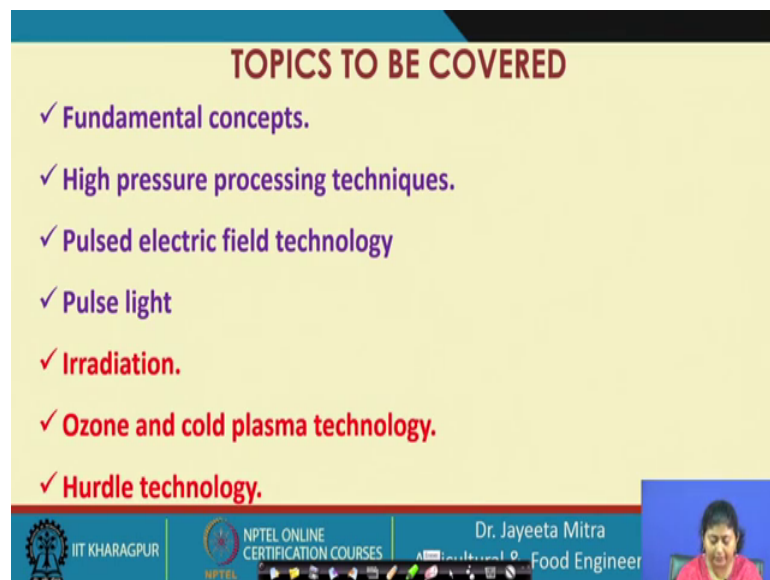


Fundamentals of Food Process Engineering
Prof. Jayeeta Mitra
Department of Agricultural and Food Engineering
Indian Institute of Technology, Kharagpur

Lecture - 59
Non Thermal Processing (Contd.)

Hello everyone, welcome to the NPTEL online certification course on Fundamentals of Food Process Engineering. We are in the last chapter of our course that is Non Thermal preservation for food and in that we have already discussed few techniques in non thermal processing.

(Refer Slide Time: 00:38)



TOPICS TO BE COVERED

- ✓ Fundamental concepts.
- ✓ High pressure processing techniques.
- ✓ Pulsed electric field technology
- ✓ Pulse light
- ✓ Irradiation.
- ✓ Ozone and cold plasma technology.
- ✓ Hurdle technology.

IIT KHARAGPUR | NPTEL ONLINE CERTIFICATION COURSES | Dr. Jayeeta Mitra | Agricultural & Food Engineer

Such as high pressure processing we have discussed pulse electric field technology and pulse light also we have discussed. We need to discuss now irradiation then ozone and cold plasma technology and finally, the hurdle technology.

(Refer Slide Time: 01:01)



So, in today's class we will discuss the food irradiation. So, food irradiation is one of the very important on thermal processing and this has been becoming very popular method day by day because of it is highly effective way for inactivating the microorganism.

(Refer Slide Time: 01:26)

IRRADIATION-INTRODUCTION:

- ✓ Irradiation is the process by which an object is exposed to radiation. The exposure can originate from various sources like α particle, β particle, high energy electron, γ rays, x-rays)
- ✓ **Food Irradiator Sources:** Cobalt-60, Cesium-137, Machine generated β or x-rays.

The diagram illustrates the electromagnetic spectrum with wavelength markers from 10^{17} nm to 1 km. It includes icons for Gamma ray, X-ray, Ultraviolet, Visible, Infrared, Microwave, and Radio. A secondary diagram shows gamma rays (represented by wavy arrows) hitting a strawberry, with a magnified view showing bacteria dying.

Footer: IIT KHARAGPUR, NPTEL ONLINE CERTIFICATION COURSES, Dr. Jayeeta Mitra, Agricultural & Food Engineering

So, we will see that irradiation is a process by which an object is exposed to radiation. Irradiation is the process by which an object is exposed to radiation. So, you have to have the clarity here. Radiation means the intensity of the light that comes intensity of the radiation that comes from any light source, but irradiation is the process by which the

object is exposed to radiation right. So, the exposure can originate from various sources like alpha particle, beta particle, high energy electron gamma rays x rays etcetera. And what happen that when this rays x ray gamma ray and this are you know capability of the ionizing the material ionizing the gas.

