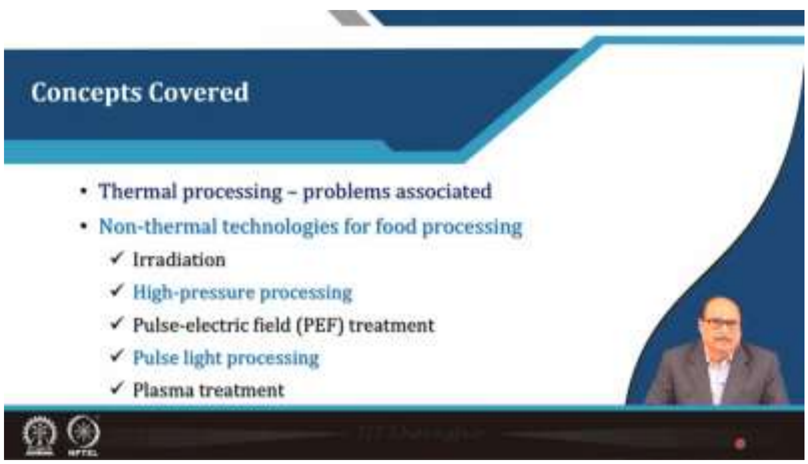
FOOD SCIENCE AND TECHNOLOGY

Lecture43

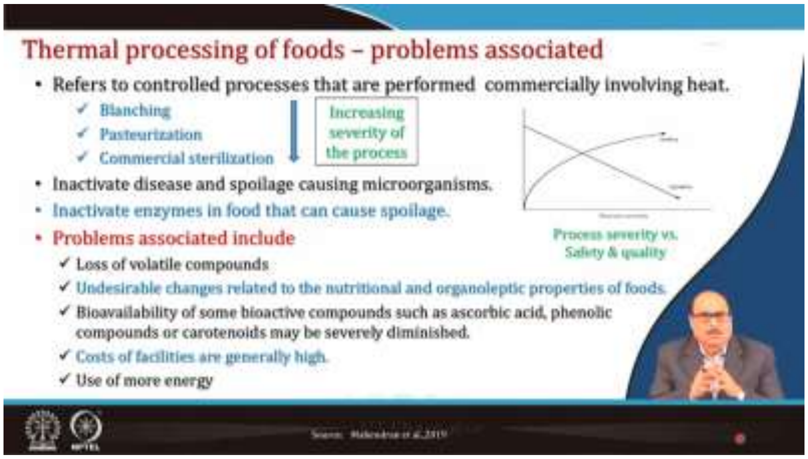
Lecture 43: Non-Thermal Technologies for Food Preservation

Hello everyone, Namaskar.

In this lecture today, we will talk about non-thermal technologies for food preservation.

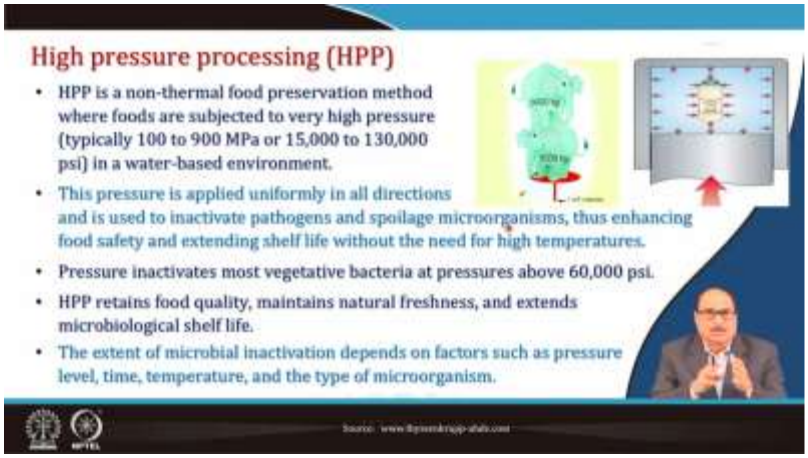


Today, we will briefly talk about the problems associated with thermal processing, and then we will take up non-thermal technologies for food processing. The non-thermal technologies we will discuss include irradiation, high-pressure processing, pulsed electric field treatment, pulsed light processing, and plasma treatment.

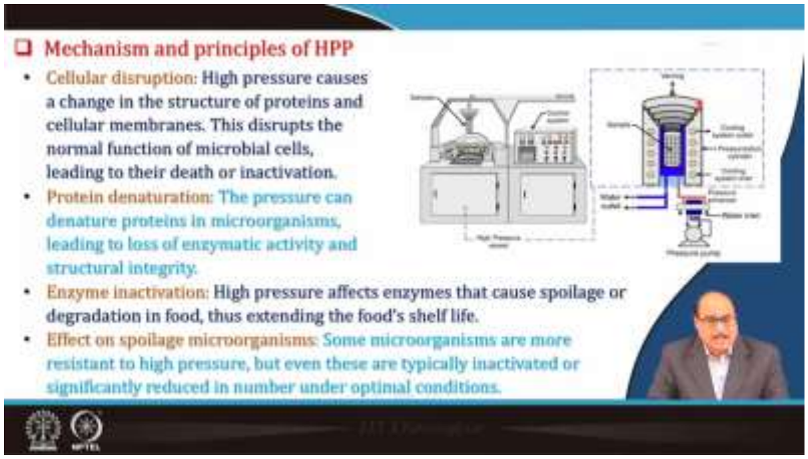


So, let us see what the thermal processing of foods is and mainly the problems associated with it. In the earlier lectures, we briefly discussed the various thermal processes that are applied to food for preservation and other purposes. Details of the thermal processes I had discussed in my other NPTEL courses, but here I will tell you the thermal processes used in food processing include blanching, pasteurization, commercial sterilization, and all that is in the increasing severity of the process. Blanching is generally less severe; commercial sterilization is the most severe. In this figure, I have tried to show you the severity of the process versus the safety and quality of food. So, as the severity of the process increases, if you go for more severe process parameters or more severe treatment. The safety will be better, but the quality is reduced, deteriorating the food quality. So, one has to take a step that is an optimum case, where you can have good quality and safe food. So, that is what is done in the So, thermal processing inactivates enzymes and spoilage microorganisms or even disease-producing microorganisms. So, that is inactivated, and you get safe food. Also, it inactivates enzymes that cause spoilage of the food, but at the same time, as I told you, there is a loss of volatile compounds in thermal processing. There are undesirable changes related to the nutritional and organoleptic properties of the food. The bioavailability of some bioactive compounds, such as ascorbic acid, phenolic compounds, carotenoids, etc., may be severely diminished if the processing conditions are over, particularly in sterilization, etcetera. Also, facilities costs are generally high, and these use more and more energy. In the thermal process, we have to give more heat energy. So, the energy is mostly energy-intensive operations.

