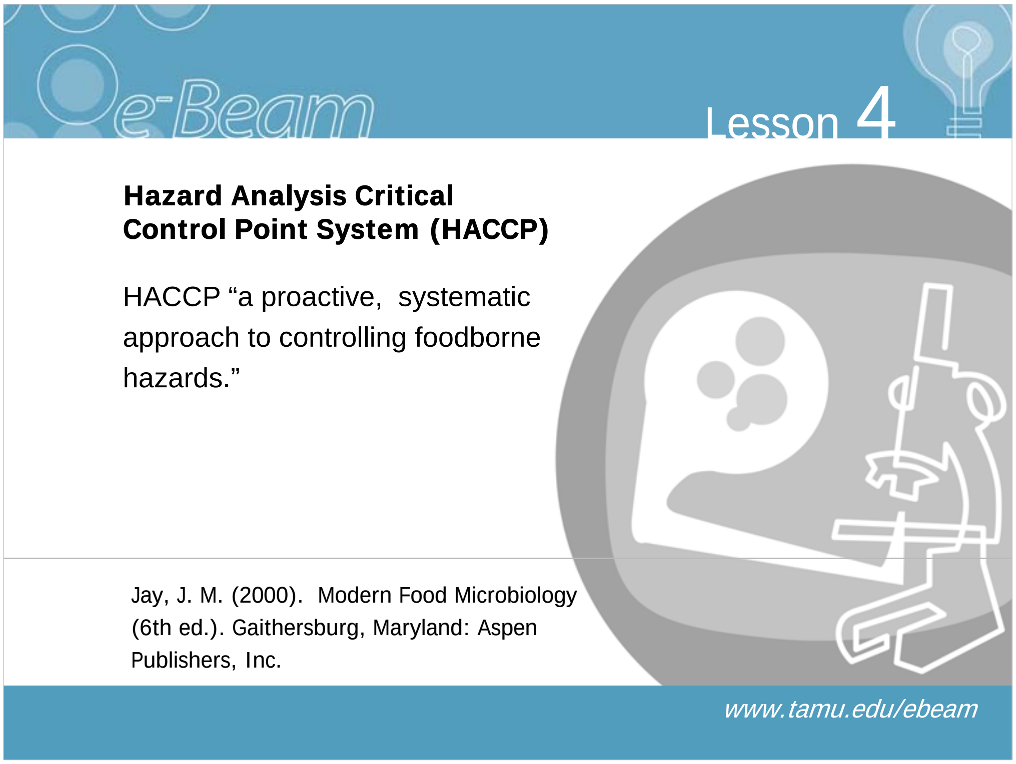
Other food processors, wholesalers, and retailers are interested in reducing spoilage organisms such as mold to minimize "shrink" or losses due to spoilage. Electron beam irradiation of strawberries and other fresh whole and fresh-cut fruits and vegetables is currently being studied for commercial feasibility (National Center for Electron Beam Research, Texas A&M University, 2005.)



Many processors use several chemical disinfection steps in conjunction with one another in an attempt to control contamination.

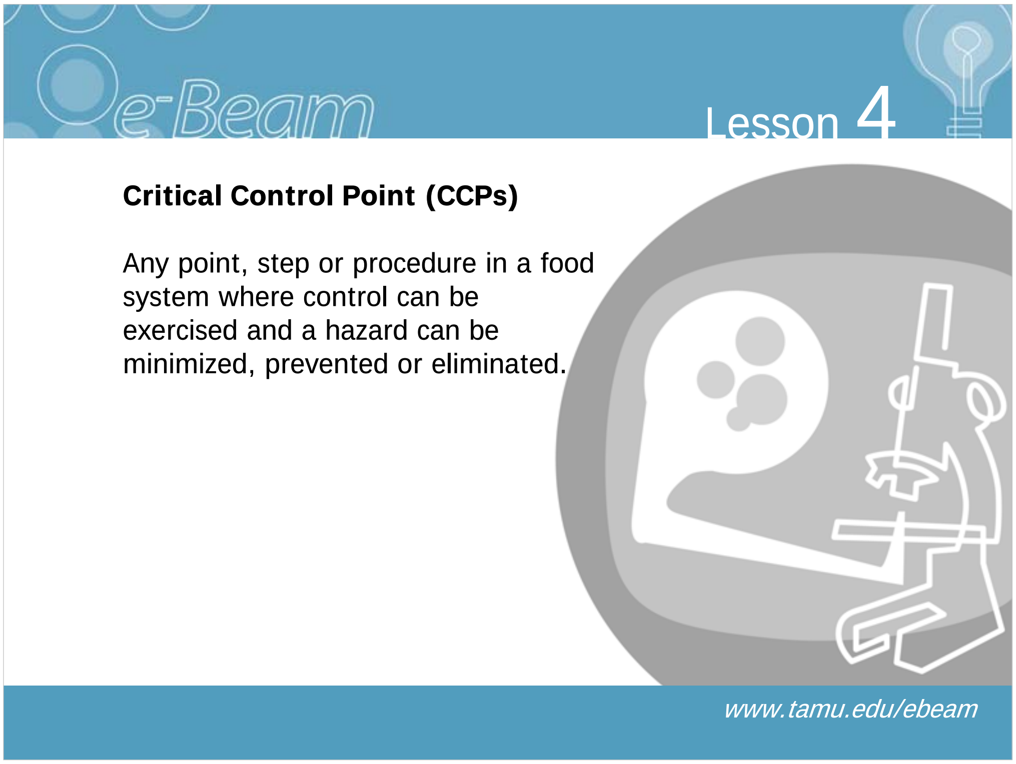
Only cooking or pasteurization completely destroys pathogenic microorganisms. The reality is that chemical disinfection only reduces the food safety risk to a certain point.