So, when they ionize that means, they remove the electron from the atom ok. So, then what happen that they produce the charged ions ok. So, this the charge ion they form and that charge ion and eventually they form the free radicals because this charge ion can stay for a very short period of time ok.

So, eventually they produce the free radical. So that means, the effect of this free radical and the charge ion they will destroy the microorganisms ok. So, this is basically how they work. So, gamma ray x ray and beta particle. So, these are having very small wave length. So, therefore, this are having very high penetration capability as well and for food system there are certain specified source which are used for this kind of irradiation treatment such as Cobalt-60, then Cesium-137, Machine generated beta or x ray.

So, when this rays fall on the any food surface. So, they because of their affect of you know ionizing radiation effect they kill the bacteria.

(Refer Slide Time: 03:49)

FOOD-IRRADIATION

- ✓ Food irradiation is the process of exposing food stuffs to ionizing radiation.
- ✓ This treatment is used to preserve food, reduce the risk of food borne illness delay or sprouting or ripening.
- ✓ These ionizing radiation that can penetrate through food to kill, or prevent reproduction of microorganisms, insects and pests.

The slide contains two diagrams. The top diagram shows potatoes: 'Irradiated' potatoes are shown with a speech bubble stating 'In Japan, irradiation is permitted to prevent germination of potatoes only', while 'Not irradiated' potatoes are shown with a starburst indicating sprouting. The bottom diagram shows strawberries: 'UNTREATED' strawberries are shown with a starburst and the text '5 days after harvesting', while 'TREATED' strawberries are shown with the text '3 weeks after harvesting'.

IIT KHARAGPUR | NPTEL ONLINE CERTIFICATION COURSES | Dr. Jayeeta Mitra | Agricultural & Food Engineering

So, food irradiation is the process of exposing food stuff to ionizing radiation as I mentioned, and this treatment is used to preserve the food reduce the risk of food borne

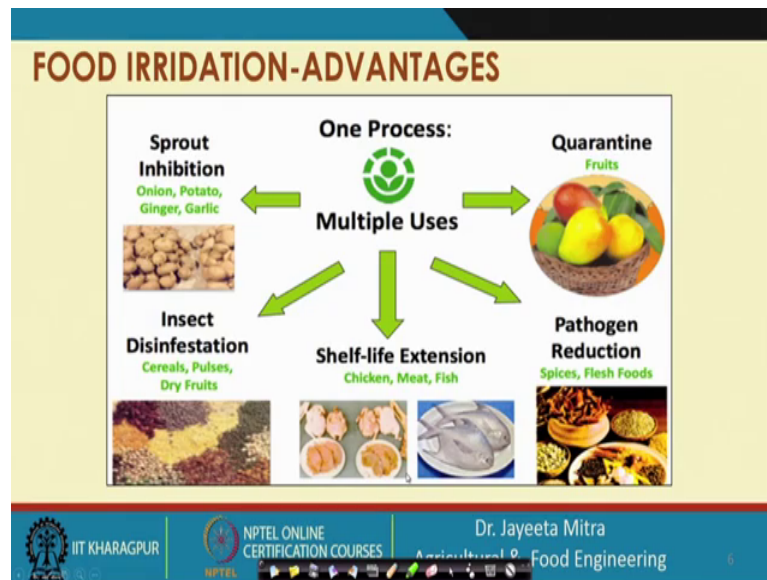
illness delay or sprouting or ripening. So, what happens that for food irradiation as I mentioned that these create the ionizing radiation and because of creating those ionizing radiation they form the charge ion and then eventually the free radical.

So, the obvious question may be that this free radical will not damage the food itself the constituents of food itself. So, the thing is their intensity of this radiation; that means, how much food can be irradiated those are fixed. So, it has been designed in such a way or it has been quantified in such a way. So, that the microbes will be affected, but not the food will be destroyed or degraded right.

So, therefore, the mentioned limit we limit of this irradiation, we had to obey clearly. So, here food irradiation is the process of exposing food stuffs to ionizing radiation. And this treatment is used to preserve food to reduce the risk of food borne illness delay or sprouting or ripening. So, these are the affects that it can cause it is not irradiated sprouting may be there, if it is irradiated then because of this irradiation sprouting will not be there. So, after harvesting if untreated food is there may be some microbial decay will be observe if these are treated there will be no such microbial decay. It will cause delay in the ripening as well and this ionizing radiation that can penetrate through food to kill or prevent the reproduction of the microorganism insect and pests.