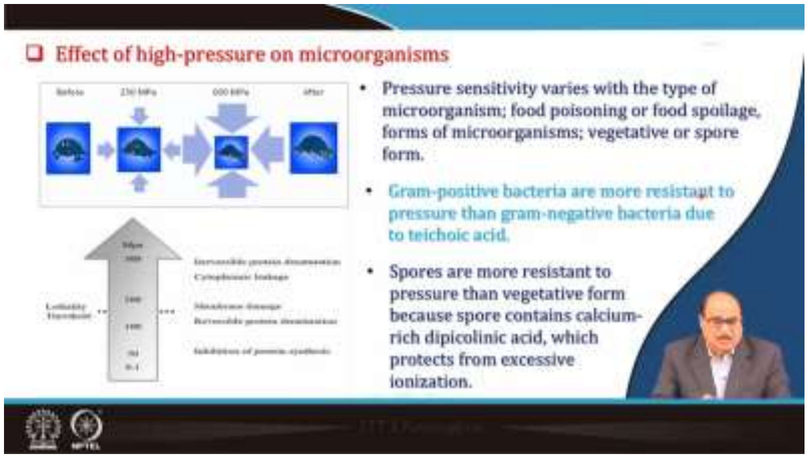
As I told you, the conventional methods produce a number of undesirable changes. They are energy-intensive operations, etcetera. But nowadays, consumer demand for minimally processed foods means the process should be as minimal as possible. So, processed food has better nutrient retention, is high quality, is additive-free, is convenient and gives a fresh-like appeal to the product. With the assurance at the same time, it should be safe and at the same time, it should have good nutritional value, quality, and fresh-like appeal. So this can be obtained by non-thermal processing, that is, this consumer demand offers, or it can be met by using non-thermal process treatment that is where that is heat energy is replaced with other non-heat sources that some non-heat sources apply energy and to bring about similar changes that we are getting by application of heat. So, food preservation techniques are improved since heat is not involved in non-thermal processes. At the same time, there is minimum processing-induced loss of colour, flavour, texture and nutritional value. They retain the highest possible quality even in stressful storage environments and provide shelf life or shelf-stable foods with fresh food attributes. So, here are the advantages or benefits of using non-thermal processing technologies.



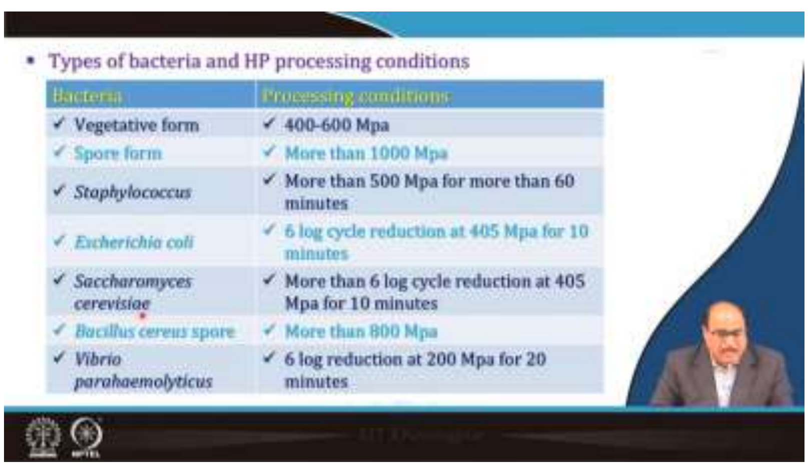
So, now we will take it up one by one, and the first and most important you can say, which is even used commercially in several countries, is the high-pressure processing of foods. So, high-pressure processing is a non-thermal food preservation method where the foods are typically subjected to very high pressure, up to 100 to 900 mega Pascal. in a water waste environment. There is an apparatus like this: a chamber in which water is killed, and then the material is compressed, and temperature pressure is brought to 100, 900, or even 1000 mega Pascal. Sometimes, even spore-forming bacteria are present, particularly in low-acid food. The pressure requirement may be as high as 1400 or 1500 megapascals. So, this pressure is applied, as you can see here in this figure, instantaneously and uniformly from all directions, and it is used to inactivate pathogens and spoilage microorganisms, thus enhancing food safety and extending the shelf life of the food without the need for high temperature. Pressure inactivates most vegetative bacteria at pressure ranges of around 60,000 psi, or 600 megapascals. High-pressure processing retains food quality, maintains natural freshness, and extends microbiological shelf life. However, the extent of microbial inactivation depends on several factors, such as the pressure level, the time for which this pressure treatment is given, and even the temperature. A temperature is also maintained in the process because if the temperature is high, then you can have the hurdle technology effect of both temperature and pressure. So, you can reduce the severity of the process in this way and the type of microorganism, whether it is a spore, vegetative cell, or mesophilic or thermophilic. All these characteristics of microorganisms will also influence.



