Novel Technologies for Food Processing and Shelf Life Extension

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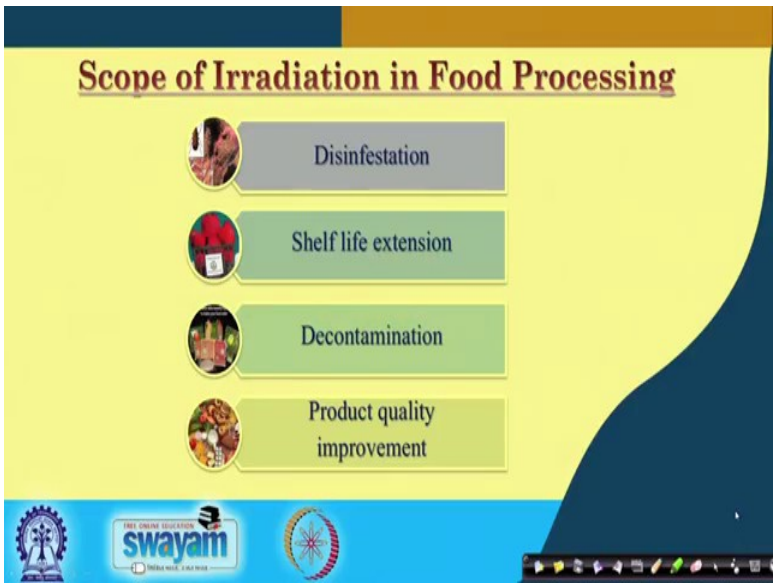
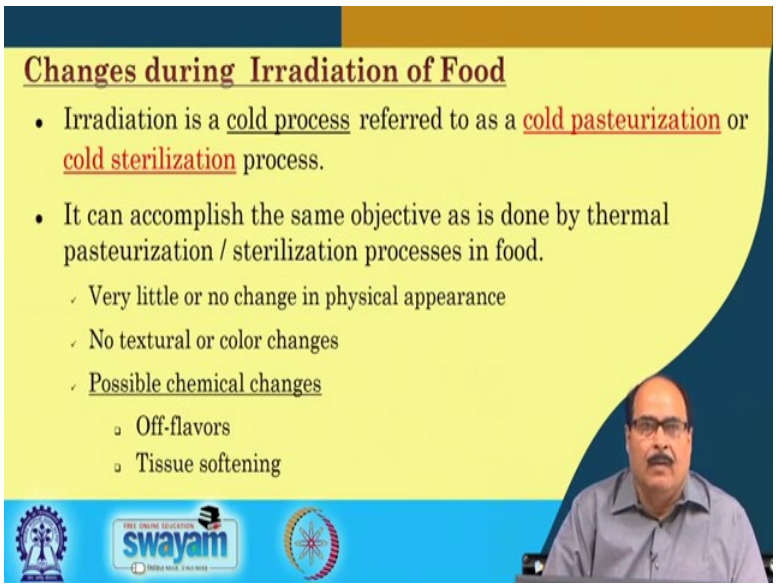
Lecture – 16
Food Irradiation – Part 2

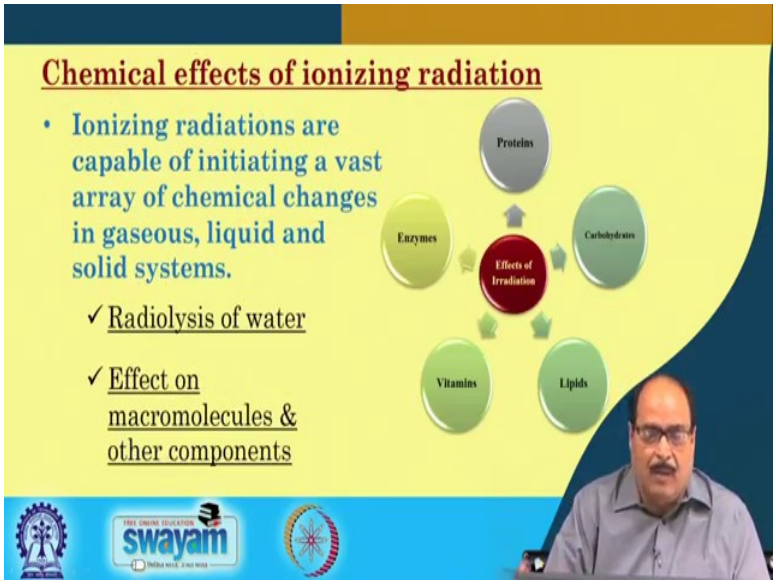


The first part of the lecture covered the process principles and technological aspects of food irradiation. This lecture will cover the effect of food irradiation on the constituents and characteristics of the food as well as application on the different types of food.