So, what will happen that when the gas become ionized. So, the effect of the ionize radical for example, this is O_3^+ ion or hydroxyl ion or the H_2O_2 all such can generate this you know free radical and the ionizing effect on the microorganism.

(Refer Slide Time: 06:25)



So, we can see that food irradiation has several advantages in industry we can use it. So, this one process that is food irradiation can cause sprout inhibition. So, onion potato ginger garlic that we need to store for longer days in warehouses or for some for some industry preparation of the product before preparing the product actually we need to store it.

So, even these are irradiated then no sprout formation will be there. So, it is very beneficial. Other thing is insect disinfestation. So, insect infestation is very common in serial pulses and dry fruits. So, we cannot keep it for a longer time the fungus attack mold attack will be very frequent. So, therefore, irradiation treatment can be followed ok.

So, thus we can save large amount of the product. So, very cost effective thing then shelf life extension since we can kill the microbes by this food irradiation method we can store the product even if it is the fleshly food we can store it for a longer time. Then pathogen reduction on the spices flesh food etcetera. So, pathogen and even the some toxic substance reduction that can be done fungal attack everything can be prevented. So, quarantine of the fruits. So, even on the on the fruit surfaces also we can apply this food irradiation treatment to quarantine them. So, that means, sprout inhibition insect disinfestation shelf life extension pathogen reduction and quarantine all this we can get by only one method that is food irradiation. So, it is a non thermal method and very effective method.

(Refer Slide Time: 08:35)

SOURCES OF RADIATION USED IN FOOD IRRADIATION

- ✓ **Gamma Rays** are emitted from radioactive forms of the element cobalt ($Co60$) or of the element cesium ($Cs137$). Gamma radiation is used routinely to sterilize medical, dental and household products and is also used for the treatment of cancer.
- ✓ **X-rays** are produced by reflecting a high energy stream of electrons off a target substance (usually one of the heavy metals) into food. X-rays are also widely used in medicine and industry to produce images of internal structures.
- ✓ **Electron beam** (or e-beam) is similar to x-rays and is a stream of high-energy electrons propelled from an electron accelerator into food.

IIT KHARAGPUR | NPTEL ONLINE CERTIFICATION COURSES | Dr. Jayeeta Mitra | Agricultural & Food Engineer

Now next is sources of radiation used in food irradiation. So, we have mentioned that gamma ray x ray and electron beam these are the source from where we can get the source of radiation. And from that we use a for example, the gamma ray these are emitted from radioactive forms of the element cobalt. So, the radioactive form is cobalt 60 or of the element cesium that is Cs 137. So, these two are radioactive forms of this element and this can emit the gamma rays. So, gamma radiation is used routinely to sterilize the medical dental and household products and is also used for the treatment of cancer.

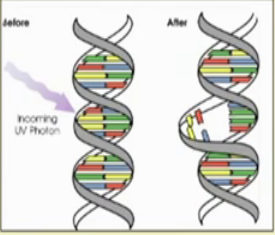
So, these are commonly used where which other than the food this has already in practice. X ray these are produced by reflecting high energy stream of electron off a target substance usually one of the heavy metal into food ok.

So, x ray are always widely used in medicine and industry to produce the images of internal structures. Electron beam or e beam this is similar to x ray and is a stream of high energy electron propelled from an electron accelerator into food. So, now, a days this all three are used on food to have the irradiation effect.

(Refer Slide Time: 10:18)

HOW DOES IRRADIATION WORKS:

- ✓ Food is exposed to a carefully measured intense amount of intense ionizing radiation.
- ✓ When food is irradiated, the radiation energy breaks the bonds in the DNA molecules of the micro-organism. Thus the organism dies or becomes unable to reproduce.
- ✓ Frozen foods take larger radiation dose to kill microbes.
- ✓ The effectiveness of the process depends on the micro-organism's sensitivity to irradiation.