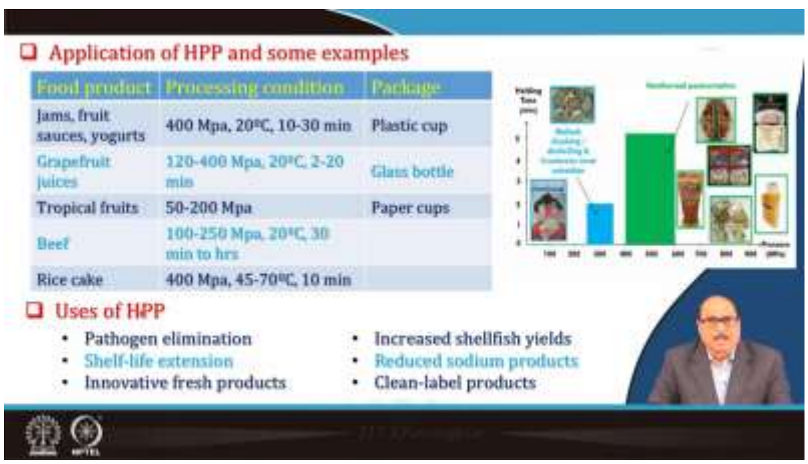
Then, let us see the mechanism and principles of high-pressure processing. In the system you see here, there is a chamber where the food is kept, arrangements for proper sealing, and a high-pressure pump. So, with a suitable conveying system, the food sample is properly packaged or unpackaged, depending upon the type of food. It is loaded into the chamber, and then pressure is applied. So, when you apply the pressure, what happens? There is cellular disruption, which is the microbial cell or enzymatic proteins, etcetera. So, the cell disrupts, and there is a change in the structure of proteins and cellular membranes. This disrupts the normal functions of the microbial cell, as we have seen earlier, because of the temperature you are seeing here. So, here, because of the pressure, the cell membrane is ruptured, and cellular functions are ruptured, ultimately leading to the microorganism's death or inactivation. That cell enzyme protein or other enzymes, etcetera, that the pressure can denature these proteins in the microorganism, in the enzymes, etcetera, leading to the loss of enzyme activities and structural integrity and, finally, inactivating them. High pressure affects enzymes that cause spoilage or degradation in food, thus extending the shelf life. As I told you, some microorganisms are more resistant to high pressure, the spore-forming bacteria. Incidentally, in food processing, such as in the dairy industry and other industries, spore formers are more prevalent and are considered. So, in those cases, you have to apply very high pressure, or one can use a combination of pressure and temperature to inactivate those spore formers using high-pressure technology.



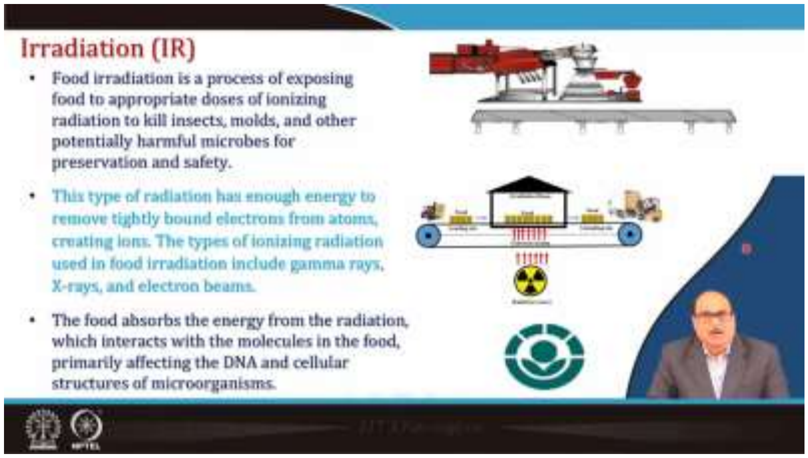
So, let us discuss the effect of high pressure on the microorganisms and the inactivation of microorganisms. I tell you that it just squeezes the microbial cell, as you can see here in the figure. That is, earlier, the microorganism was like this, but when you increase the pressure, that results in the cellular that is compression of the microbial cell and blockage of the membrane. So, in this figure below, up to about 150 or so, if you increase the pressure above 150 or so, the membrane will rupture, and this protein will get denatured. So this way, the microorganisms get inactivated. Gram-positive bacteria are more resistant to pressure than gram-negative bacteria, mainly due to teichoic acid in the gram-positive bacteria. Spores are more resistant to pressure than vegetative forms because the spore mainly contains calcium-rich echolonic acid, which protects it from excessive ionization.



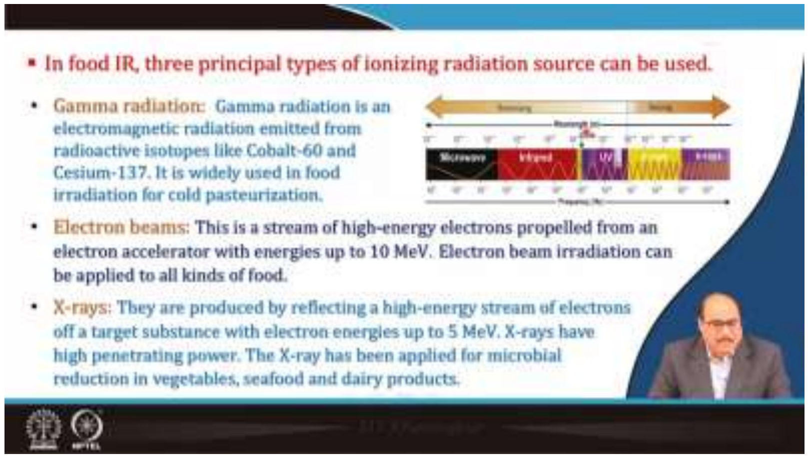
Now, if you look at the various types of bacteria and high-pressure processing conditions, the vegetative cells of the bacteria can be inactivated using 400 to 600 mega Pascal. There are more than 1000 megapascals spore farming bacteria or spore farms. Staphylococcus is about 500 megapascal for more than 60 minutes. If the food is exposed to around 405 megapascal for 10 minutes, it may result in 6 log cycle of reduction of E. coli. Saccharomyces cerevisiae is reduced to more than 6 log cycles at 405 megapascals for 10 minutes. Similarly, Bacillus cereus requires more than 800 megapascals for inactivation. Vibrio shows a 6-log cycle reduction at 200 megapascals for 10 minutes. So, you must find out what the major microorganism is and its death kinetics under pressure. All those calculations can be made, like in the thermal processing region. Similarly, one can do all those calculations and optimize the process here.



