Thermal Processing of Foods
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Lecture 17
Overview of Non-Thermal Processing Technologies

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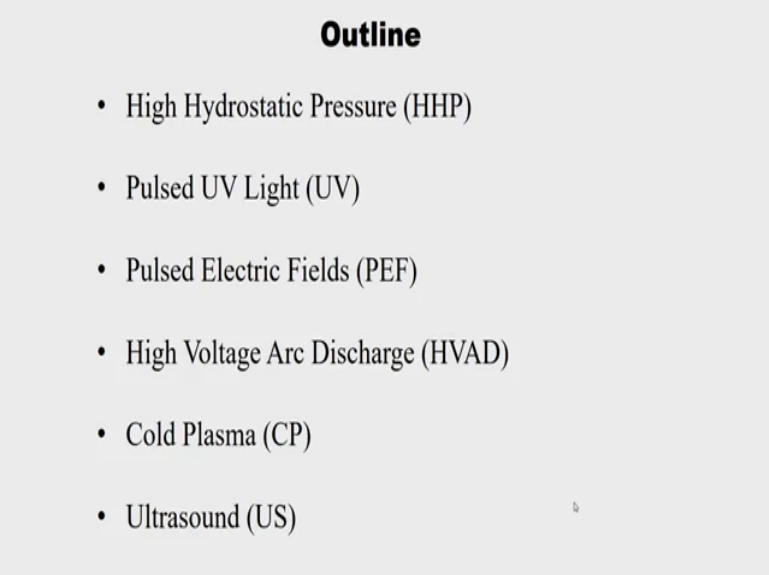

Today we are going to see about overview of non-thermal processing technologies. The outline goes like this, the high hydrostatic pressure technology, pulsed UV light technology, pulsed electric field technology and high voltage or discharge technology, cold plasma and ultra sound.

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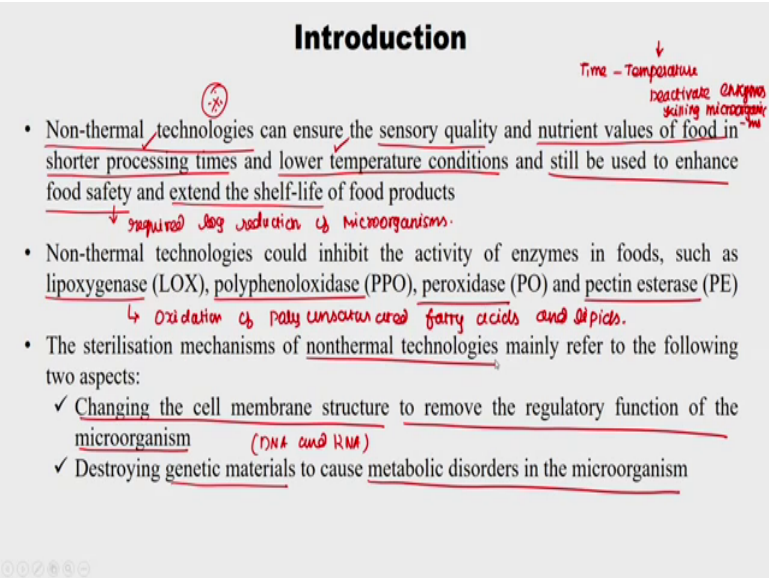

The introduction about non thermal processing technologies. So, they are mainly employed to ensure the sensory quality and nutrient values of food, by employing short processing times and low temperature conditions. So, the movement I say what we have discuss in thermal technologies, that time temperature combination would be very much important. So, this time temperature combination is very much important to maintain the lethality for to deactivate enzymes. Which spoils the food and also the keeling of pathogenic and spoilage microorganisms.

So, most of the thermal technologies so we apply this time temperature combination for this purpose. So, what happens is because we are always concern about the killing of microorganisms. Sometimes my food may get over cooked. So, when in the process establishment we have also seen. So, i supposed to find the equivalent F value. So, that means even if the wealthy processes ENF to ensure the safety. So, for all safety purposes i would go for extra three or 2D mode.

So, that means though it is said that wealthy processes is safe. So, normally industries would apply more than that may be 16D process. So, the disadvantage of that is what happens is when you go for such a safer value. Sometimes, your food gets over cooked and your nutrient values will go for from the food. So, to ensure this sensory quality and nutrient values we thought about that how to do it with lower temperature conditions in shorter processing time. So, that my food will get a fresh look it should not cooked or over cooked.

So, that is the way this non thermal technologies are emerged with that motivation, and still be used to enhance the food safety so, that they are talking about. Even though i am employing lower temperature and shorter processing time. I will ensure the required log reduction in terms of microorganisms. And that way i will extend the shelf life of the food. And also the non-thermal technologies could inhibit the activity of enzymes in the food. Such as lipoxygenase and polyphenoloxidase and peroxidase and pectin esterase.

So, this are all enzymes which indirectly or directly favors the oxidization reaction for an example if you see here. So, it catalyze the oxidization of poly unsaturated fatty acids and lipids. So, these technologies will inhabit this kind of activities of the enzymes as well. So, this is also oxidize this polyphenoloxidase this peroxidase so this non thermal technologies here inhibit the oxidation of hydrogen peroxide. And, this is pectin esterase so all this enzymes activity also get inhibited when we use non thermal technologies.

So, we have understood the mechanism how it happens during thermal technologies. We told that most of the nutrient reduction or the log reduction of microorganisms follow the first order kinetics. So, the kinetics involves temperatures and time combination. But, here I am not using that higher temperature. So, that it means if it is not a function of temperature then by which mechanism my log reduction of organisms happens. So, that is by changing the cell membrane structure to remove the regulatory function of the microorganism.

So, for the regulatory function of the microorganisms the essential thing is the membrane structure. So, I will alter the membrane structures so that some of the regulatory function in the microorganisms get changed. So, that way microorganisms gets killed and another one is destroying the genetic materials. So, genetic materials here is DNA or RNA to caused metabolic disorders in the microorganism. This two are the principles behind the killing of microorganisms in non-thermal technologies.

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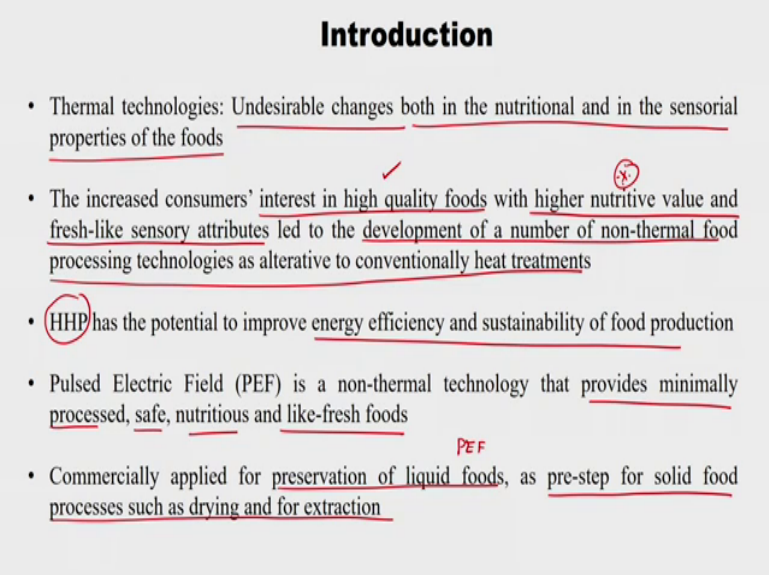

We have just seen the thermal technologies, the disadvantages undesirable changes both in the nutritional and in the sensorial properties of the food. Sometimes, if it gets over cooked I do not feel the taste as well. And, it is sometimes the textures is not pleasing to have that food. So, this two are main disadvantages when using the thermal technologies. The increased consumer interest in high quality food with higher nutrient and fresh like sensory attributes. You will get this in thermal technologies as well.

But, mainly it is done for high nutritive value and fresh like sensory attributes. Which led to the development of a number of non-thermal processing technologies alternative to conventional heat treatments. So, the first one we have already seen in outline which is nothing but a high hydro-static pressure. Which has the potential to improve the energy efficiency and sustainability of the food production. And, pulsed electric field technology which is also a non-thermal technology.

Which provides minimally processed safe nutritious and fresh like foods. And commercially applied for preservation of liquid foods. This P of mainly applied for liquid foods or as pre step for solid food processes such as drying or extraction. So, before going for this solid food processing technologies PEF is applied.