IIT KHARAGPUR | NPTEL ONLINE CERTIFICATION COURSES | Dr. Jayeeta Mitra | Agricultural & Food Engineering

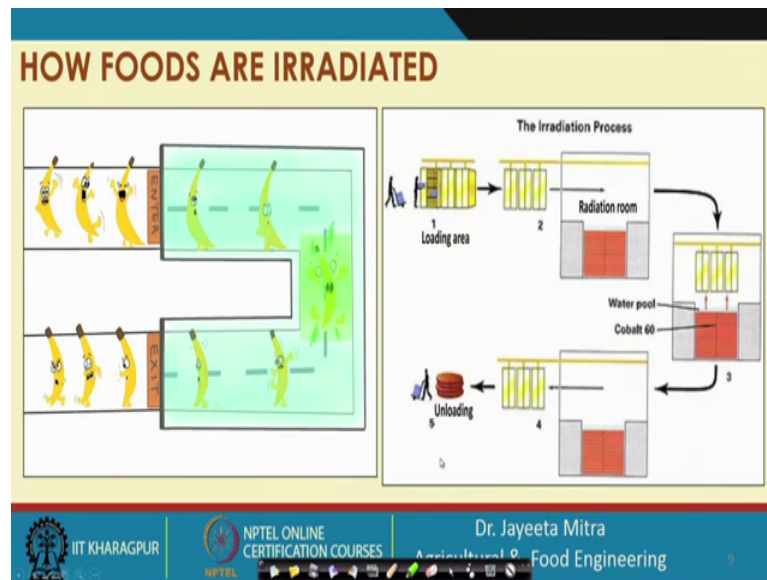
So, how the irradiation works? So, food is exposed to carefully measured intense amount of ionizing radiation. So, this is very important carefully measure intense amount of ionizing radiation. And this has been given by there are authorities on specifically working on this standard measurement, I mean how much those measurement we can see that how much radiation those can be given to food material.

So, that it is constituent will not be you know degraded because of the action of the ionizing radiation or free radical, but because the finally, the radio Lytic action will cause destruction to the constituent as well if it applies beyond a certain limit and the food will loss it is food value or nutritional value.

So, that is why this is very important. Now when food is irradiated that is exposed to the radioactive source of either x ray or e beam source or gamma ray. The radiation energy breaks the bonds in the DNA molecule of the microorganism.

So, this breaks the bond in the DNA molecule of the microorganism and thus the organism dies or become unable to reproduce. And frozen food takes larger radiation dose to kill the microbes. And the effectiveness of the process depends on the microorganisms sensitivity to irradiation. So, again it depends on because the same dose may not be applicable for all the microorganism. So, we have to decide the dose requirement for the different microorganism.

(Refer Slide Time: 12:08)



So, this is how it is been done the food when entered into the chamber where they are you know they come in contact with the source of irradiation. And then while they exceed they the microbes has been fully damaged. Similarly the irradiation process we can apply on a on a large scale unit where the there is a loading area. And after loading of all the food material into crates or proper sections those are inserted into the radiation room and after radiation there is a for example, here we are applying the cobalt 60, that generate the gamma rays and then it has been unloaded ok. So, this is how the irradiation process they are food are exposed to the irradiation process.

(Refer Slide Time: 13:05)

DOSE AND DOSE RATE

- ✓ Ionizing energy processes create enough of an absorbed dose to destroy microbes.
- ✓ Unit of absorbed dose in food: kGy (kilograys) and can be divided into 3 categories.

Radicidation (Low doses <1 kGy): Controls insects in grains and fruits, inhibit sprouting in tubers, Delay the ripening of some fruits/vegetables and Reduce the problems of parasites in products of animal origin. (e.g: *Trichinella spiralis* in pork)

Radurization (Medium dose (1~10 kGy)): Control Salmonella, Shigella, Campylobacter, Yersinia, Listeria and E.coli in meat poultry & fish and delays mold growth on strawberries, other fruits.

Radapperization (High dose (>than 10kGy)): Kill microorganisms and insects in spices, commercially sterilize foods, destroying all microorganisms of public health concern (i.e, special diets for people with weakened immune systems)

IIT KHARAGPUR | NPTEL ONLINE CERTIFICATION COURSES | Dr. Jayeeta Mitra | Agricultural & Food Engineering

So, dose and dose rate ionizing energy processes create enough of an absorbed dose to destroy microbes and unit of absorbed dose in food that is kilo grays and can be divided into three categories. Radicidation that is low dose that is less than 1 kilo gray. This control controls the insect in grain. So, doses as low as less than 1 kilo gray, it can control the insects in grain and fruit inhibit the sprouting in tubers delay the ripening of some fruits and vegetables and reduce the problems of parasites in products of animal origin for example, *Trichinella spiralis* in pork.