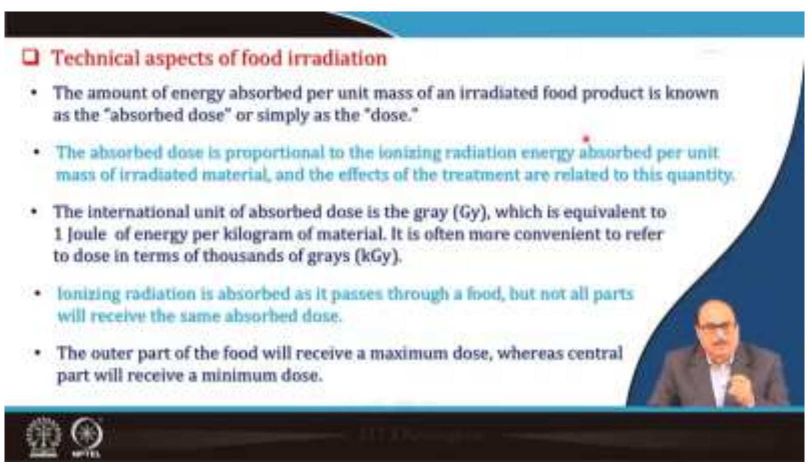
High-pressure processing can sterilize and extend the shelf life of jams, fruits, sauces, yoghurt, etc. Normally, these are packaged in plastic cups and processed at 400 megapascals and 20 degrees Celsius for 10 to 30 minutes. Similarly, grapefruit juices in glass bottles can be processed at 120 to 400 megapascals and 20 degrees Celsius for 2 to 20 minutes. Rice cakes can be processed at 400 megapascals and 45 to 70 degrees Celsius for 10 minutes. So, here in this figure, you see that at around 100 megapascals, there is almost no significant effect, etcetera. So, some changes are taking place. Still, around 300 megapascals, there is molecular breaking and de-sealing, etcetera, and the extraction of this in non-thermal pasteurization, maybe 400 to 600 megapascal. For sterilization, you must go for more than 700, up to 900 megapascals. So, high-pressure processing can eliminate pathogens for shelf-life extension of food, innovative fresh product production, increasing shelf-life, improving yields, reducing sodium in products, or clean-label products. So, these are the various uses of high-pressure processing.



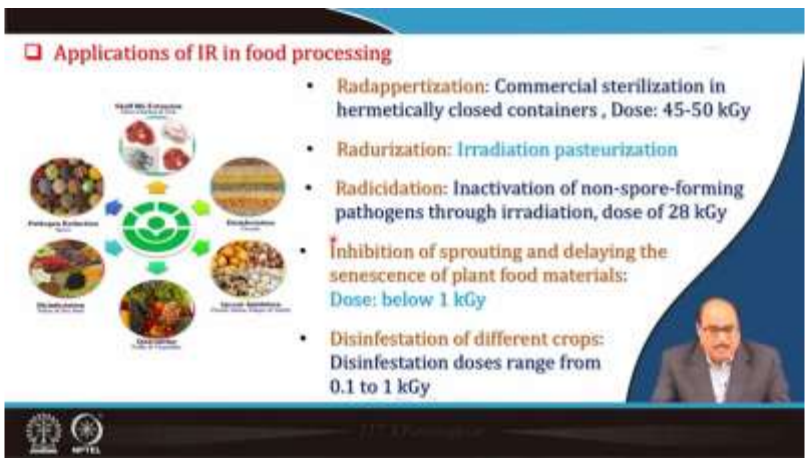
Now, let us talk about irradiation, such as food irradiation. Irradiation exposes food to an appropriate dose of ionizing radiation to kill insects, moulds, and other potentially harmful microbes for preservation and safety. This type of radiation has enough energy to remove tightly bound electrons from atoms, creating ions. The types of ionizing radiation used in food irradiation are gamma rays, X-rays, and electron beams. The food absorbs the energy from the radiation, which interacts with the molecules in the food, primarily affecting the DNA and cellular structure of microorganisms. Also, ionizing radiation-radiated foods must be kept at this radura level as per international regulations. So, you can see that the irradiation facility has an irradiation chamber, and there should be some radiation source. So, the food, again in the packaged or unpackaged form, is taken with the help of a conveyor belt to the chamber where it is exposed to a calculated amount of energy either from one side or for both sides the purpose may be for is to get the pathogenic microorganism inactivator or sterilization etcetera that I will tell you in the next slide.



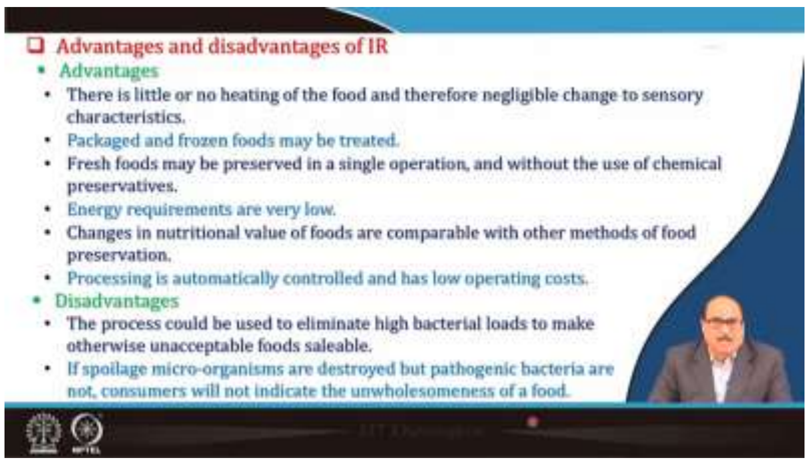
Then, three principal types of ionizing radiation, as I told you, are used in food irradiation. It is gamma radiation; it is electromagnetic radiation emitted from radioactive isotopes like cobalt 60 and Cesium 137. It is widely used in food irradiation for cold pasteurization, and most commonly, the cobalt 60 source is used to produce gamma rays. Then, electron beams are also a stream of high-energy electrons propelled from an accelerator electron accelerator with energies up to 10 MeV. Electron beam irradiation can be applied to all kinds of food. Then, X-rays are produced by reflecting a high energy stream of electrons of a target substance with electron energy up to 5 MeV. X-rays have high penetrating power. They were applied, and an X-ray was used for microbial reduction in vegetables, seafood, and dairy products.



So, if you talk about the technical aspects of food irradiation a little bit, you know that the amount of energy absorbed per unit mass of an irradiated food product is known as the absorbed dose or simply the dose, which is very common, like the dose of radiation applied there is. So, the absorbed dose is proportional to the ionizing radiation energy absorbed per unit mass of the irradiated material, and the treatment's effects are related to this quantity. The international unit of absorbed dose is grey. Earlier, it was red, but now the most commonly used unit is gray (Gy), equivalent to 1 joule of energy per kilogram of the material. It is more often convenient to refer to the dose in terms of thousands of gray, kilogray (kGy), and so on because of the energy supplied for bacterial inactivation, etcetera. So, kilogray is more commonly used. Ionizing radiation is absorbed as it passes through food, but not all parts will receive the same absorbed dose, and that will depend upon the type of food, the penetration power of the radiation, and so on. The outer part of the food will receive the maximum dose, whereas the central part will receive a lower dose and sometimes even the minimum dose.