These disinfection steps should be CCPs in the HACCP plan of a produce processor.



HACCP has replaced the traditional system for food inspection. In the past, food inspection focused on visible hazards. Food inspectors, and the food industry, made arbitrary decisions on the acceptability (or unacceptability) of what was seen (or not seen).

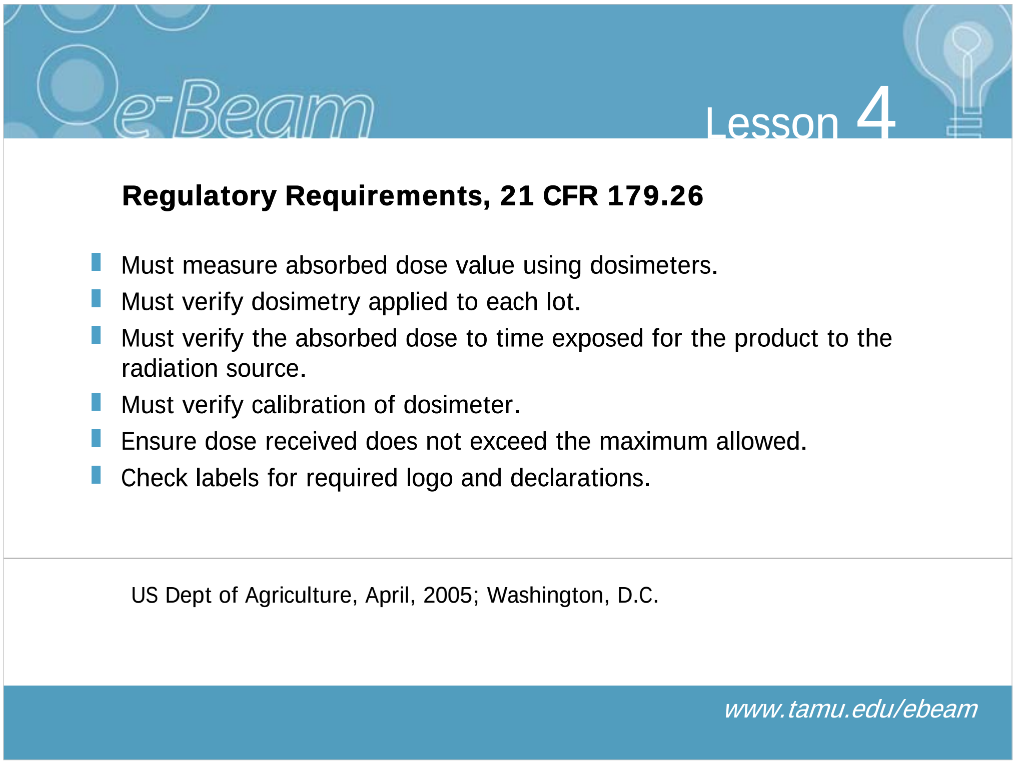
HACCP has allowed industry and regulatory personnel to focus on those food safety hazards that are shown - through scientific justification - to be problematic in foods. Furthermore, this has allowed the food industry to implement preventive measures to control those hazards identified in the hazard analysis.