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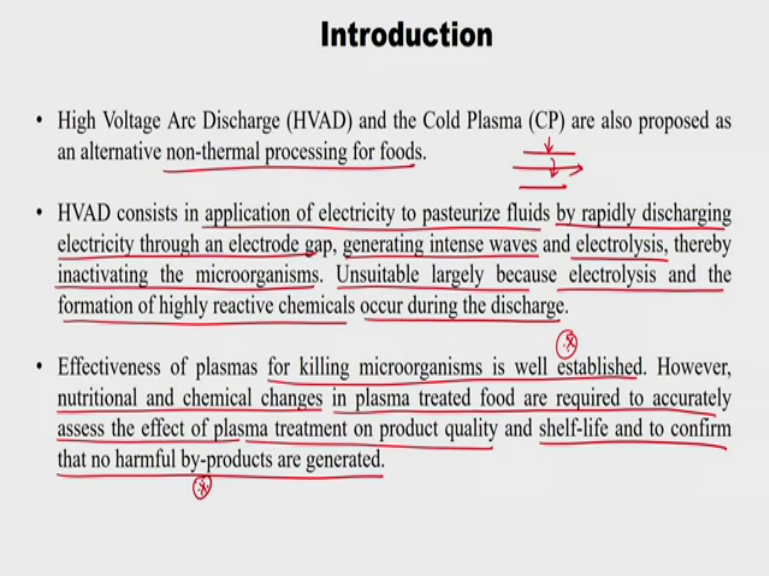

And, other one what we have seen in the outline is high voltage or discharge and cold plasma. So, this are also proposed as alternative to conventional thermal processing treatments. And, HVAD consists in application of electricity to pasteurize fluids by rapidly discharging electricity through electrode gap. So, you have two electrodes in between your fluid is flowing, so you apply the electricity by which the electrical charge is conducted to the fluid.

So, in that way it kills the microorganisms generating intense waves an electrolysis, electrolysis means the lithic of the components. So, that means you are breaking down the components their by inactivating the microorganisms unsuitable largely. Because, electrolysis and the formation of highly reactive chemicals occurs during the discharge. So, the mainly

the electrolysis happen in the microorganisms and they get killed, the same is applicable for food as well. For example how we compared in the thermal technologies though, I am applying a high temperature microorganism gets killed at the same time my nutrient quality also get affected.

The same way in if you are using HVAD that is nothing but an arc discharge it is not only killing the microorganisms it also promotes the electrolysis in the food products. So, that is nothing but a liquid food products when I am pasteurizing. So, what happens when electrolysis happens in the food there may be highly reactive chemical formation or sometimes the nutrients also forms a free radicals. So, that is unwanted thing in the HVAD process. Effectiveness of plasmas for killing the microorganisms is well established.

However, nutritional and chemical changes in plasma treated food are required to accurately access the effect of plasma treatment on product quality. Actually, in all five whatever we are going to discuss today in the class. We will have disadvantage because, the mechanism of the microorganism get killed is not clear cut. So, no one told this is what happened in that. There may be a theories different theories so it is proposed but, there is no confirmation.

So, this is the correct mechanism which is happening in that non thermal technologies for that the literatures were very limited. So, it is not well established that is what it is said, it is not that it is established it is not well established. And, also when such kind of the free radical formation we need to be extra careful. Because, the food is to be consumed so, we do not want any extra by product formation or any electrolysis happens during the food processing. And, shelf life and to confirm that no harmful by products are generated. So, this is what I taught so we need to ensure when we apply non thermal technologies.

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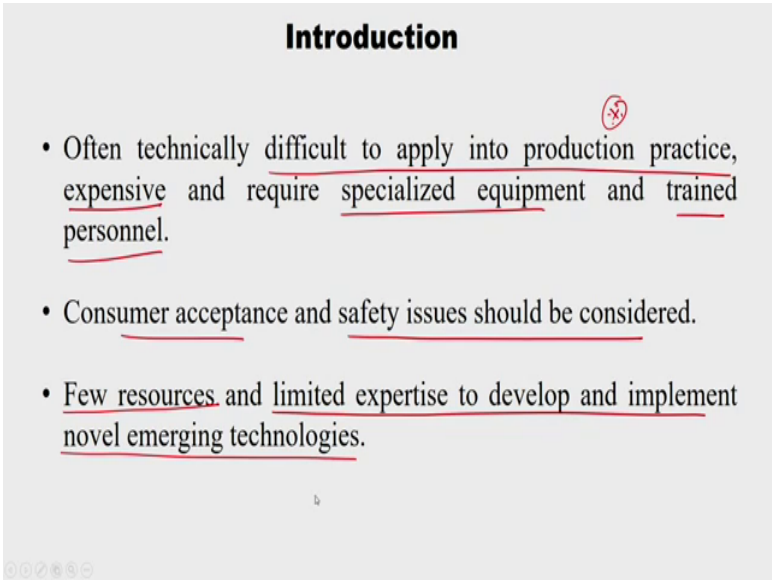

So, this is the main disadvantages often, technically difficult to apply into the production practice. Because, very few studies are their confirming their food safety. And, they are expensive because, the electric discharge or cold plasma are if, you see the high hydrostatic pressure everything is high pressure to maintain high pressure high temperature equipment and training the personal it is very much difficult. And, consumer acceptance and safety issues.

The movement you say, i am using the electricity for processing then we are also safe tic about. Whether any by product produce during the non-thermal processing or not so the consumer acceptance also one of the main criteria and few resources and limited expertise to develop and implement novel emerging technologies. This also stops the non-thermal technologies widely applied in the industry.

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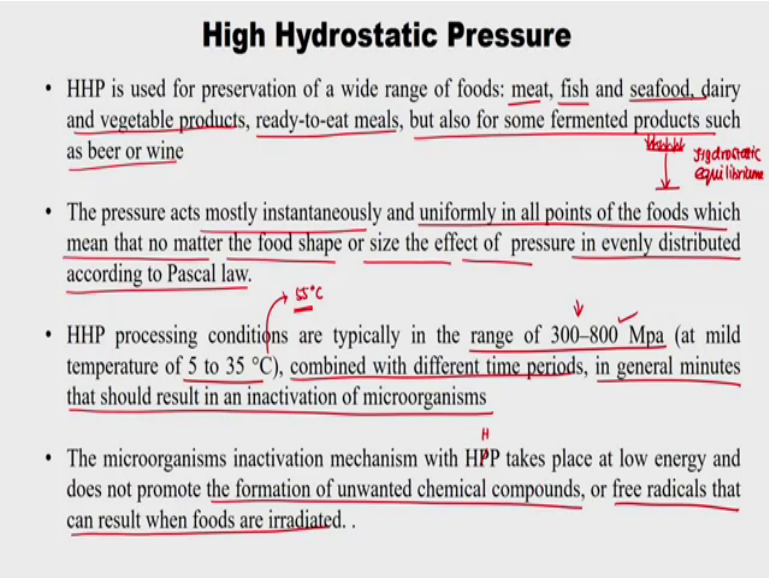

The first two technic is high hydro static pressure technic. So, this is applied for preservation of wide range of foods meat, fish, seafood, dairy and vegetable products, ready to eat meals. But, also for some fermented products such as beer or wine. So, all this technology is among non-thermal technologies this technology is well establish and some of the industry also adopted it. And, the pressure acts mostly instantaneously and uniformly in all points of the food.

Which mean that no matter the food shape or size effect the pressure and the pressure is evenly distributed according to Pascal law. So, what it means is so, if you see the pressure concept so the pressure increases with respect to depth. And, if see in at particular height the pressure is evenly distributed. So, that we call it as a hydrostatic equilibrium. At certain height the pressure is equally distributed, it does not matter which size which shape of the food is their so that is nothing but a Pascal law.

So, with this principle only high hydrostatic pressure technology works. So, the pressure range we apply here in the is 300 to 800 mega Pascal. The mild temperature range is 5 to 35 remember this is when we apply initially. So, due adiabatic heating because the chamber is close to chamber during processing it may rise up to 55 degree centigrade due to adiabatic heating. Adiabatic heating is without heat transfer to the environment the heat is builded up within the chamber. So, that is nothing but adiabatic heating.

So, due to which the temperature may increase up to 50 degree, combined with different time periods in general minutes that should result in an inactivation of microorganisms. So, that this pressure and temperature combination with certain period will take care of the inactivation of the microorganisms. The microorganisms inactivation mechanism with HHP takes place at low energy and does not promote the formation of unwanted chemical components, or free radicals that can result when food is irradiated.

If you see pulsed UV light or pulsed electric field. So, there is a irradiation of energy is involved. But, that is not here in the HHP process so, that means there is no formation of unwanted chemical components is there compare to other irradiation technologies.