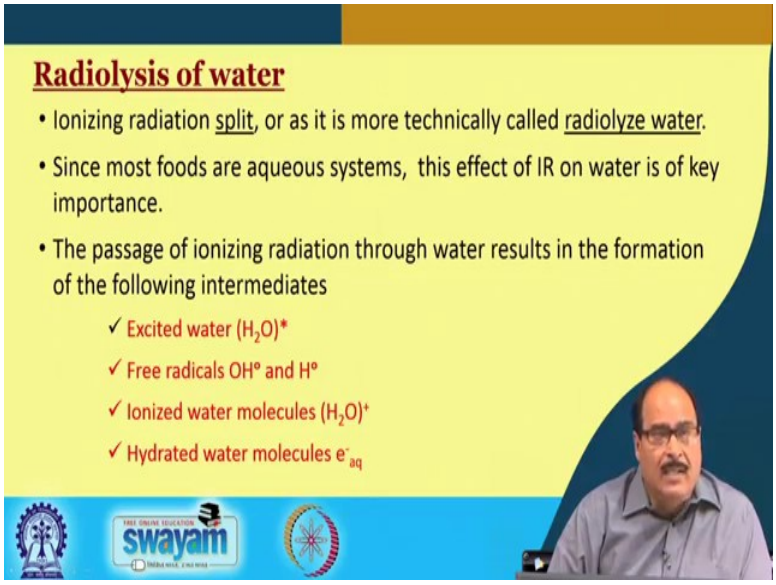


There are certain changes that take place into the food during irradiation process. It is necessary to ensure that it is not resulting into any undesirable change in the food characteristics. Food irradiation is also called as cold process. It can accomplish the same objective as is done by the thermal pasteurization and sterilization processes.

The food irradiation has very little or no change in the physical appearance of the food, there are very minimum textural or color changes in the food; however, there may be some chemical changes into the food and that if properly not taken care of, may result into the off flavor. It may result into the softening of the fruits and vegetables or many such other problems.

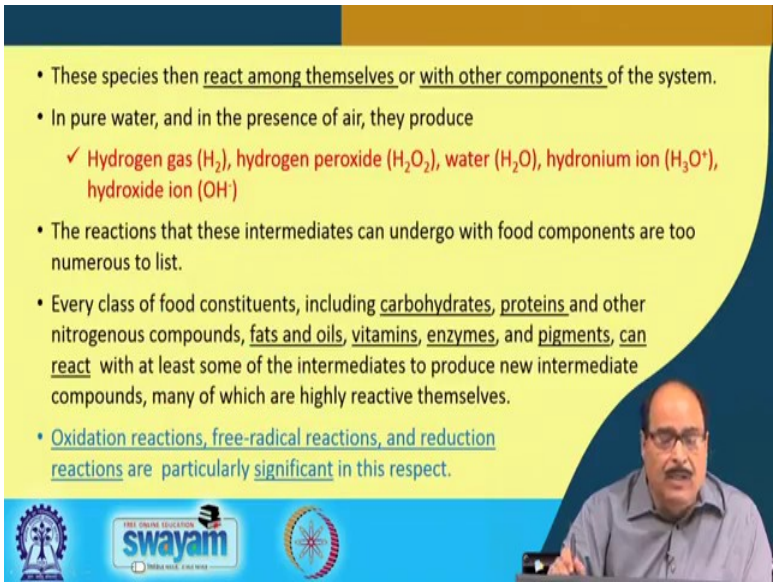


Ionizing radiations are capable of initiating a vast array of chemical changes in all the systems like in the gaseous, liquid as well as in solid systems. There are two important things to consider; one is the radiolysis of the water and the other, the effect of this ionizing radiations on macromolecules like protein, carbohydrate, lipids, etc. and other components of the food like vitamins and enzymes.