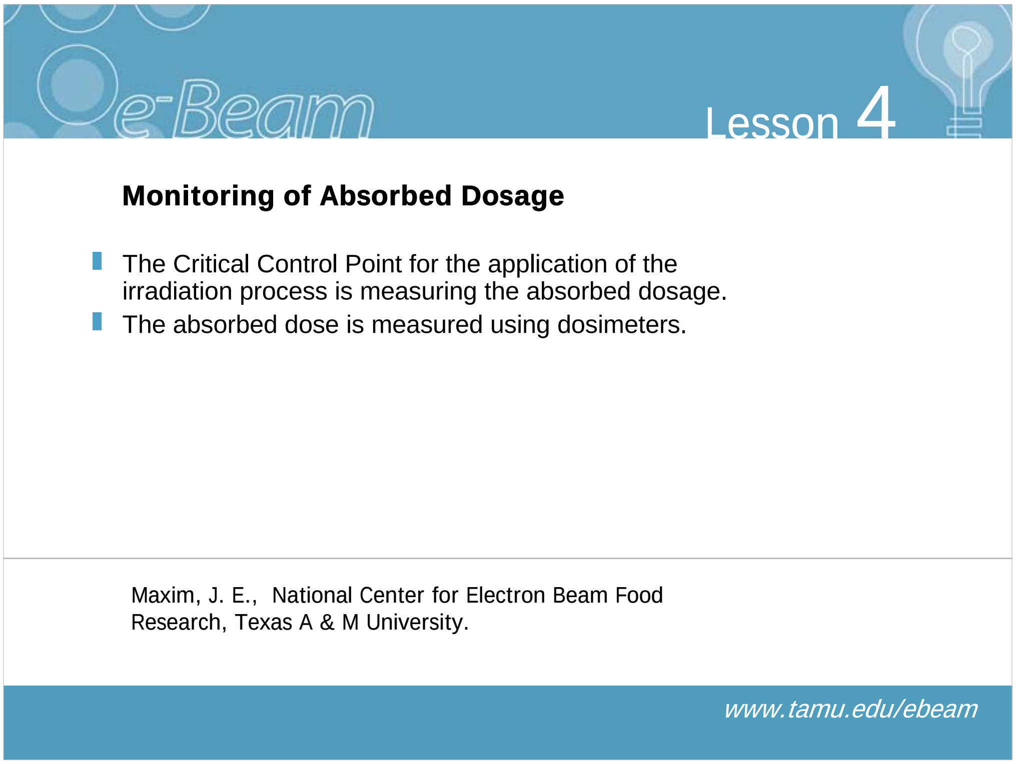
The establishment of the critical control points to control the hazards identified in the hazard analysis is the main component of the HACCP system.

A critical control point is any point or procedure in a food system where control can be exercised and a hazard can be minimized, eliminated, or prevented.

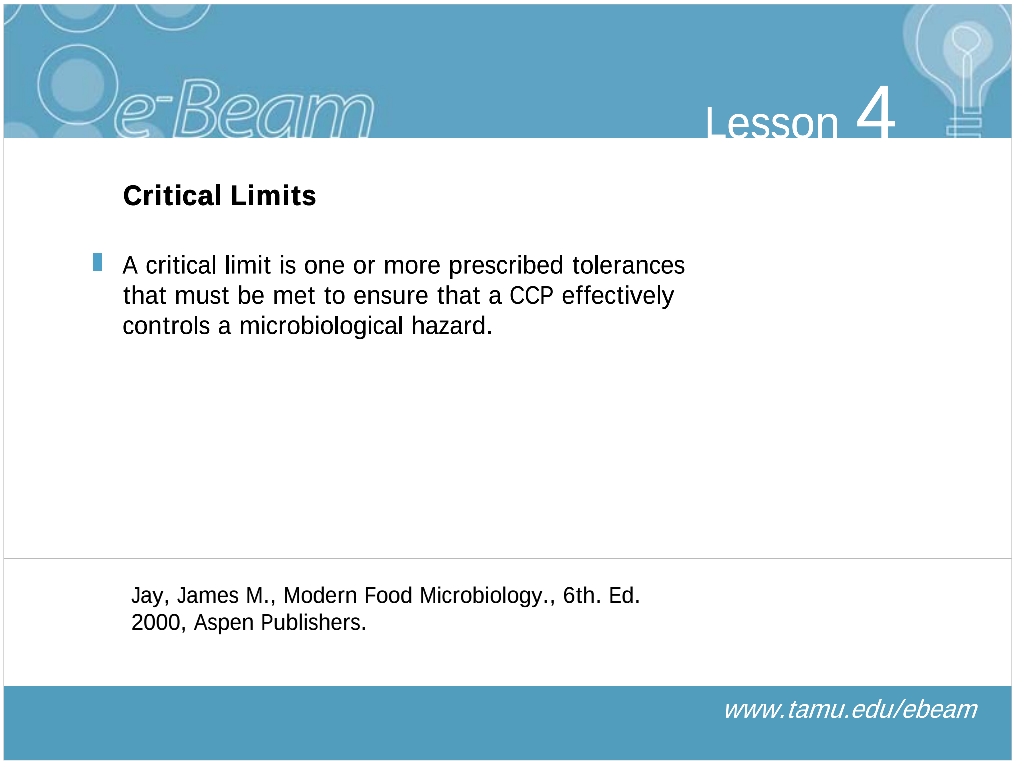
Many times a preventive measure is in place prior to HACCP plan development and that preventive measure can become the CCP.