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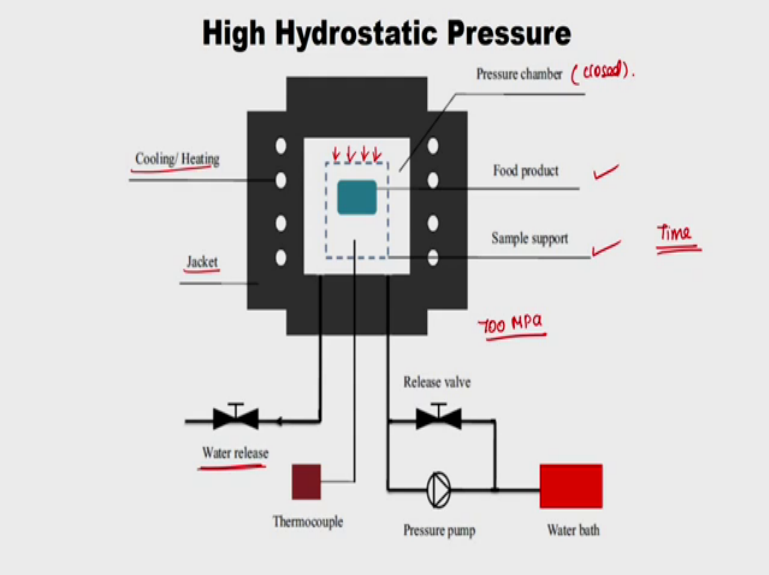

So, this is the basic diagram so what happens is this is your closed pressure chamber. So, here is your food material is there. So, this is a sample support so using the pressure pump the water is pressurized inside the chamber. So, ones the required level of pressure for example so, if you are doing it with some 700 MPA. So, ones the 700 MPA pressure is reached so, this is the pump is stop. So, then we already told it this is the certain time period. It is kept so, that means the 700 pressure is applied equally on the food material.

So, that is nothing but, due to Pascal law which is nothing but, a hydro static equilibrium. Then ones this time period after keeping it in this particular time period. So, using the water release wall this is decompressed. Decompressed in the sense depressurized the chamber is depressurized. And this is a heating and cooling medium this is a jacket around the chamber. So, that is the way this hydrostatic pressure works.

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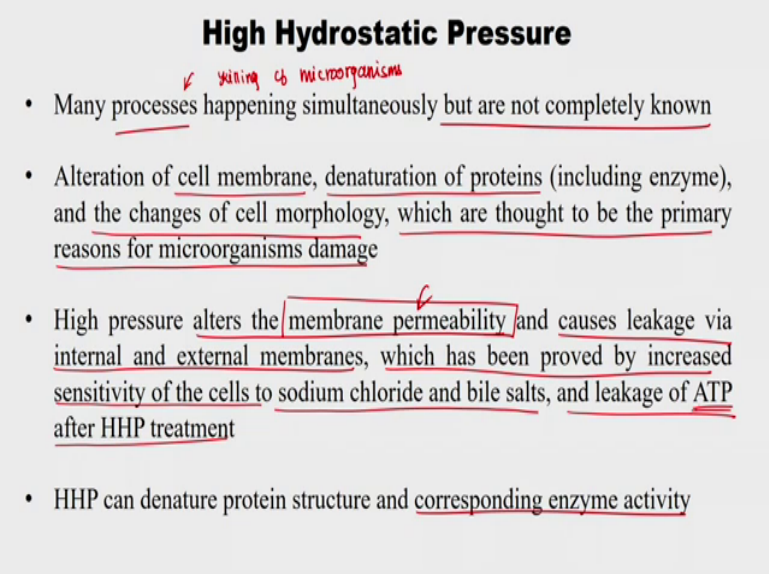

So, many process happening simultaneously but or not completely known. What is this process this process they tell in term of killing of microorganisms. So, as I told there is no clear cut definition by which this mechanism only my killing of microorganism happens there is no well established theory for that. So, it happens due to alteration of cell membrane. Denaturation of proteins which includes enzymes as well and the changes cell morphology. Which are thought to be a primary reasons for microorganisms damage.

And, it is not like one particular principle. High pressure alters the membrane permeability and causes leakage via internal and external membranes, which has been proved by increased sensitivity of the cells to sodium chloride and bile salts, and leakage of ATP after HHP treatment. So, after the HHP treatment the products were analyzed and it was well understood that the components which has to be inside the cell membrane where out of the cell membrane.

And the products whatever there in the outside of the cell membrane were also went inside. So, that means the membrane permeability got changed. So, the membrane permeability normally what happens it permeates certain components not certain components. So, when this got changed we do not know we are not sure what are all the inside components came out of the membrane. And, what are all outside components went into the membranes. And, also it was proved that the cells are sensitive to any cells also.

That means so, there may be some compositional changes and also the ATP Adenosine Tri-Phosphate. So, that was found in the sample after HHP treatment. So, that means the leakage happened through the cell membrane. HHP can denature protein structure and corresponding enzyme activity. So, these were the theory proposed after HHP treatment by which the microorganisms get damaged.

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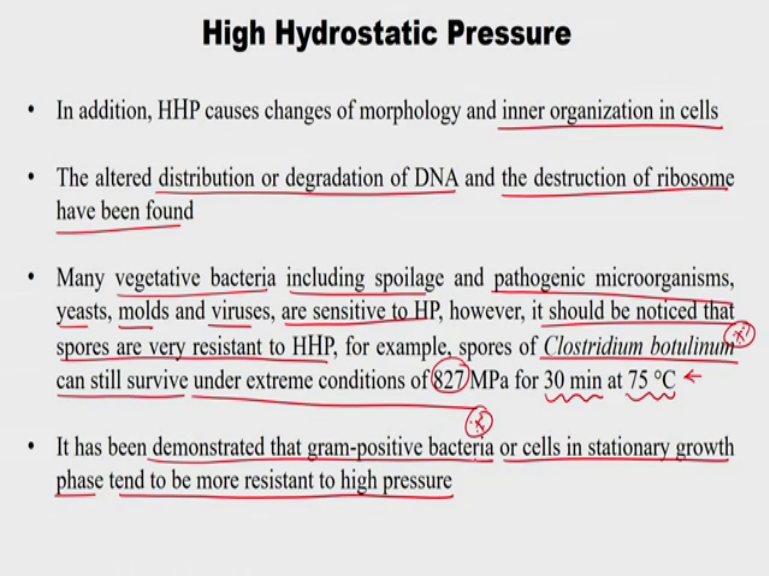

In addition, HHP causes changes of morphology and inner organization in cells. That we have seen and the altered the distribution at degradation of DNA and the destruction of ribosome have been found after the HHP treatment. And, many vegetative bacteria including spoilage and pathogenic microorganisms, yeasts, molds and viruses, are sensitive to HHP. And however, it should be noticed that the spores are very resistive to HHP even in the thermal technology we have seen.

So, most of the thermal technologies were able to handle the vegetative forms of the spoilage as well as pathogenic organisms. But, very few thermal technologies only able to kill the spores form of the microorganisms. The same thing is applied for HHP as well. So it is told that so many vegetative bacteria.

Which includes spoilage as well as pathogenic and yeast mole viruses get killed but, it is noted that the spores of clostridium botulinum can still survive. This is just we discuss in many classes. under extreme conditions of 827 mega Pascal for above 30 minute at 75 degree. Even applying this high pressure and high temperature for about 30 minute Which is also nothing but a high time the spores of clostridium botulinum did not get killed.

It has been demonstrated that the gram positive bacteria or cells in stationary growth phase tend to be more resistance to high pressure. So, this is gram positive bacteria if your food is prompt to gram positive bacteria or cells then this technology may not work better.

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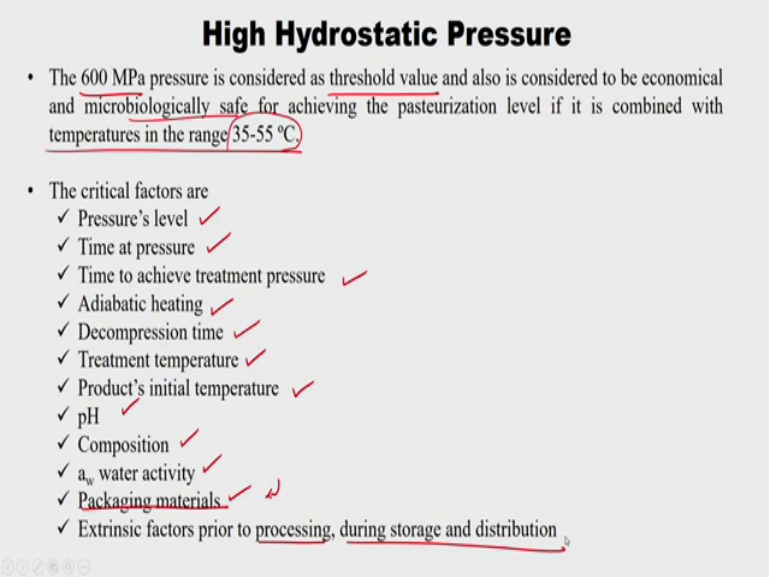

600 mega Pascal pressure is the threshold value and also is considered to be economical and microbiologically safe for achieving the pasteurization level. If it is combined with temperatures in the range of 35 to 55 degree. So, 35 to 55 degree and 600 mega Pascal pressure is enough to pasteurize the food which are micro biologically safe. The critical factors are pressure level, time at pressure, time to achieve treatment pressure, adiabatic heating is i have told and decompression time.

So, after the process finished how much time I am taking for decompression and treatment temperature, products initial temperature, pH, water activity, and composition of the product packaging materials this is very much important criteria. Because, when you are applying the high pressure then you need to take the pouch materials or pouched packed materials. And, it should withstand that high pressure the packaging materials should be stand the high pressure processing. And, extrinsic fact is prior to processing, and during storage and distribution.