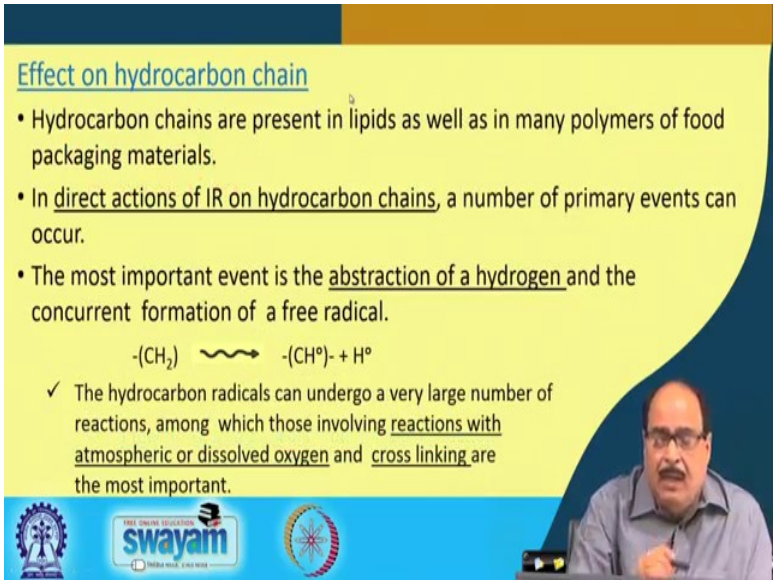


Radiolysis of the water is the effect of ionizing radiations on water. These ionizing radiations split or radiolyze water. Since, most of the foods are aqueous systems, they have less or more amount of water present in them. So, the effect of ionizing radiation on water is of key importance.

The passage of ionizing radiations through water results in the formation of intermediates like excited water, free radicals like hydroxyl free radical or hydrogen free radicals, ionized water molecule, or even hydrated water molecule.



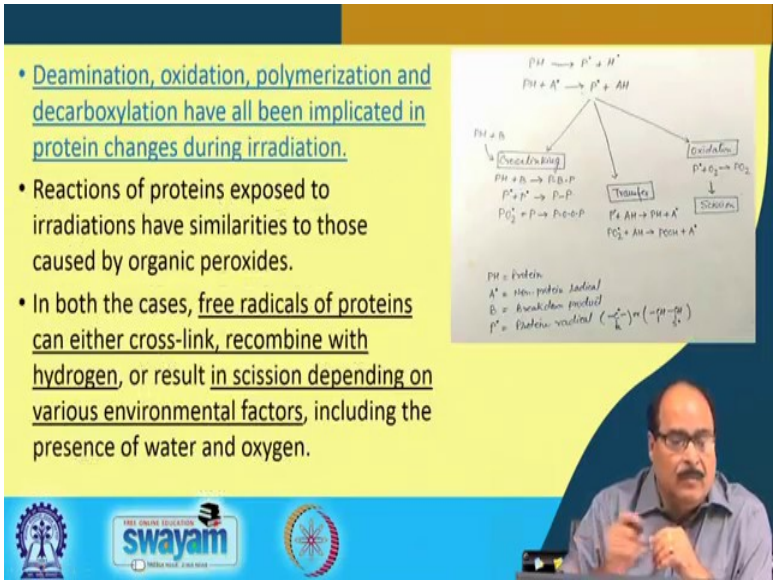
These intermediates which are formed, due to exposure of the ionizing radiation, they can react among themselves as well as with other food components of the system.



And if it is a pure water where only water molecules are there and no other macromolecules etc., then the interactions among these intermediates may result into the formation of hydrogen gas, hydrogen peroxide, water molecule again, hydronium ion, hydroxide ion and so on.

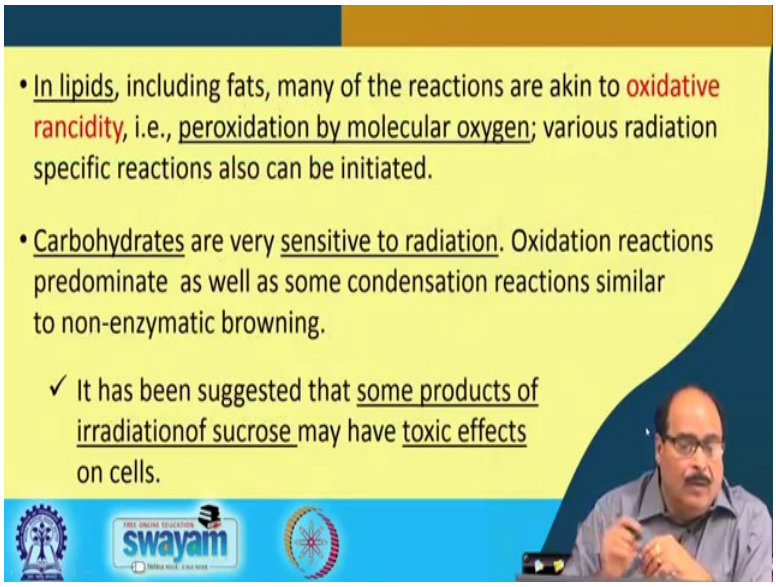
These intermediate as well as new compounds which are formed like hydronium ion, hydroxide ion etc. can again catalyse or influence several reactions in the food material, they can interact with the other components of the food like carbohydrate, protein and other nitrogenous compound, fats and oils, vitamins, enzymes, pigments, etc. They can react by at least with one or the other of these intermediates to produce new intermediate compounds and many of which are highly reactive themselves.