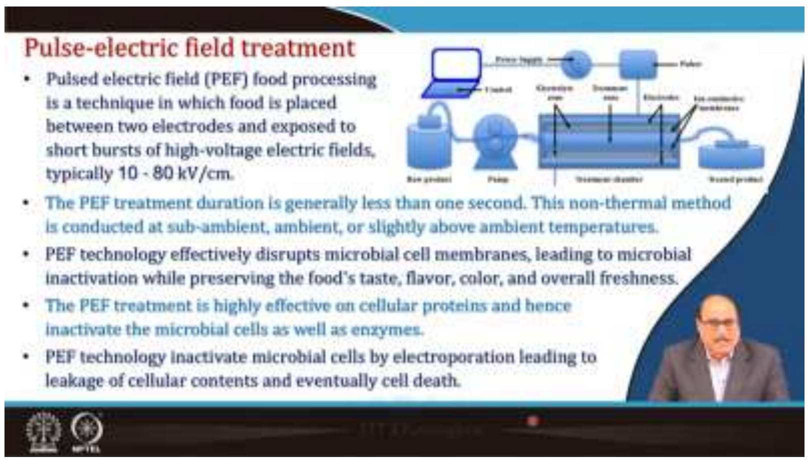


As far as the application of ionizing radiation in food processing is concerned, it can be used for various purposes like shelf-life extension, or it can be used for disinfestation of cereals, etcetera. There is a need for disinfestation storage facilities for sprout inhibition, that is, sprouting in onions and potatoes, etcetera, which are major problems. So, a simple application can quarantine, sterilise, disinfect dry fruits, reduce pathogens, etc. So, various processes are named, like the radappertization. The radappertization, like in thermal processing, appertization means sterilization. It was a process that completely removed all the microorganisms, based on the process named after Nicholas Appert. So, that is kining. So, here, when the same objective is done, radiation is done with the same objective for removing all and inactivating all the microorganisms; the process is known as radappertization or radiation sterilization, and doses here normally are 45 to 50 kilogray, that is comparatively higher dosage liquid. Then, there is radurization. Radurization is pasteurization using radiation energy, and dosages are comparatively less here. So, this results in an almost 90 per cent reduction of spoilage and pathogenic microorganisms, disease-causing microorganisms, mostly sometimes radiation, and a 90 per cent reduction. Radiation is the normal process for inactivating non-spore-forming pathogens through irradiation, and the dose requirement is 28 kGy. Then, an inhibition of sprouting and delaying or the senescence of the plant food materials normally less low than 1 kilogram by this infestation of different crops like insects' etcetera that there can be 0.1 to 1 kilogram, and there are various other applications. sterilization of army ration, that is, ageing of the scotch whisky or even improving the rehydration characteristics of the dehydrated food materials, etcetera. So, these are the various purposes for which irradiation processing can be used.

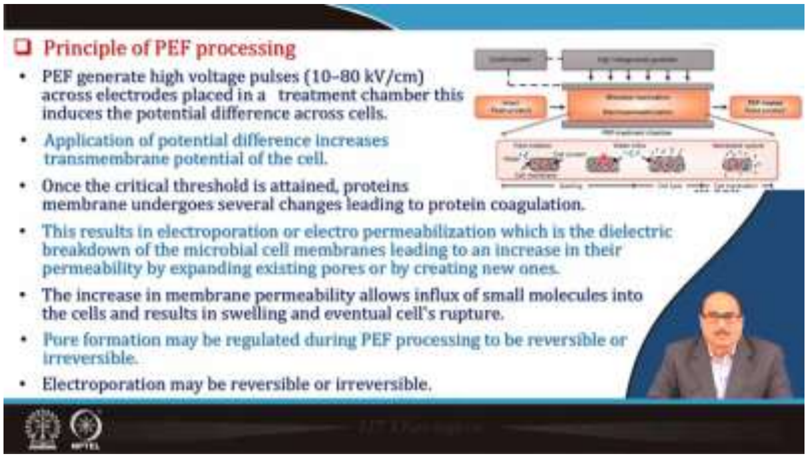


Now, if you look at the advantages and disadvantages of irradiation, the advantages we already explained include there is little or no heating of the food and, therefore, that is, heat-associated undesirable changes in the quality characteristics of the food are entirely almost eliminated in this case. This is even packaged or frozen foods that can be treated here with ionizing radiation. Fresh foods may be preserved in a single operation and without chemical preservatives. Energy requirements in this process are very low compared to those in thermal processing. These are very low here, and changes in the nutritional value of the food are comparable with other food preservation and processing methods, are automatically controlled, and may have low operating costs. Disadvantages, however, are that the process could be used to eliminate high bacterial loads to make otherwise unacceptable food foods saleable, and if pathogenic bacteria destroy spoilage microorganisms, consumers will not be able to find that it will not indicate the wholesomeness of food. However, the use of radiation energy for treating the food has to be taken with caution because one has to see that is what the induction of radioactivity, finally, is into the food. So, there are many countries they have approved, and it has the process because of the. obvious dangers of ionizing radiation, the process has to get specific approval from the Atomic Energy Regulatory Commission regarding the dose, the facility establishment, etcetera, and so on.

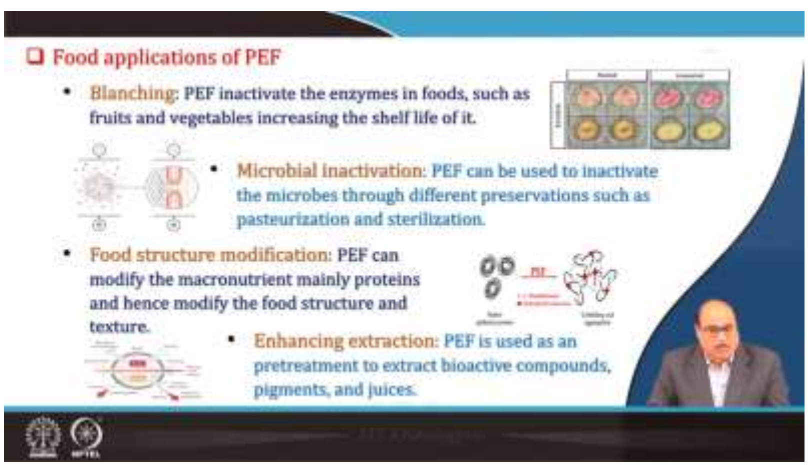
Then we talk about pulse electric field treatment. This pulse electric field treatment processing is a technique in which the food is placed between two electrodes and exposed to short bursts of high-voltage electric fields, typically in the 10 to 80 kilowatt per centimeter range.