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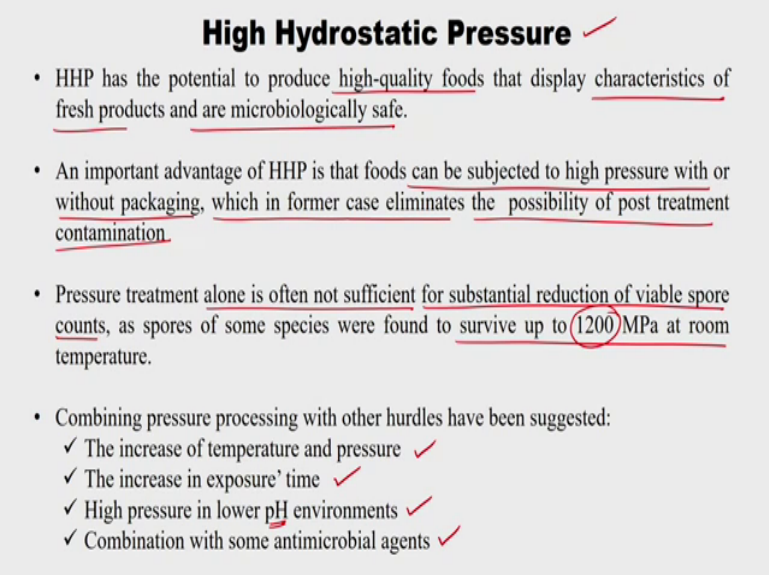

HHP has the potential to produce, high quality foods and display characteristics of fresh products and are microbiologically safe. Important advantage is nothing but, it is subjected to high pressure with or without packaging. So, both way we use but which in former case eliminates the possibility of post treatment contamination. So, whatever the thermal non thermal technologies we say we failed it thermal technologies where based in terms of microbial damage because, the mechanism is well understood.

But, here what they wanted to tell is when you are subjecting a high pressure it may be done with or without packaging but if you do it with packaging. The post treatment contamination we can better avoid when pressure treatment alone is often not sufficient for substantial reduction of viable spore counts this we have seen, So as some spores of some species see but, were found to survive up to 1200 mega Pascal at room temperature. So, in that case the some of the species spores can survive up to 1200 mega Pascal at room temperature.

So, this only HHP may not be micro biologically safe. So, in that case we also combine temperature as well as the pressure process so, combining pressure processing other hurdle have been suggested in that case, in case of temperature as well as pressure both and increasing exposure time. But, also we have seen in the previous slide even if you apply 827 mega Pascal 30 min at 75 still spores of clostridium botulinum survive.

So, that were it is told either increase both pressure and temperature are increase exposure time are high pressure in low pH environment so this we have seen. So, pH environment are micro biologically same combination with some antimicrobial agents. So, that also it may be tried along with high pressure processing along with high pressure you increase temperature as well or go for increment in exposure pressure or lower the pH or add some outside antimicrobial agents.

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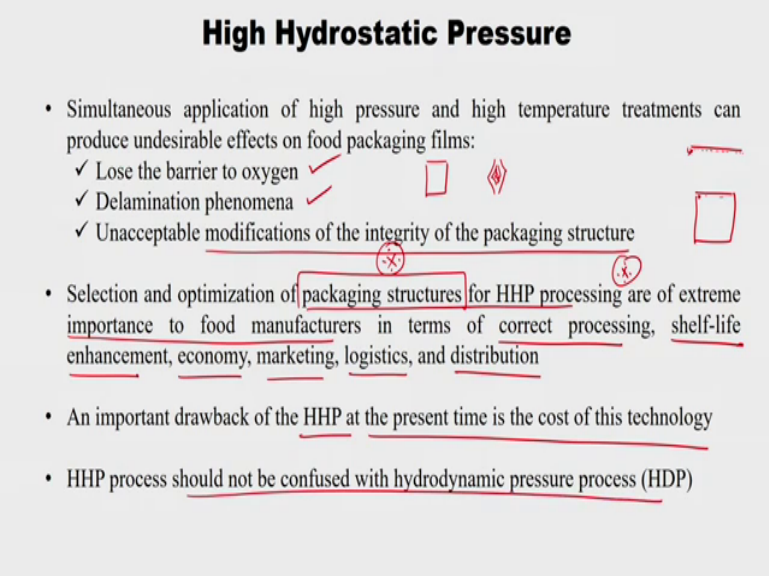

Simultaneous application of high pressure and high temperature treatments can produce undesirable effects. So we told the solution here the increase of temperature and pressure. But, what is the disadvantage again lose the barrier to oxygen. And delamination phenomena in the sense so, you have a packaging material so, when you apply high pressure and high temperature there may be a farming layer. For example, if the some crack will be the so, you will the different layers of that.

So, that is nothing but a delamination and unacceptable modifications in the integrity of packaging structure that also happens. And, selection and optimization of packaging structures for HHP processing are of extreme importance. I have just mentioned that in terms of correct processing, shelf life, enhancement, economy, marketing, logistics and distribution. So, for this one thing I would like to take example from that there was some case study in some of food industry.

When there were storing after the particular thermal processing they formed this contamination. So, in the contamination they supposed to throw that particular batch but still.

When they were inspecting what was the reason for contamination. So, they found that in the pouch when there were sealing it there is some one particular hole, due to sealing mission rearrangement. So, for example while sealing the packet there were another line another extra line happened. Due to which there is some damaged happen during the sealing.

So, through which the contamination happened so, that is what here it is mentioned. So it is the packaging structure of is of very much essential when you apply HHP because, even in the sterilization. We have told that when you switch over from heating to cooling if, there are pouches there will be a pressure in balance in inside the pouch material and outside the pouched material. So, to common site we used compressed air over to give the cushion effect.

So, here also we are applying a high pressure. So, we need to be extra careful about the packing structure. And, important draw back of the HHP at present time is the cost of this technology due to high pressure processing. We need to take care of all the control when, we apply the high pressure. This process should not be confused with hydrodynamic pressure process.

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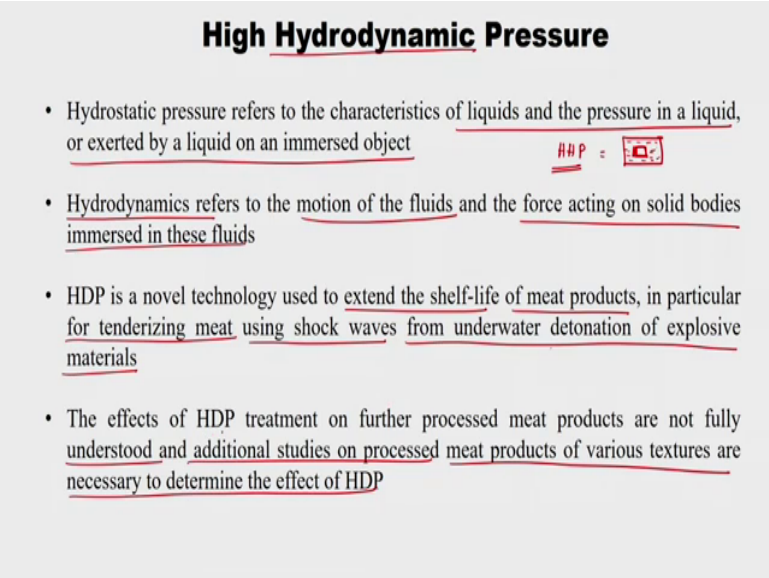

So, this is another process so actually high hydrostatic refers to the liquids and the pressure in a liquid or exerted by a liquid in immersed object. So, that means this HHP technology will be used for static mode in the sense if you see. So, you have a food particle here around which water is there at high pressure or this comes under the submerged object under liquid. So, either it will applied to pure liquid if the food is liquid products then the pressure is applied on the liquid or, if it is a solid product so you are using the submerged object in within the liquid.

So, based on this two mechanism HHP works. But, hydrodynamics refers to the flow of fluid and the force acting on solid bodies immersed in these fluids. So, when the fluid is in motion it is called as high hydrodynamics pressure technology. HDP is normal technology used to extend the shelf life of meat products in particular for tenderizing meat using shock waves from the underwater detonation of explosive material. So, this detonation of explosive material when it is under water it creates a shock waves.

So, this pressure of shock waves is use to process the meat products in HDP technology. The effects of HDP treatment on further process meat product or not fully understood. Additional studies on processed meat products of various textures are necessary to determine the effect of HDP. So, this mechanism is not well established so, HDP treatment is at its initial stage.