Even, the oxidation reactions, free-radical reactions, reduction reactions may take place and these become important and may have important influence on the food characteristics. In addition to that, these ionizing radiations can also have the direct effect or influence on the hydrocarbon chain. The direct action of ionizing radiations on these hydrocarbon chain also become important i.e. a number of primary events can occur. Most important event is the abstraction of hydrogen from the hydrocarbon. The hydrocarbon free radical formed can undergo a very large array of reactions among which those involving reactions with atmospheric or dissolved oxygen and cross linking reactions etc. are important.



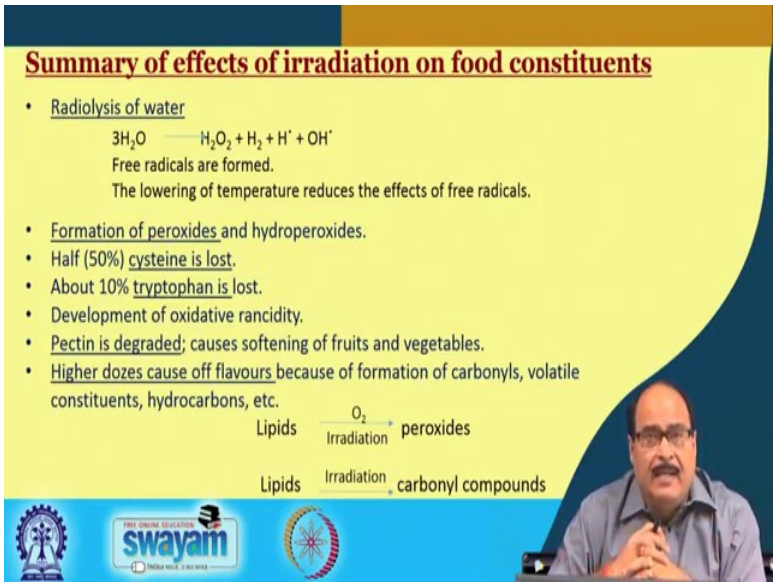
Deamination, oxidation, polymerization, decarboxylation all these have been implicated in protein changes during irradiation. Reactions of protein exposed to radiations have similarities to those caused by organic peroxide etc. In both the cases, the free radical of proteins can either cross-link or recombine with hydrogen, or result in scission and depending upon that, there may be a transfer of groups or cross linking etc.

As far as the effect of influence of ionizing radiation on the large number of compounds is concerned, there are possibilities that there may be a large number of compounds formed which have several effect on the food, food constituent and even on the surrounding environment.



Apart from that, they have effect on lipids i.e. lipids including fats. Many of the reactions are akin to the oxidative rancidity type reaction, peroxidation by molecular oxygen, even various radiation specific reaction can also take place there.

Carbohydrates are also very sensitive to radiation. Oxidation reactions predominate as well as condensation reaction similar to non-enzymatic browning may also take place. And it has been suggested in some literature that some products of radiation of sucrose even may have toxic effects on the cell.



Radiolysis of water results in the formation of peroxide or hydroperoxide; about half of the cysteine i.e. 50 percent of the cysteine may get destroyed during irradiation; about 10 percent of the tryptophan is lost. There may be development of oxidative rancidity, pectin is degraded which may cause softening of fruits and vegetable. And even, higher doses can cause off flavours because of the formation of the carbonyls compound, volatile constituents, hydrocarbon, etc.

The effect of radiation can be minimized by lowering down the water content. Because if the water content in the food is less, then there will be less radiolysis of the water, less free radicals will be formed and then the free radical initiated or mediated reactions will be stopped.