So, we can see that very low dose is required for all such activities. And these are very common to the common problems of the industry and some in some cases the small you know the small business man or the small farmers who need to store this product for sometime. So, they have to they can apply this techniques, then Radurization that is the medium dose 1 to 10 kilo gray. So, this control *Salmonella Shigella Campylobacter Yersinia Listeria E coli*. So, basically we can see all the bacteria to control them we need this range that is 1 to 10 kilo gray that can control the bacteria that is *Salmonella Shigella Campylobacter Yersinia Listeria E coli* in meat poultry and fish and delays the mold growth on strawberries. And other fruit ok.

That means we can see that how mild radiation treatment to moderately high radiation treatment can cause the different functions in the preservation of the food. So, the next thing is little bit higher than this Radappertization that is high dose greater than 10 kilo gray that kill the microorganism and insect in spices commercially sterilize foods destroying all microorganisms of public health concern, that is special diets for people with weakened immune system. So, for them this is to be used and after that irradiated food can be consumed.

So, this is how we can define that what kind of dose or what is the rate dose rate required for different functions whether it is preserving the produce for a longer time, whether it is delaying the ripening whether it is killing the bacteria ok. So, this is how we apply the irradiation.

(Refer Slide Time: 16:30)

EFFECTS OF IRRADIATION ON MICROORGANISMS
(indirect effect)

Due to formation of the free radicals during radiolysis of water molecules.

Free radicals are highly reactive - form stable products.

Combine with one another or oxygen molecules – oxidizing agents.

Can damage bacterial cell components.

Unstable free radicals react with bacterial cell membranes damage their structure- bacterial death.

Water molecule $[H_2O]$ → Hydroxyl ion $[OH^\cdot]$ + Hydrogen ion $[H^\cdot]$

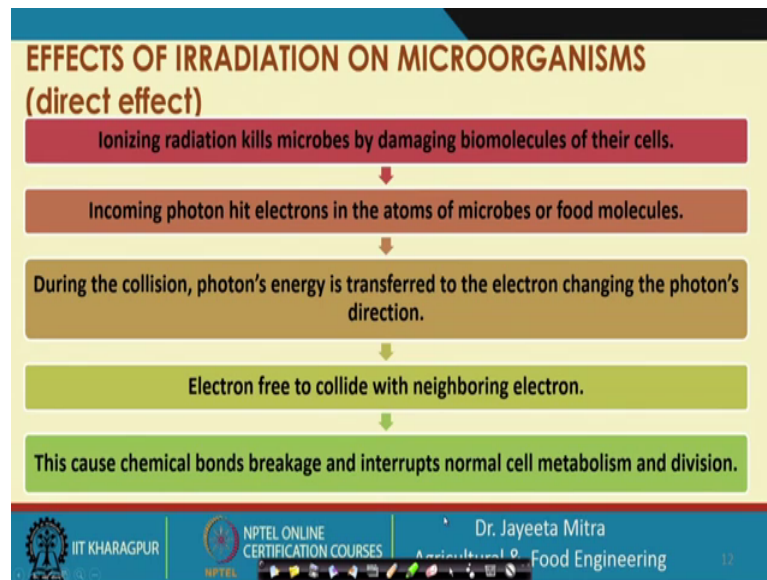
Dr. Jayeeta Mitra
Agricultural & Food Engineer

Now, effects of irradiation on microorganism which is an indirect effect. Later on, it will come to the direct effect. So, indirect effect is that due to formation of the free radical during the radiolysis of the molecule. So, what happens that when the ionizing radiation or this x-ray gamma ray falls on a food product. So, there are the particles of water and oxygen. Those particles are there. So, radiolysis of those water molecules will generate some free radicals. Those free radicals are highly reactive; they produce the hydroxyl ion or O_3 plus ion etcetera.

So, they are highly reactive and they eventually form stable products. So, they combine with one another because they are highly reactive. So, they have to you know make other products to be a stable form. So, combine with one another or oxygen molecules and which works as oxidizing agents.