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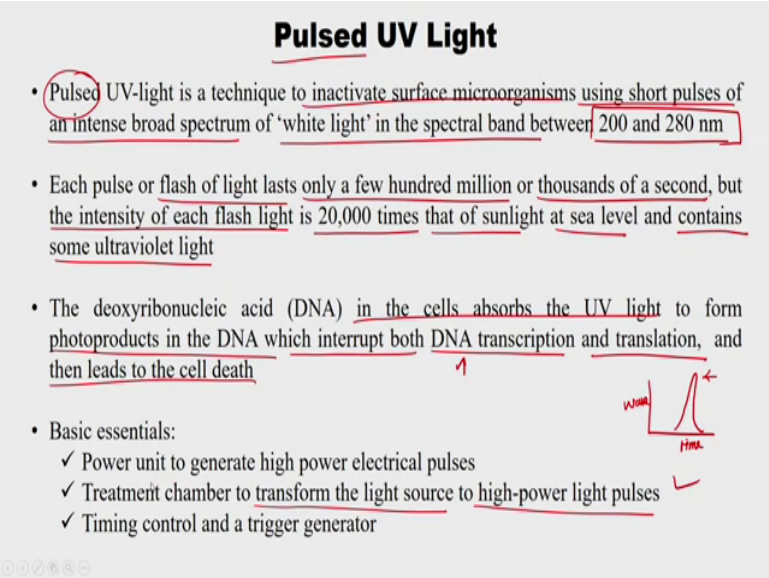

The second one is pulsed UV light so here what we are going to use is in the white light of spectral band 200 to 280 nanometer. So, this range of spectral band from the white light we use as a UV light to inactivate the surface microorganisms using short pulses and of an intense broad spectrum. So, short pulses in the sense. For example so you have a wave so this is time so, how my pulses go with respect to time so, at particular time how much intensity of pulses is being applied on the particular food product.

So that is what it is called as pulsed, pulses with respect to time. Each pulse are flash of light lasts only a few hundred million or thousands of a second. But the intensity of each flash light is 20000 times that of sunlight at sea level which contain some ultraviolet light as well. So, it is applied on specific time. But, the intensity of this UV light is 20000 times what we seen in sunlight at normal sea level. The deoxyribonucleic acid which is nothing but a DNA in the cells observes this UV light to form photoproducts in DNA

Which interrupts the both DNA transcription and translation and then leads to the cell death. This is not very common in the DNA transcription and translation in the normal microorganism regulatory function. But, the movement the microorganism sees the UV light it starts absorbing for its photo product synthesis. So, that way this transcription as well as translation of DNA gets changed so, that is where the cell death happens. So, what are all needed so, by name itself you have might have understood.

I need one pulse generator treatment pulse generator which is nothing but a timing control and trigger generator. Pulse generator you need so to power this you need a power unit of high pressure electrical pulses and also the treatment chamber to transform the light sources to high power light pulses. So the treatment chamber as well as the pulse generator and the power unit to power all the units and timing control and trigger generator.

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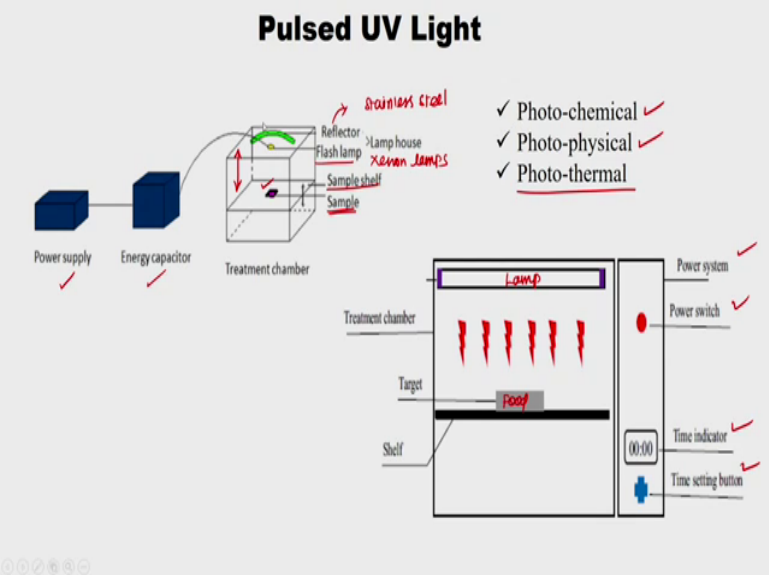

So, this is basic diagram so here you have a power supply. So, it is given to energy capacitor unit. So this is given to flash lamp mostly xenon lamps. You have a reflector over here it is a stainless steel most of the time. So, what it function is to trap the UV light inside the chamber inside the treatment chamber. Here, is your sample and this the sample shelf so which has the vertical regulatory mechanism. So, that this distance between the pulses created from the source and the food particle is very much important.

So, this vertical regulatory mechanism helps in that. For example if I have to maintain 5 centimeter where the sample shelf should be or, if I have to maintain 2 centimeter there the size of the sample should be. So, by that we can also regulate he intensity of the pulse. And this is another way of treating the food using UV light. So, this is lamps so from which your UV light is coming up so this is the shelf, this is the target food product or food sample.

You have a time indicator here and time setting button and power switch and power system. What happens is photo chemical, photo physical, photo thermal. Photo thermal in the sense you normally you know when you have lamp it is on for certain time. So, if you touch it, it will be hot. So that is nothing but photo thermal effect due to this UV pulses. The food also get heated to certain extend and photo chemical.

We just have discussed the DNA absorbs the UV light and it synthesis the photo product. And, photo physical is sometimes when the UV light is observed by the DNA there may be a changes in the cell membrane activities. Cell rupture also can at a so that is nothing but photo physical mechanism.

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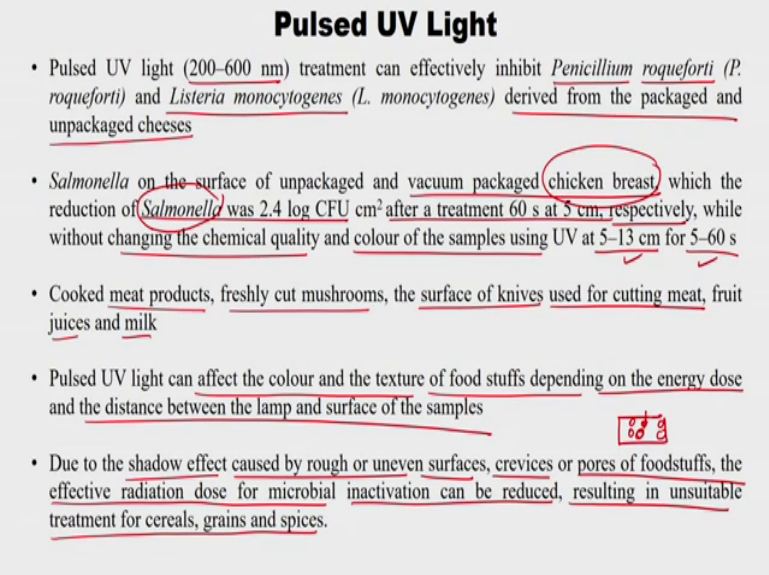

Pulsed UV light which has 200 to 600 nanometer treatment, can effectively inhibit the penicillium roqueforti and listeria monocytogenes derived from packaged and unpackaged cheeses. This are all examples, so how this technology is being employed and it is also employed in vacuum packaged chicken breast. Which is the reduction of salmonella was 2.5 logs CFU per centimeter square after the treatment of 60 seconds at 5 centimeter respectively.

And while without changing the chemical quality and color of the sample using UV at 5 to 13 centimeter for about 5 to 60 seconds. This are all example what are all the microorganisms and what are all the food products or process used in pulsed UV light. So this are all just example of how much is the distance 5 to 30 centimeter distance between the pulse and your food sample. So, this is the time limit.

And cooked meat product, freshly cut mushrooms, the surface of the knives which used for cutting the meat were also processed using pulsed UV light. Juices and milk also comes under that category. So, this light can affect the color and texture of the food stuff depending on the energy dosage and the distance, between the lamp and surface of the sample. So, if you increase the distance there may be a good killing of microorganism. But, that also affects the surface texture of the food.

Due to shadow affect caused by the rough and uneven surfaces, the crevices or the pores of foodstuffs, the effective radiation dosage for microbial inactivation can be reduced, resulting in unsuitable treatment for cereals, grains and spices. So, what does it mean so if i have a food particle so it has the pores kind of thing so inside the pores your UV light may not have got inside the pores. So, that the contamination what is there in the pores it is last long so, it cannot be treated using pulsed UV light. So, when you have such a foodstuff with the pores or crevices it is better to avoid this technology.