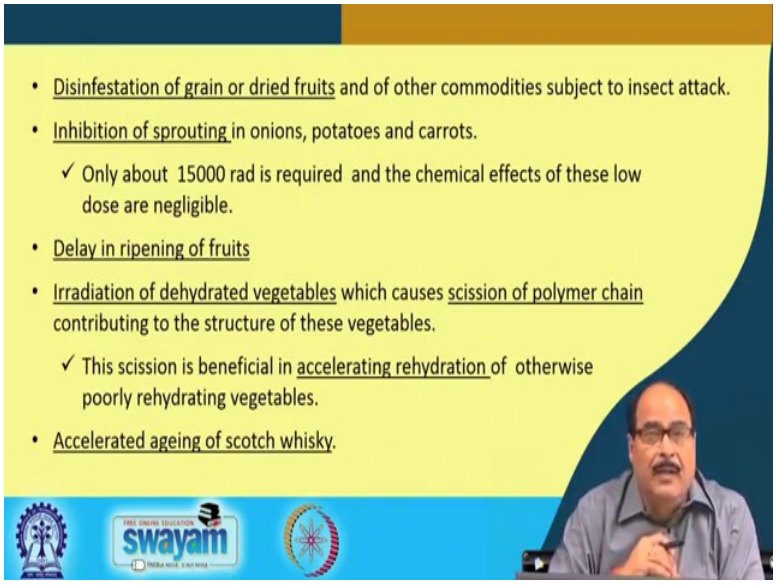
If irradiation is done in the less aerobic conditions and the food irradiated are kept in anaerobic environment, it will help in preventing off flavour and off color associated reactions. Reducing the temperature gives a better quality because the sub freezing radicals or immobilized free radicals play major roles. Irradiation of food in the frozen state is considered to be a better approach.

Addition of free radical scavengers depends upon the type of the food in the system particularly liquid or powder system and free radical scavengers or chelating agents can be added into the food.

The ionizing radiation has a vast ranging application in food processing. It can be used for different purposes in different food like, for sterilization of the army ration or stabilization of the other food, making the food stable at room temperature, etc. In fact, in many countries, irradiation is being used for sterilization of the army rations or sterilization of the ration to be given to the hospital patients and obviously, here the microorganisms are killed and food is made shelf stable or room temperature stable.

Another application is the extension of shelf life of various foods which are normally distributed or transported or stored at refrigerated temperatures. Particularly perishable foods, like fish, poultry, meat, fresh fruits and vegetables, milk, egg, cheese all these should be transported under refrigerated condition or even sold under refrigerated conditions for quality reasons. These foods can be exposed to irradiation treatment and can be made room temperature stable without any significant loss and influence on the quality factors; irradiation can be used for treatment of water and food processing waste. Thereby the whole refrigeration setup can be eliminated.

And interesting application in this respect is the treatment of cooling water for fish on board ships and by this, water is used for their cooling and transportation in the ship. By maintaining the microbial count in this water at a low level without heating the water; it should be possible to retard deterioration of fish prior to the time of their delivery for subsequent processing at the harbor.



Other possible areas where there is scope for application of the irradiation is the disinfestation of food grains or dried fruits. In fact, the insect infestation is one of the major causes for the spoilage of the grains or several dried fruits. Insects are very sensitive to ionizing radiation just by giving few 100 or 1000 rads of ionizing radiation, these insects can be killed.

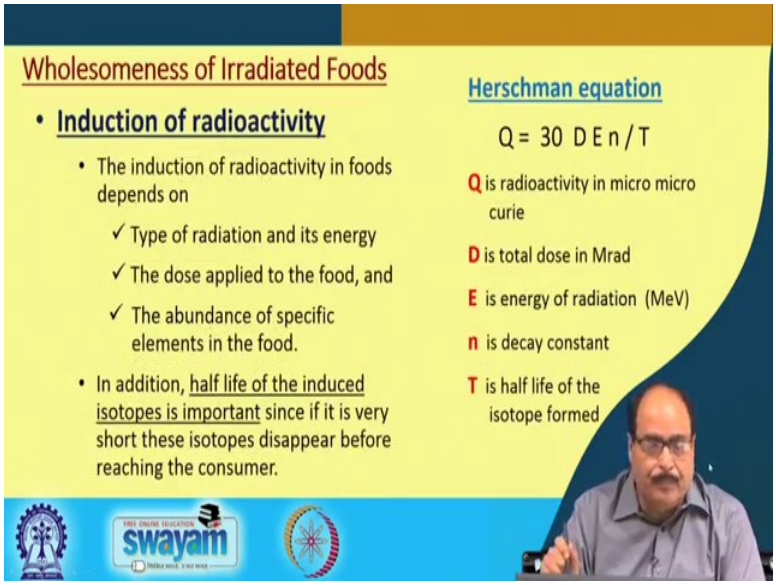
It is also used for inhibition of sprouting in onions, potatoes, etc. other such vegetables, when they are stored at room temperature for longer period. Sprouting is a major problem in such fruits and vegetables limiting their shelf life. So, all though there are chemical methods for control of sprouting, but these chemical methods invariably influence the flavor and bring about other changes in food. So, ionizing radiations becomes a very good source for inhibition of sprouting with only just a few thousand dose small doses like about 15000 rad etc is required and the chemical effect under these conditions are also very negligible or almost nil.