So, this oxidizing effect can damage the bacterial cell components and then unstable free radicals react with the bacterial cell membrane, damage their structure, and the bacteria die. So, from this as we have seen, the water molecule when it ionizes, it will form hydroxyl ion which is minus and hydrogen ion H^+ plus. Further two of these will add and then form again more ion. So, this process will continue.

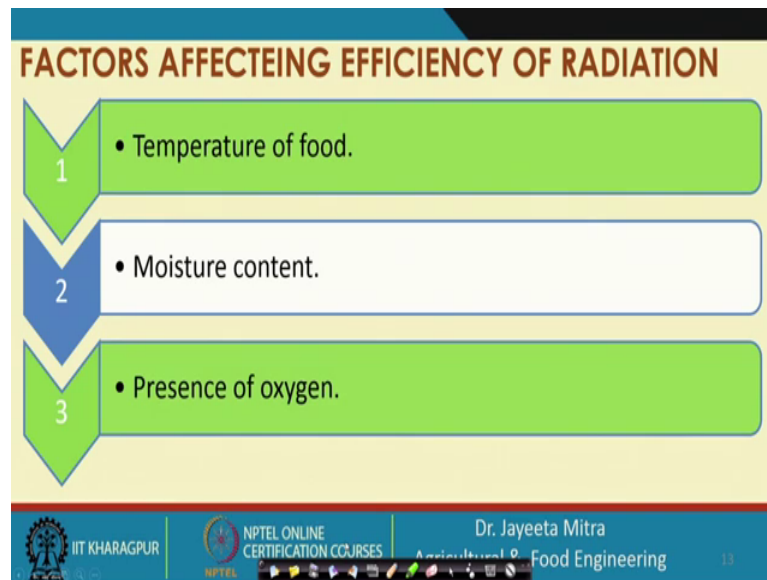
(Refer Slide Time: 18:25)



Now, the direct effect is what the ionizing radiation kills microbes by damaging the biomolecules of their cell. So, in coming photons hit the electrons in the atom of microbes or food molecules. And during the collision photons energy is transferred to the electron changing the photons direction. Electron free to collide with the neighboring electrons and this causes chemical bond breakage. So, it has seen that most of the organic bonds are getting effected by this and interrupts normal cell metabolism and cell division ok

So, directly the cell division is getting effected and indirectly the free radicals will form the destruction of the cell wall. So, these two will combiningly you know define the total effect of the irradiation on the microbes.

(Refer Slide Time: 19:32)



Factors Affecting the efficiency of radiation. So, the factors are temperature of food then moisture content and presence of oxygen. So, temperature of the food this will have some effect because along with the ionizing effect if the temperature of the food is also vary. So, that will cause some additional effect in destruction. Moisture content because if the moisture will be there that will because of the ionizing radiation that will form the free radical and hydroxyl ion or hydroperoxyl ions etcetera those are detrimental to the microorganism.

So, this will help also the presence of oxygen because when it will cause the higher amount of you know oxygen will cause the oxygenation in higher amount and that will kill the microorganism. So, oxidation the amount of oxidation or the quantity of the oxidation will increase.

(Refer Slide Time: 20:32)

EFFECT OF FOOD IRRADIATION ON FOOD QUALITY

- ✓ The food molecules are made of water, lipids, proteins, carbohydrates & vitamins.
- ✓ Radiation energy generates a degradative reaction when it interacts with food called as radiolysis.
- ✓ Products of radiolysis is known as radiolytic products.
- ✓ Irradiation cause changes to food molecules particularly at high doses.
- ✓ Sterilization levels causes nutrient loss and desirables effects.

IIT KHARAGPUR | NPTEL ONLINE CERTIFICATION COURSES | Dr. Jayeeta Mitra, Agricultural & Food Engineer

So, the food molecules are made of water, lipid, protein, carbohydrate and vitamins. These are the constituents main constituents radiation energy generates a degradative reaction with when it interact with food called as radiolysis. So, what happens as the microorganisms are getting effected, when this radiation energy comes in contact with food all this constituents also they are exposed to the effect of radiolysis.

So, products of radiolysis is known as radiolytic product. Irradiation causes changes to food molecules particularly at higher doses that is why we have to very cautious. So, that we strictly follow the dose requirement. Sterilization levels causes nutrient loss and desirable nutrient loss and some effects also ok. So, this is about the irradiation and will stop here and will move on to the next topic.

Thank you.