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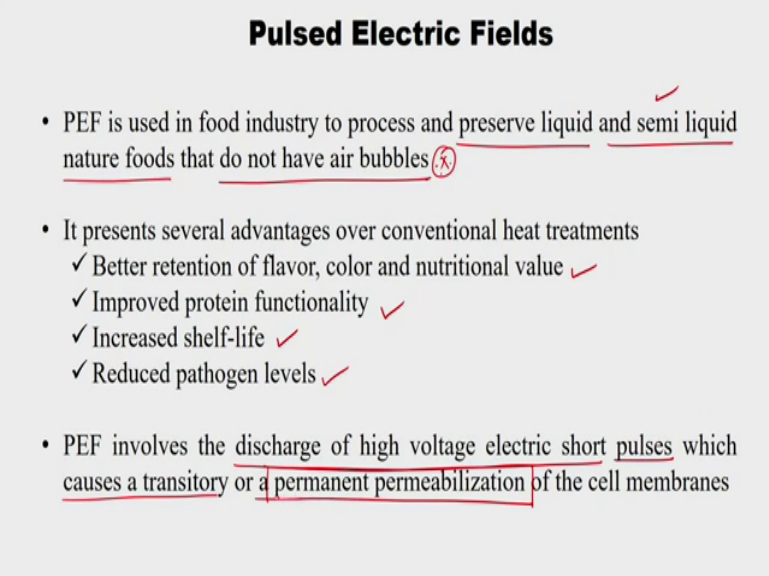

Pulsed electric field, it is same as that of the UV light so, there you used a lamp to create a pulsed UV light. Here, you use the electricity to create a pulsed electric field. And, which preserve the liquid and semi liquid nature foods to increase their shelf life. And, also the important thing is so you can process liquids semi liquids food. But, it should not contain any air bubbles. Because, otherwise it will go for gas ionization processes as well. It presents several advantages over conventional heat treatments.

One is the better retention of flavor, color and nutritional value, improved protein functionality, increased the shelf life and reduces the pathogen levels. Which involves the discharge of high voltage electric short pulses there it is UV light here it is a high voltage electric short pulses. Which causes the transitory for permanent permeabilization of the cell membrane. So, the mechanism here is use to damage the microorganism is permanent permeabilization.

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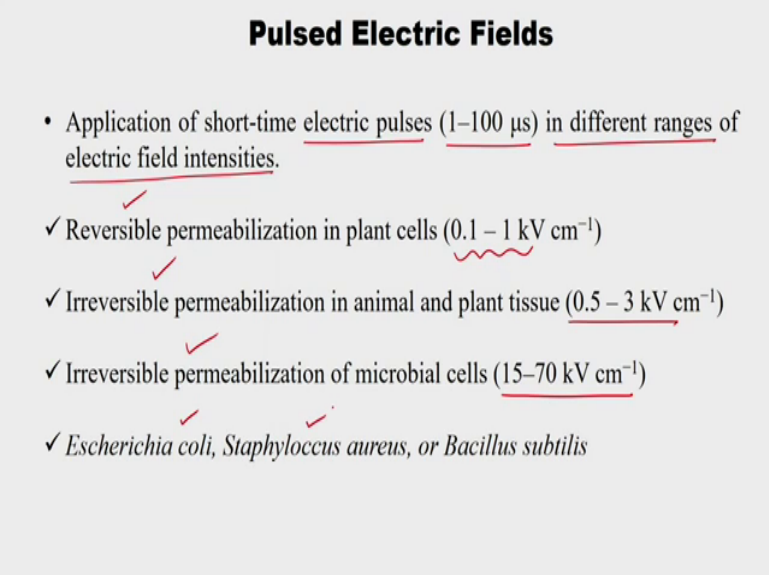

So, short time electric pulses 1 to 100 micro seconds in different range of electric field density. For example 0.1 to 1 KV per centimeter which is for reversible permeabilization in plant cells, 0.5 to 3 kilo volt per centimeter is used for irreversible permeabilization, 15 to 70 kilo volt per centimeter is use for irreversible permeabilization of microbial cells. The organs treated here is Escherichia coli, Staphyloccus aureus, or Bacillus subtilis.

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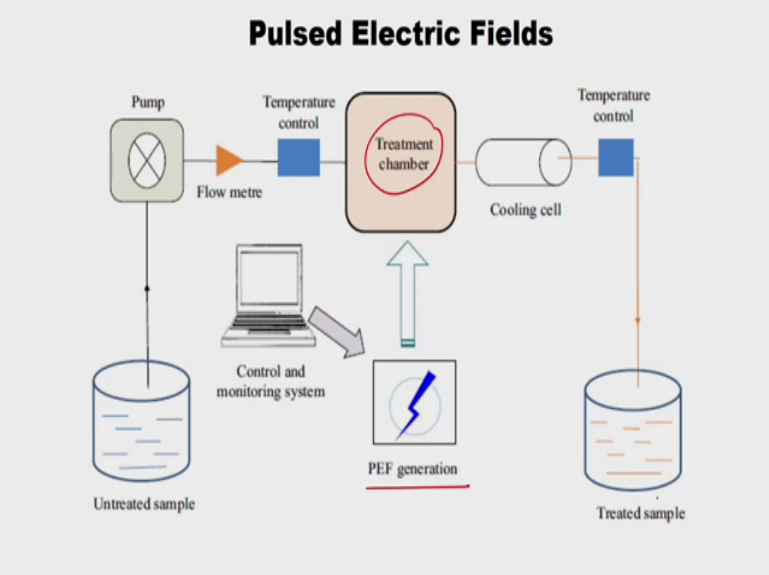

So, this is the basic diagram so, here you have a treatment chamber so, you have a PEF generation here. So, generated PEF goes to the treatment chamber. You untreated liquid food sample so, which is pumped through pumps. And, here it is the flow meter which measures the flow rate and it goes to temperature control which measure the temperature. And, it is fad ant to the treatment chamber. This PEF generation taken care by the control and monitoring system and after that it is getting cooled and after measuring the temperature it is collected in the treated sample tank.

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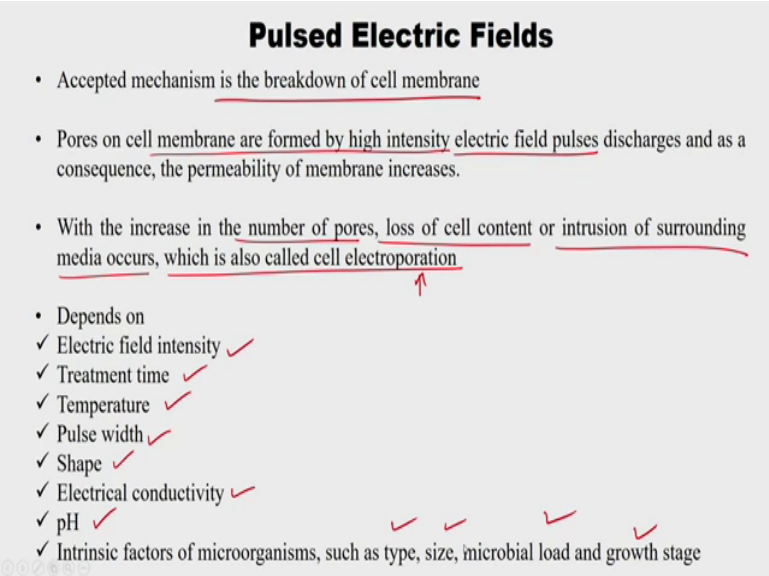

Accepted mechanism is breakdown of cell membrane we have already told permeabilization. The pores on cell membrane are formed by high intensity electricity field pulses. So, what happens in UV the microorganism observes the UV light by which the photo products were formed in the DNA molecules. But, that is not a normal regulatory function of DNA. So, due to which translation transcription mechanism of DNA gets changed for that particular microorganism that is the way it gets killed.

But, here what happens is here the cell membrane observes this high intensity electric field. So, that way the pores are generated in the membrane so which causes for the permeable nature of outside components to inside the cell and components inside the cells comes out of the cell membrane. With the increase in the number of pores loss of cell content intrusion of surrounding media occurs, which is also called as cell electroporation.

So, a pores creation of pores using electric field that is nothing but a cell electroporation. Which depends upon electric field intensity, treatment time, temperature, pulse width, shape, electrical conductivity, PH, and intrinsic factors of microorganisms. Such as type size, and microbial load and growth stage everything is a important factor when you apply PEF technology.

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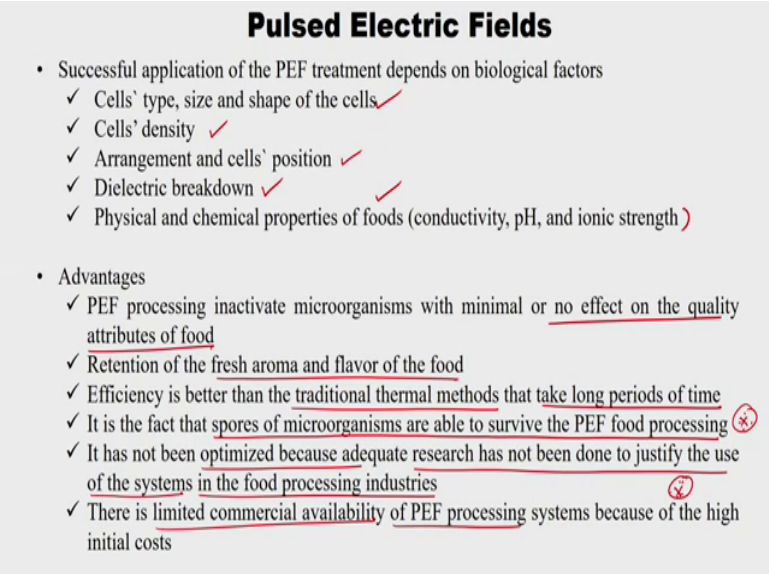

And successful application of the PEF treatment depends on biological factors cells types, size shape and cell density, arrangement and cells position, dielectric breakdown. Dielectric breakdown is nothing but how the component gets broken when application of electric field is happening. And physical chemical property changes of the food conductivity pH and ionic strength. Advantage is PEF processing inactivate microorganisms with minimal or no effect on the quality attributes of the food.