Another very interesting effect of irradiation is the delay in ripening of the fruit. And in fact, there are many fruits like mango which are even commercially treated by irradiation and they are shipped or transported to some countries. Then another very important application of ionizing radiations in the vegetables and fruits is to improve the rehydration characteristics of dehydrated vegetables.

Dehydrated vegetable products, if exposed to even little comparatively lower dose of irradiation, then it causes scission of the polymer chains; the longer polymers may be

broken into smaller ones which contributes to the structure of the vegetables. This scission is beneficial in accelerating the rehydration or it improves the reconstitution properties of dehydrated vegetables.

Irradiation can also be used for the accelerated ageing of scotch whisky. The freshly produced whisky do not have the desired flavoring characteristics and the aging is a very important step in their manufacturing process. In fact, they are stored for several years to get the desired flavor in the whisky. Ageing of the whisky or such other materials can be greatly accelerated by exposing them to the ionizing radiation.



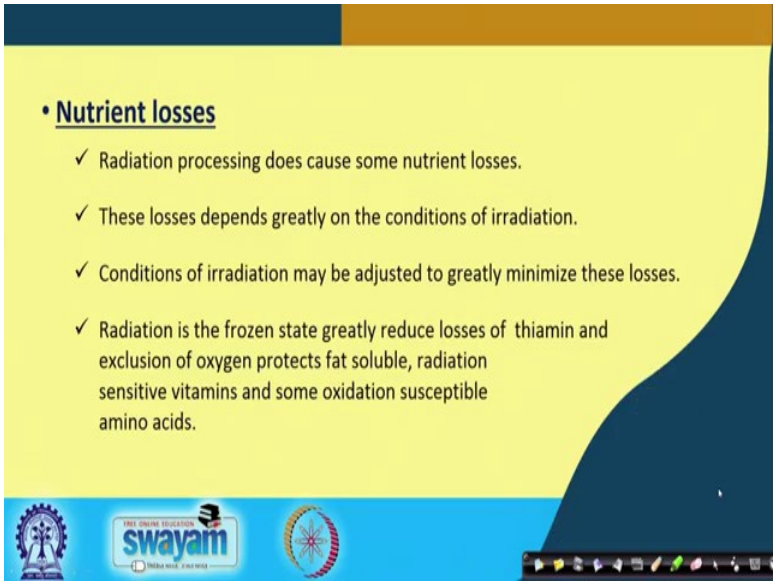
The induction of radioactivity in foods depends on: the type of radiation, its energy, the dose applied to the food, and the abundance of specific elements in the food.
In addition, half-life of the induced isotopes is important since if it is very short, these isotopes disappear before reaching the consumer.
As far as the induction of radioactivity is concerned, the Herschman equation can be used to measure how much radioactivity will be produced into the food material.
Herschman equation

$$Q = 30\ D\ E\ n / T$$

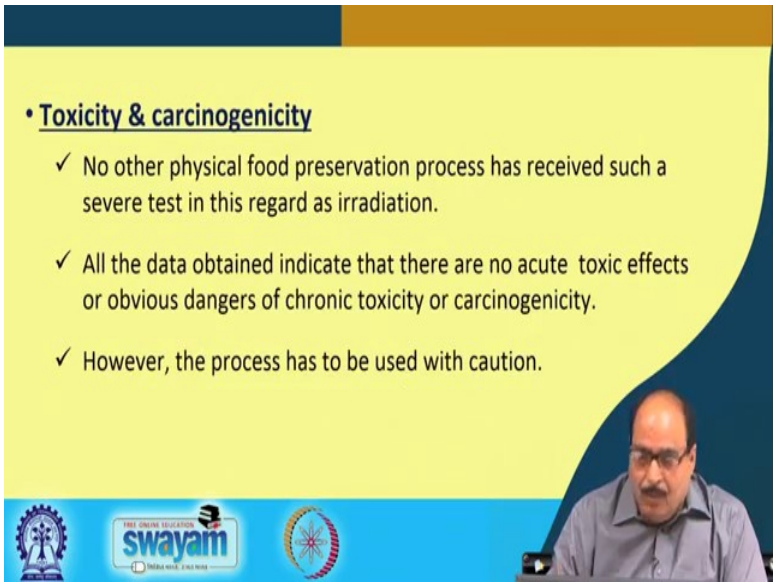
Q is radioactivity in micro micro curie
D is total dose in Mrad
E is energy of radiation (MeV)
n is decay constant
T is half life of the isotope formed

So, using this equation, one can calculate the induction of radioactivity.