The USDA goes on to provide additional guidelines for control of the irradiation step in the processor's operation (Regulatory Requirements, 21 CFR 179.26.)



If a processor chooses to use irradiation, the CCP is the absorbed dose of irradiation received by the product as measured by the dosimeter.



If we must measure the absorbed dose then what dose is required to reduce or eliminate the pathogen?

The answer is - it depends.

It depends on the target pathogen and on the environmental conditions (i.e. nutrients (food), temperature, oxygen, etc.) as well as food (or package) shape.

Critical Limits: D-Value for Selected Food-borne Pathogens; dose required for 90% (1 Log) reduction

Pathogen	*D-Value (kGy)
Salmonella	0.48
Campylobacter jejuni	0.18
E. coli O157:H7	0.25
Listeria	0.40

Information provided by Maxim, J. E, , National Center for Electron Beam Food Research, Texas A & M University.

Federal Register, Vol. 64, No. 36, p.9090 (1999).

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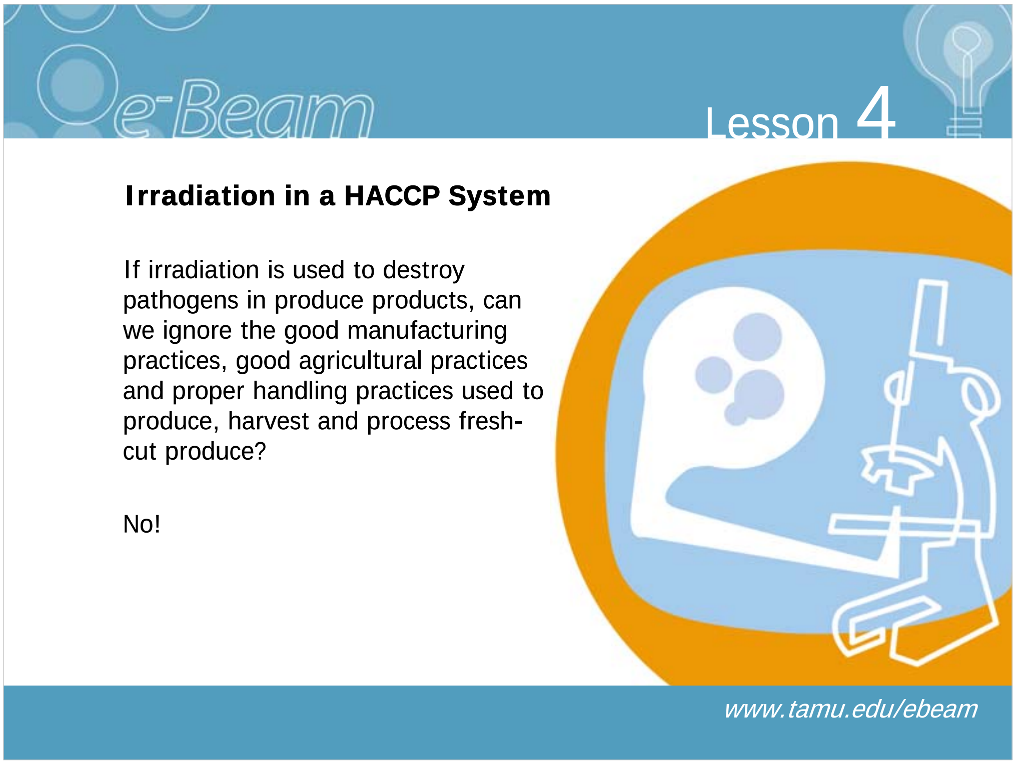
Listed above are values of absorbed dose needed to achieve a 1 – Log (90%) reduction of a given pathogen.

Absorbed dose is product and package configuration specific and must be determined for each product and package system through dose mapping.

For example; to achieve a 5-log kill of *Listeria* in deli meats or produce one would apply a minimum of 2.0 kilograys of e-beam irradiation.



We use every available approach to further reduce foodborne disease. Certain levels of radiation have a negative impact on product quality, sometimes softening its outer layer of skin. If we discontinue normal practices to eliminate as many pathogens as possible through Good Manufacturing Practices (GMPs) and Good Agricultural Practices (GAPs), a higher dose of radiation is needed to reduce the microbial population. This will negatively impact product quality. Thus the answer to the above question is, No!

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Conclusion

- Irradiation, if used as part of a comprehensive food safety system, is an additional tool in our efforts to reduce foodborne disease.

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No notes.

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Summary

- Irradiation is not widely understood
- Scientific community endorses safety of irradiated product
- Some people describe irradiation in terms that purposely confuse consumers
- Consumers are choosing irradiated food in 4000+ supermarkets and restaurants
- U.S. consumers purchased approximately 30 million pounds of irradiated meat and produce in 2004
- Wholesale or retail distribution in all 48 contiguous states.

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No notes.