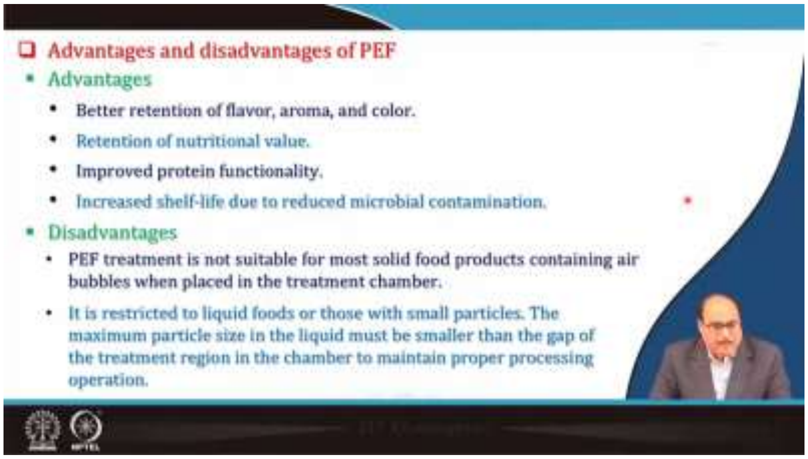
So, you see here that is the apparatus. There are two electrodes. So, food is placed between two electrodes, the high electric pulse voltage. It is exposed with the help of these two electrodes. The PEF treatment duration is generally less than 1 second. This non-thermal method is conducted at sub-ambient, ambient, or slightly above ambient temperatures. PEF technology effectively disrupts microbial cell membranes, leading to microbial inactivation while preserving the food's taste, flavour, colour, and freshness. The PEF treatment is highly effective on cellular proteins and inactivates microbial cells and enzymes. This technology inactivates microbial cells by electroporation; when these foods' biological materials are exposed, it causes either new pores to form in the membrane cell membranes or the existing pores to enlarge. Because of this pore formation, electroporation is when the cellular materials ooze out, and the cell's biological activities get affected, ultimately leading to the cell's death.



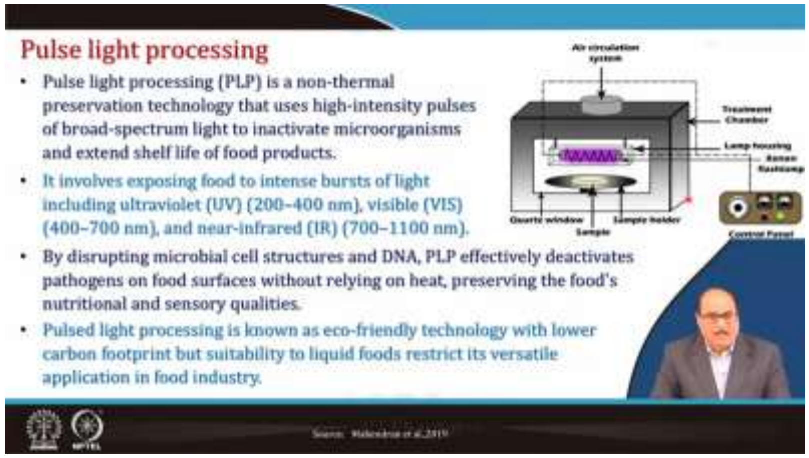
So, the principles of PEF processing, you see again, you can see here that is the same that is the food intact is sent here, and that is the high voltage pulse generators, and these are the two electrodes there is a control system. So, material goes the food. So, in the PEF treatment chamber, I told you, there is a pore initiation, a water receptor cell membrane, swelling, water index, and finally, the membrane ruptures. So, this is the main function. So, applying potential difference increases the transmembrane potential of the cell. The increase in the membrane permeability allows the influx of small molecules into the cell, resulting in cell swelling and, finally, cell rupture. The pore formation may be regulated during PEF processing to be reversible or irreversible, electroporation may be reversible or irreversible.



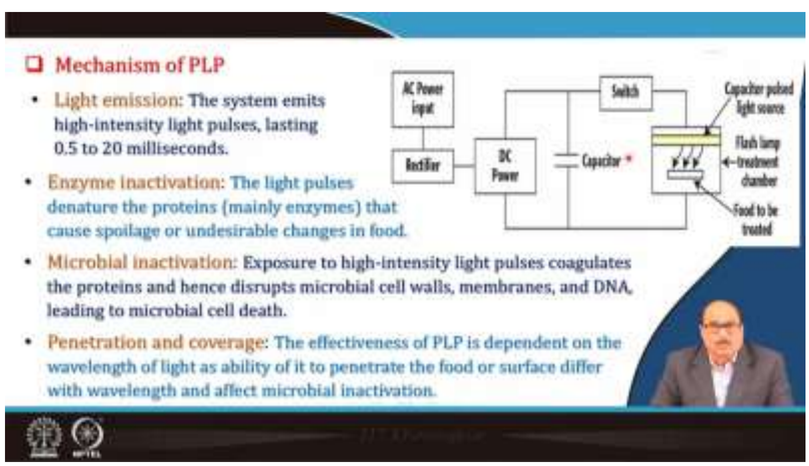
Food applications of PEF may be used for branching, such as inactivating enzymes in food such as fruits and vegetables and, therefore, increasing their shelf life. Even microbial inactivation, PEF, can be used to inactivate the microbes throughout. preservations like pasteurization, sterilization, etcetera. Then, food structure modifications, that is, PEF, can modify the micronutrients, mainly proteins, and hence, they modify their structures. Finally, it can also be used for enhancing the structure; one very thing that may be a very interesting application of PEF processing is particularly in fruits and vegetables, where you want to get more extraction and more bioactive may be extracted with and without no destruction of it. So, here, when you give the PEF pore, pore formation that is plant cell pores, etc., then it releases more bioactive because there is not much temperature involvement. So, these bioactives retain their activity bioavailability, etcetera, in the fruit juices.



The advantages of PF are better retention of flavour, aroma, and colour, retention of nutritional value, improved protein functionality, and increased shelf life due to reduced microbial contamination. However, the process has certain disadvantages, such as PF treatment not being suitable for most solid food products; there is the requirement that the product be pumpable. So, liquid foods are more likely to be treated here, but products, even those containing air bubbles when placed in the treatment chamber, can cause problems. It is restricted to liquid foods or those with small particles; the maximum particle size in the liquid must be smaller than the gap of the treatment region in the chamber to maintain proper processing operations.