The effect of ionizing radiations on induction of radioactivity into the food has been thoroughly debated and it has been reported that irradiation of the food with the gamma rays, and with the x-rays of energies values up to 5 MeV and electrons with energies value up to 10 MeV are safe.

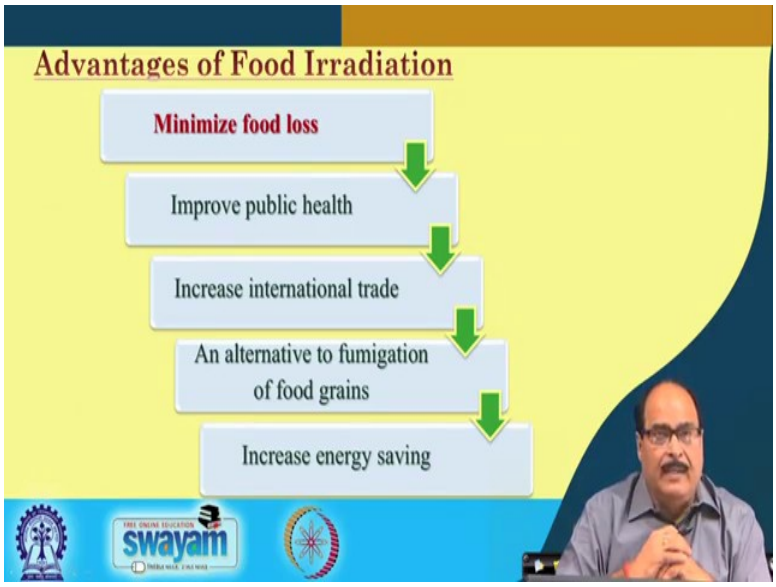


Radiation processing does cause some nutrient losses. These losses depend greatly on the conditions of irradiation. Conditions of irradiation may be adjusted to greatly minimize these losses. In particular, radiation is the frozen state greatly reduce losses of thiamin and exclusion of oxygen protects fat soluble, radiation sensitive vitamins and some oxidation susceptible amino acids.

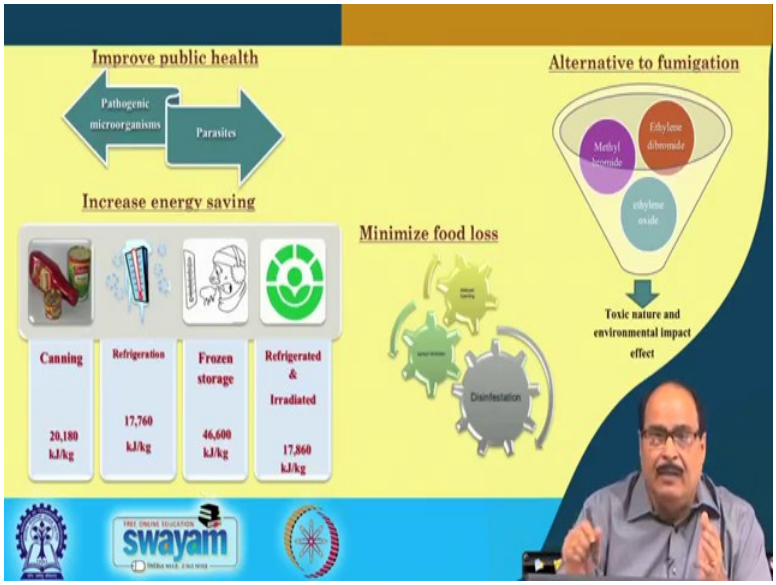


Though, third aspect regarding the production of toxic components or carcinogenic components in the irradiated food or during food irradiation; no other physical food preservation process has received such a severe test in this regard as irradiation. All the data obtained indicate that there are no acute toxic effects or obvious dangers of chronic toxicity or carcinogenicity.

However, a rigorous proof of safety is yet to come which will decide the fate of radiation processing as a commerical application.