Retention of the fresh aroma and flavor of the food. Efficiency is better than traditional thermal methods that take long periods of time. It is the fact that pores of microorganisms are able to survive PEF food processing spores till now we have discussed three technologies pulsed UV, pulsed electric field and HHP. None of them could take care of spores it has not been optimize because, adequate research has not been done to justify the use of this systems in the food processing industries.

It is not that no industries using there are industries using this non thermal technologies. Since, the kinetic mechanism of the killing of microorganism is not well established for this non thermal technologies it will be very difficult to employ in the higher scaled process in the industries. There is limited commercial availability of PEF processing systems because of the high initial cost. Cost is also another common disadvantage in all the non-thermal technologies.

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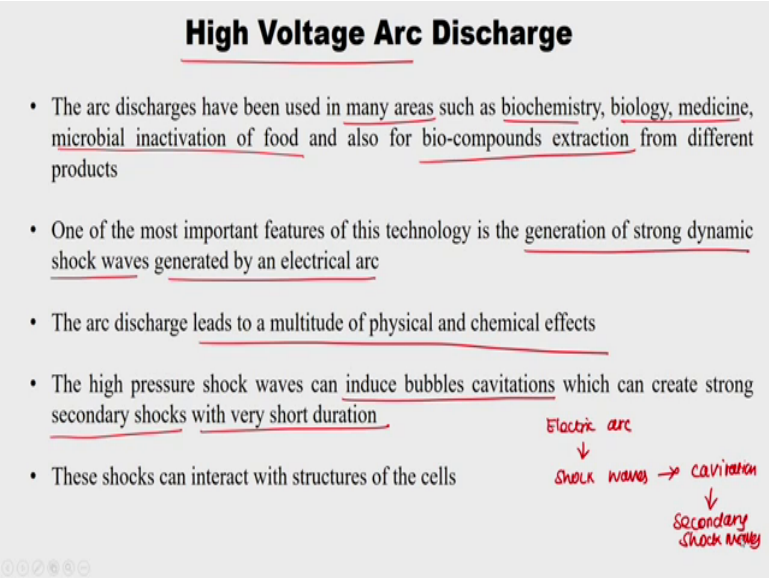

The next one is high volt or discharge so, this is used in many areas such as biochemistry, biology, medicine and microbial inactivation of food. Already and it is also used in bio compounds extraction from different products. Main feature is that this generation of strong dynamic shock waves generated by the electric arc. It creates the electric arc which further creates the shock waves those shock waves act on the food particle and it kills the microorganisms.

The arc discharged leads to a multitude of physical and chemical effects. The high pressure shock waves can induce bubbles cavitations which can create strong secondary shocks with very short duration. These shocks can interact with structures of the cells. So what we told electric arc which further creates the shock waves high pressure shock waves. So, this high pressure shock waves leads to cavitation. Cavitation is the process when the local pressure is reduced.

There may be a formation of bubbles this bubbles coiled with each other and forms the cavitation. So, this cavitation further produce the secondary shock waves so this secondary shock waves are reason for the killing of the microorganisms. So, that is the main principle behind the HVAD process.

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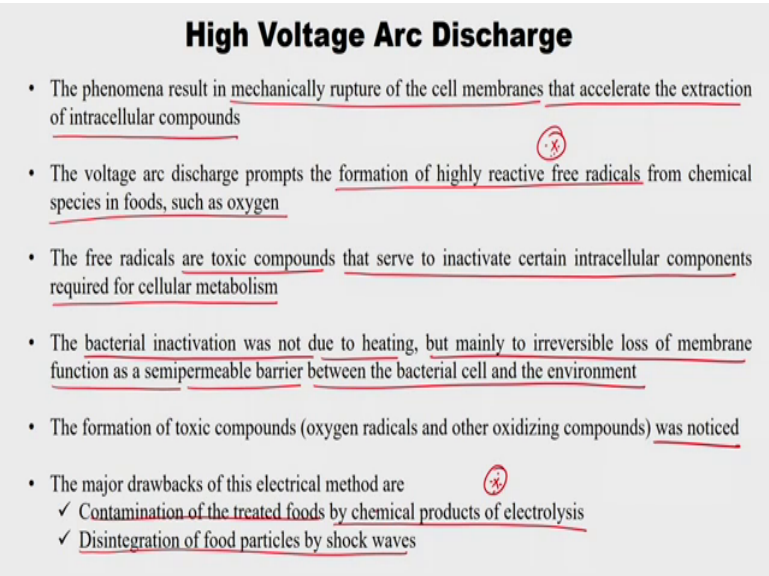

The phenomena result is mechanically rupture of the cell membrane that accelerate the extraction of intracellular compounds. So, intracellular components comes out of the cell membrane. And, the voltage are discharge prompts the formation of highly reactive free radicals. So, this is important from chemical species in food, such as oxygen. It forms the highly reactive radicals so this free radicals are toxic components that serve to inactivate certain intracellular components required for cellular metabolisms.

So, this free radicals are toxic components that serve to inactivate certain intra cellular components. See this is to way around, one is it forms free radicals in the cell structure of the microorganisms and at the same time its also creates, such free radicals it may also create such free radicals in the food particles as well. So in the microorganisms it said it is the advantage for us because, this free radicals changes cell function and regulatory function. So, that way microorganisms gets killed.

But, in the food side it is the unwanted one if creates any reactive free radicals. The bacterial inactivation was not due to heating, but mainly due to irreversible loss of membrane function as a semipermeable barrier between the bacterial cell and the environment. The formation of toxic components which is nothing but a oxygen radicals and other oxidizing components was noticed. The measure drawback is contamination of the treated foods by chemical products of electrolysis this i told.

So, if it is done on the microorganisms side it is advantages for us because that is the way microorganisms gets killed, but it also does the same thing in the food particle side as well. The disintegration of food particles by shock waves is another disadvantage in HVAD process.

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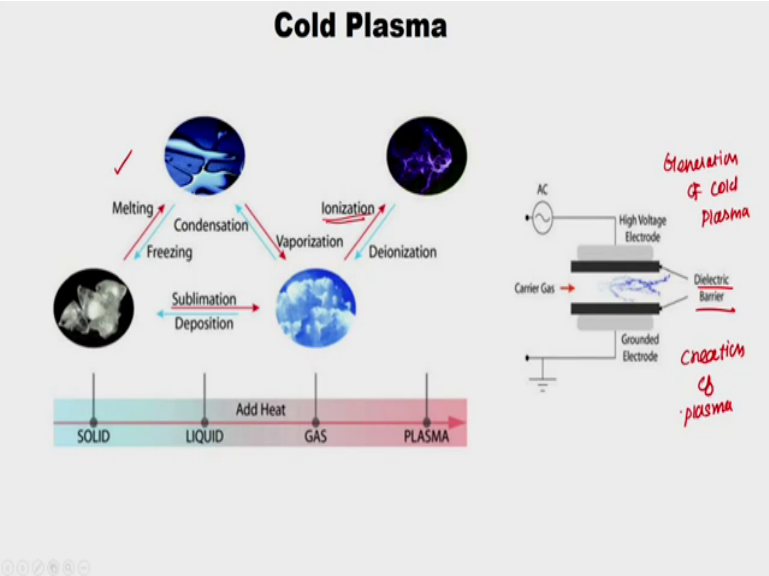

The next one is cold plasma technic the cold plasma this you might be knowing. How to change solid to liquid, liquid to gas. So, the cold plasma comes here so what happens is when the gas is heated it gets ionized. So, that is the way plasma is created when it is deionized it comes back to original gasses form. So, this is the generation of cold plasma so there is a AC power unit through which the high power is given to the electrodes.

So, between this electrodes your carrier gas is flowing so that is the way gas is getting ionized. The energy is given by the high voltage AC source to the electrodes so from their gas ionization happens between the by electric barriers. So, this is the way the creation of cold plasma the creation of plasma generation happens. So, this set up is given to the treatment chamber.