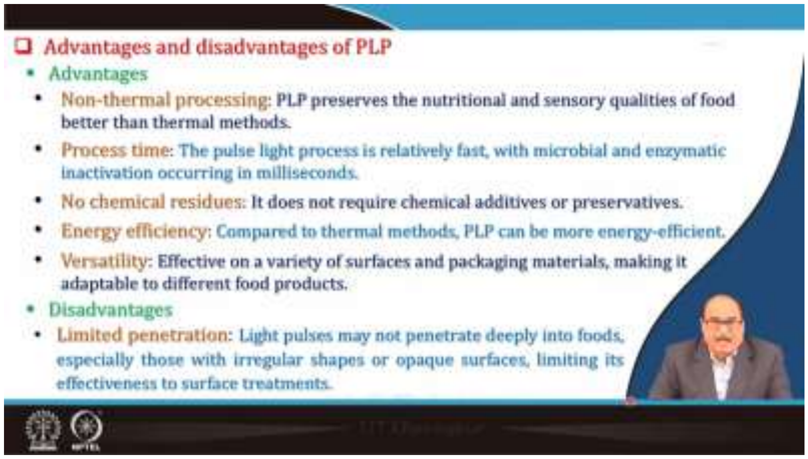
Now, pulse light processing pulse light processing is almost similar, but here, light is used. It is here also, but here light is present. It is a non-thermal preservation technology that uses high-intensity pulses of broad-spectrum light to inactivate microorganisms and extend the shelf life of food products, as you can say here. Again, there is a treatment chamber where the material is placed and exposed to various light sources, see. It involves exposing food to intense bursts of light, including ultraviolet, visible, and near-infrared light sources, and then this results in the disruption of the microbial cell structures and DNA. Therefore, the pulsed light processing effectively deactivates pathogens on food surfaces without relying on heat. It preserves the food's nutritional quality and sensory qualities. Pulsed light processing is known as an eco-friendly technology with a lower carbon footprint, but its suitability for liquid food restricts its versatile application in the food industry because, again, it is more suitable for liquid food processing.



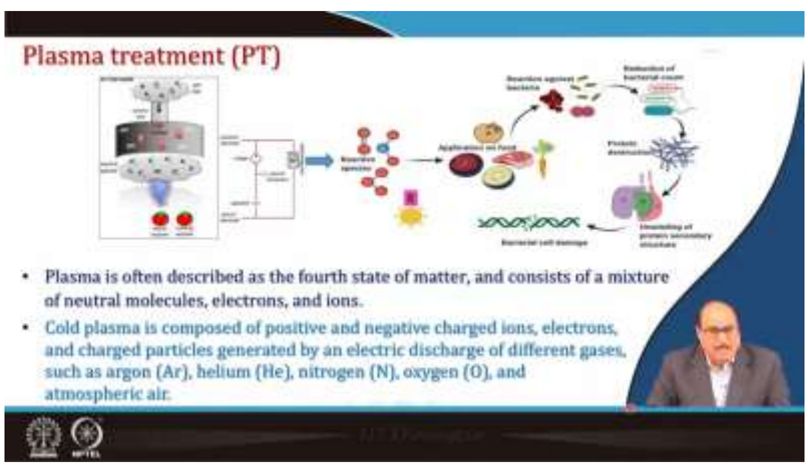
The mechanism is that a light emission system emits high-intensity light pulses lasting about 0.5 to 20 milliseconds. You can see the structure here. A material is put here to treat food, and light is flashed. Then, it results in enzyme inactivation and microbial inactivation, as we discussed earlier. space and then penetration and coverage. The effectiveness of PLP depends on the wavelength of the light as its ability to penetrate the food or surface differs with the wavelength and affects microbial inactivation. So, it is mainly restricted to surface destruction or surface inactivation of the microorganism.

As far as the food application of pulsed light processing is concerned, yes, it is used. It can be used for surface treatment, that is, surface decontaminating various solid foods such as fruits, vegetables, meat, packaged foods, etc. It can even decontaminate the packaging material before the food is packaged. PLP can be employed to treat beverages without affecting their nutritional quality.

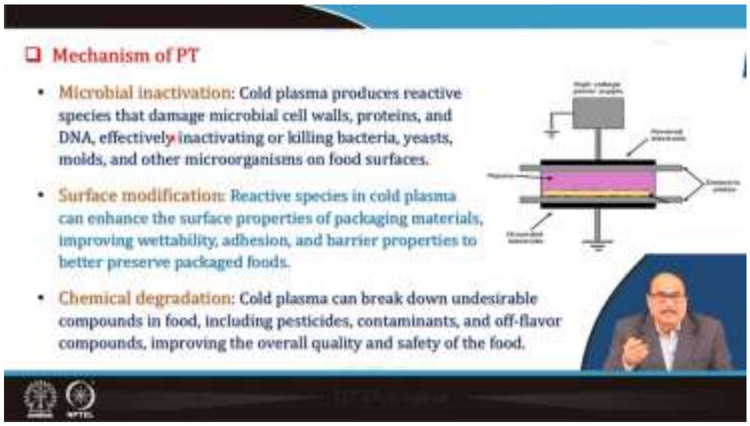
Then again, in enhancing extraction, it is used as a pretreatment to extract bioactive compounds and pigments, as well as to increase the rate of juice extraction to get more and more recovery of the juices with a higher amount of bioactives.