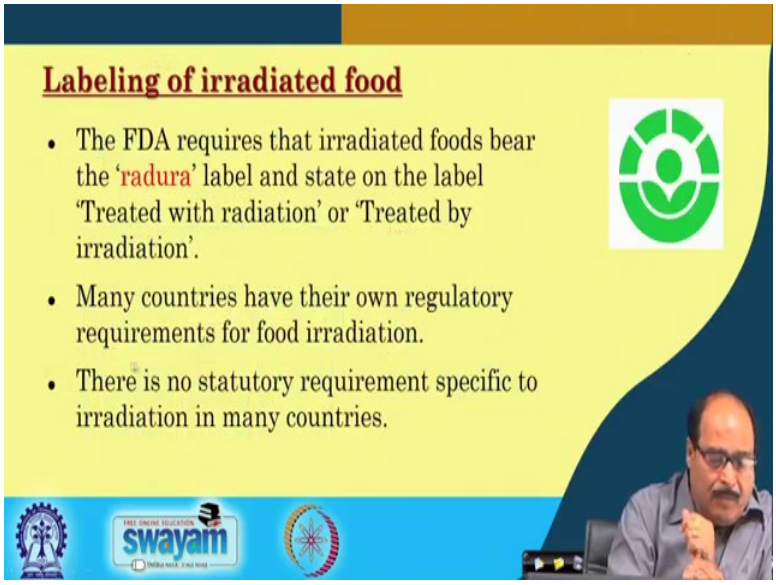


So, advantages of the food irradiation includes minimization of the food losses, improving public health, and increase in international trade. It is an alternative to fumigation of food grain, and it increases energy saving.

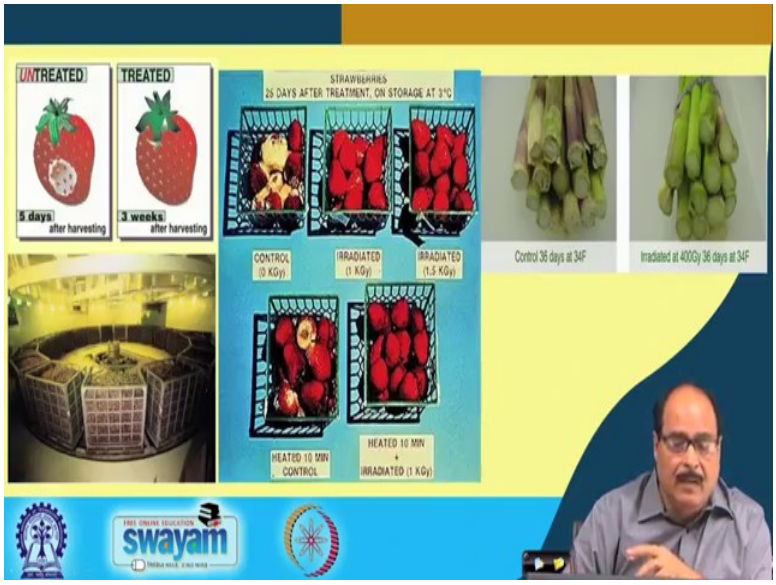


By eliminating pathogenic microorganisms or parasites, it reduces the possibilities of the toxicity and other things from the food.

Some comparative studies for utilization of energy in different processes like canning, refrigeration; canning, refrigeration then frozen storage and refrigerated and irradiated are shown. In the case of canning, 20180 kJ/ kg energy involvement is there where as in the refrigeration and frozen storage the respective figures are 17760 or around 46500 kJ/ kg, but in a food which is both refrigerated and irradiated, the total involvement of energy is around 17860 kJ/ kg. So, the data shows that the irradiation of food results in energy saving.



The irradiated food should be properly labeled, and in fact, FDA requires that, the irradiated food bear this radura label; this is the sign which has to be compulsorily put on the irradiated foods. And of course, in addition to this, should state on the label that 'treated with irradiation' or 'treated by irradiation'. Many countries have their own regulatory and labeling requirement for food irradiation. In some countries there is no statutory requirement specific to irradiation. In some countries it has been legalized, while in others still there is under consideration for legalization. But overall, this process has a great potential for application in food processing industry.



The effect of irradiation on strawberry and sugarcane stalk is shown in figure which are self-explanatory.

It can be concluded that the food irradiation is a better non-thermal means and novel technology and it has a vast potential for application in food processing for various useful purposes.

However, the process should be used with caution. It should be appropriately designed and the facilities should be well constructed; it should be made sure that there is no adverse effect of the process on the food constituents.