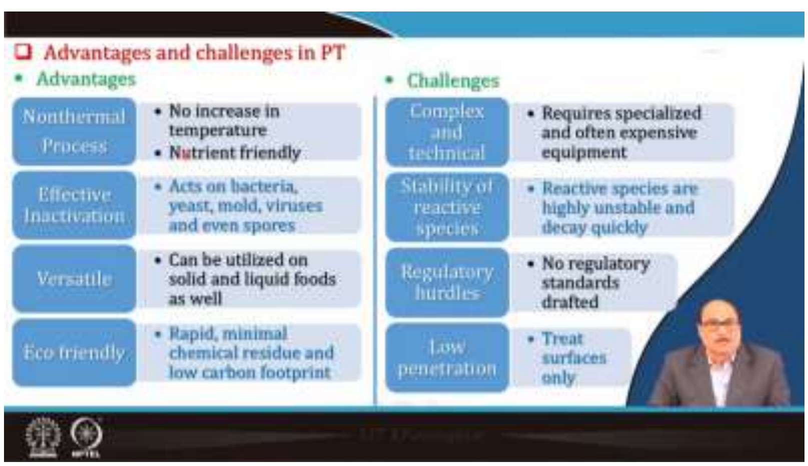
Advantages and disadvantages: if you talk about advantages, it is a non-thermal process. So, it gives all the advantages of non-thermally processed foods. The pulsed light process is relatively fast, with microbial and enzymatic inactivation occurring mainly in milliseconds. So, the treatment time is very short and does not require chemical additives. Compared to the thermal method, PLP can be more energy-efficient and effective on various surfaces and packaging materials, making it adaptable to different food products. So, the major disadvantage, you can say, is the limited penetration. The light pulses may not penetrate deeply into foods, especially those with irregular shapes or opaque surfaces, limiting their effectiveness in surface treatments.



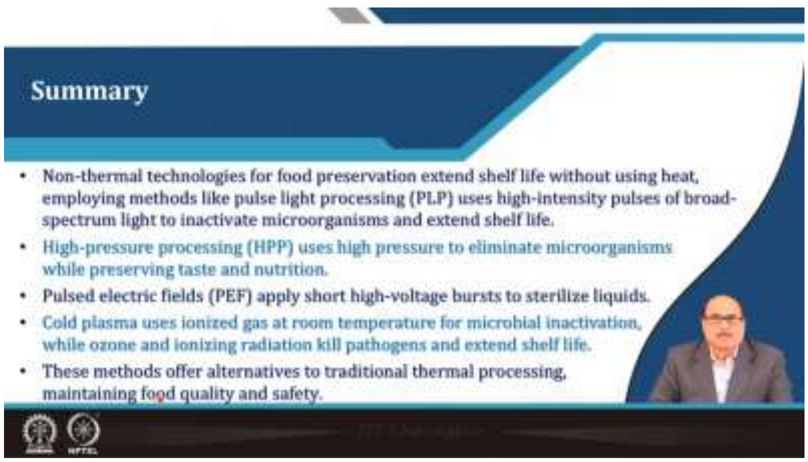
Now, we will talk about plasma treatment. And you know, plasma is often described as the fourth state of matter and consists of a mixture of neutral molecules, electrons, and ions, as you can see here. That is the material; there is plasma. This is the fourth state of matter, different gas mixtures of various molecules, neutral molecules, etcetera. It may be oxygen, nitrogen, OH, and so on these ions. Cold plasma comprises positively and negatively charged ions, electrons, and charged particles generated by an electric discharge of gases such as argon, helium, nitrogen, oxygen, and atmospheric air.



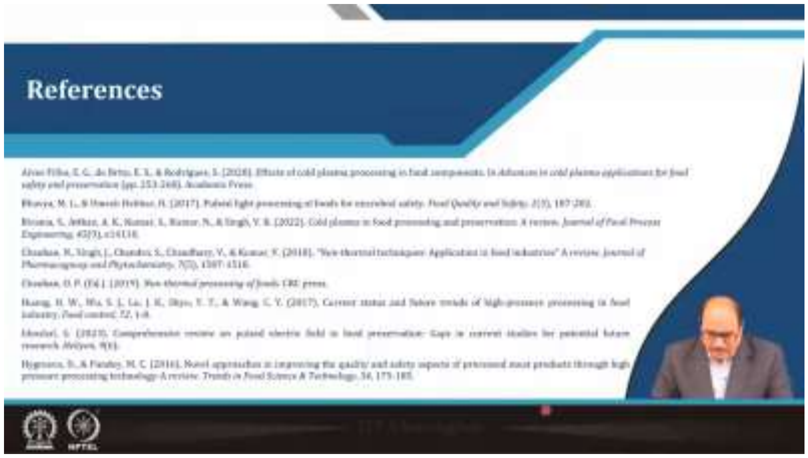
So, how does it work? It results in microbial inactivation, like cold It produces reactive species that damage microbial cell walls, proteins, and DNA—effectively inactivating or killing bacteria, yeast, moulds, etcetera, or even some other microorganisms on the food's surface. Surface modification, like reactive species in cold plasma, can enhance the surface properties of the packaging materials, improving adhesion and barrier properties to preserve the packaged foods better. Even cold plasma can break down undesirable compounds in food, including pesticides, contaminants, off-flavour compounds, etcetera, improving the overall quality and safety of the food.



So, advantages and challenges in plasma treatment—if you can say advantages it is a non-thermal process. So, no increase in temperature. So, it is a nutrient- and quality-friendly process. It results in the inactivation of almost all sorts of bacteria, even spores, which can be easily inactivated using plasma treatment. This is a versatile process that can be applied to solids as well as liquid foods, and it is an eco-friendly technology. There is rapid action, minimal chemical residue, and a low carbon footprint. However, to make it a commercially viable process, there are certain challenges still facing this technology, such as its complexity and the fact that it is a technical process that requires specialized and often expensive equipment. The stability of the reactive species is an issue, as they are highly unstable and decay quickly. So this makes the process somewhat challenging, and there are also no specific regulations in most countries globally. So, regulatory hurdles, etc., are present, and this again results in low penetration, as it does not go deep and cannot penetrate materials deeply, etc. So, generally, it is used to treat the surface, whether solid or liquid food. So, that is one where microorganisms inside the food are not generally easy to inactivate. It won't be easy to inactivate them.



So, now finally, I would like to summarize this lecture by saying that these non-thermal technologies for food preservation extend the shelf life of food without using heat. They employ high-pressure processing, irradiation, pulse light processing, high-intensity pulses, etc., to inactivate microorganisms and enzymes. High-pressure processing uses high pressure to eliminate microorganisms while preserving the taste and nutrition. A pulsed electric field applies short high-voltage bursts to sterilize foods. Cold plasma uses ionized gas at room temperature for microbial inactivation, while ozone and ionizing radiation kill pathogens and extend the shelf life of food. So, these methods are alternatives to thermal processing. They result in good and reasonable shelf life of the food material, ensuring good quality and safety. Non-thermally processed foods are better because their safety is well established. Still, it is time to tell that is how safe, particularly from microbes and toxins, is a how safe that it has to be time tested. Still, it will need to be established that these non-thermally processed foods are safe.



These are the references used in this making this power point.

Thank you very much for your patience hearing. Thank you.