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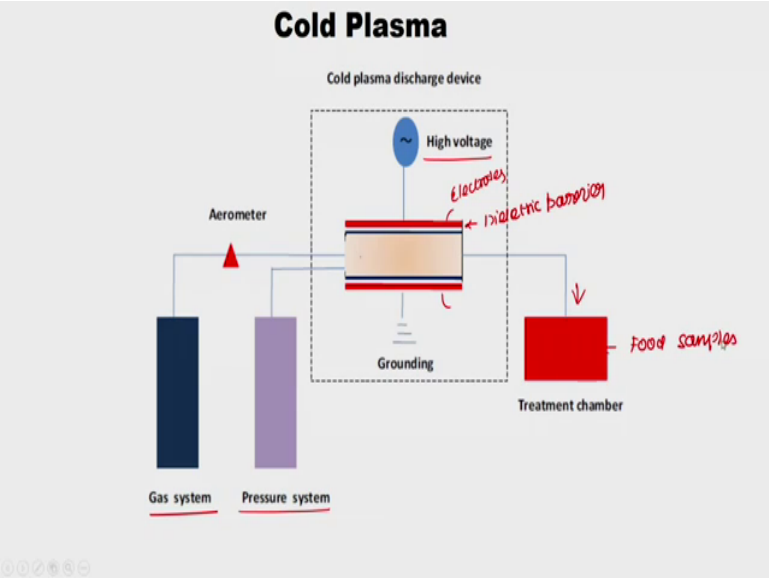

So that probably here we are seeing. So, this is the gas system through which gas is coming here so this is the pressure to maintain the pressure level. So, this is your high voltage ac current. So, this two are electrodes so this is dielectric barrier. So through which when the gas is flowing in between. Then it creates the ionization which is nothing but a plasma. So, this is fad ant to the treatment chamber where your food samples are kept.

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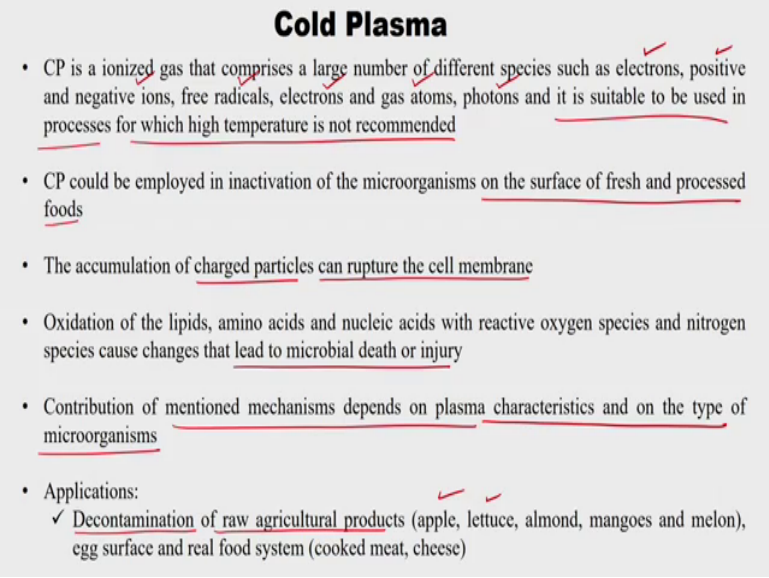

The CP is an ionized gas cold plasma which comprises of large number of different species. There may be electron positive and negative ions, free radicals, electrons gas atoms, photons all are generated during the plasma generation. And, it is suitable to be used for the process for which high temperature is not recommended. CP could be employed in inactivation of the microorganisms on the surface of fresh and processed food. And, the accumulation of charged particles can rupture the cell membrane.

And, the oxidation of the lipids, amino acids and nucleic acids with reactive oxygen species and nitrogen species cause changes that lead to microbial death or injury. The same way that what we have seen in the HVAD. So, here also oxidation of lipids amino acids nucleic acids happens so that way it alters the cell regulatory function and that is the way microbial death happens. The contribution of mentioned mechanism depends upon the plasma characteristics and the type of the microorganisms used.

So we have seen one example clastodium botulinum even if you apply 827 mega Pascal at 75 degree the spores will not get killed, but the optimally microbial safe pressure for HHP is 600 mega Pascal itself. So, even if you apply high pressure certain organisms will not get killed the same is applicable for cold plasma as well it depend upon the type of organisms. The application is decontamination of raw agricultural product of apple lettuce, almond, and mangoes melon and egg surface and real food system which is nothing but a cooked meat cheese etc.

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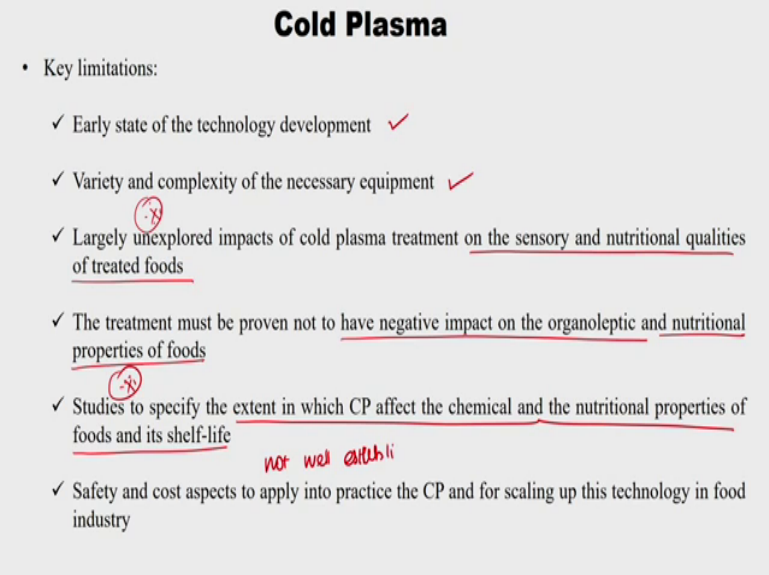

Key limitation early state of technology and development. Variety and complexity of the necessary equipment. And, largely explored impacts of cold plasma treatment on the sensory nutritional qualities of treated food it is unexplored largely unexplored. The treatment must be proven not to have negative impact on the organoleptic and nutritional properties of the food it should be proven. So, why it is we have already told since it creates all organoleptic changes in the cell functions.

But, also it is also responsible to create such a organoleptic changes in the food as well, but that is unwanted for us. Because, we supposed to maintain the nutritional level of the food. So, that is the way this cold plasma is disadvantages and studies to specify the extend in which CP affect the chemical and the nutritional properties of food and shelf life. So, that is very much needed. And safety and cost aspects to apply into practice the CP and scaling up this technology in food industry is not well that established. So, this we have seen already.

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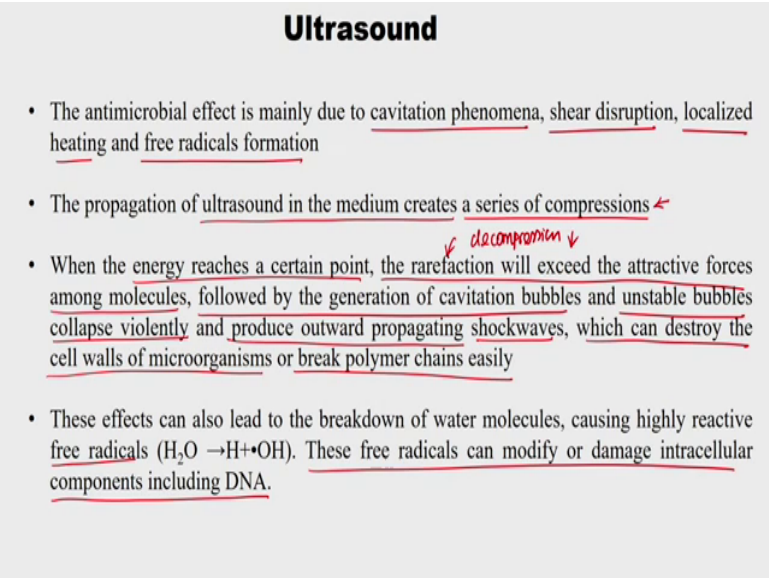

Another is ultrasound, ultrasound is nothing but whatever we could here. So, beyond that level that is nothing but an ultrasound technology. So, this is happens due to cavitation phenomena I have already explained you shear disruption, localized heating and free radicals formation, so this is the way the microorganisms gets killed. The propagation of ultrasound in the medium creates a series of compressions and through which due to compression the damage of microorganisms happens equivalent to HHP.

When the energy reaches the certain point the rarefaction will exceed the attractive forces among the molecules rarefaction is nothing but decompression followed by the generation of cavitation bubbles. I have told when the pressure is reduced locally reduced the formation of bubbles happens so that is the way then the coiled and that is the way cavitation forms. Unstable bubbles collapse violently and produce outward propagating shockwaves. Which can destroy the cell walls of microorganisms or break polymer chains easily.

The effects can also let to the breakdown of water molecules causing highly reactive free radicals it may be generated in the oxygen species as well and water molecules as well. So, which is nothing but H2O will become H and OH. There is a free electron so free radicals these free radicals can modify or damage the intracellular components including DNA. So this happens at the microorganisms side as well and food side as well. So, this kind of free radicals may be happening at the food side as well but that is unwanted.

So, at that particular ultra sound level at that particular time. It should only form a free radicals in the cell functions of the microorganism but not on the food that is the optimization level we need to be extra careful.

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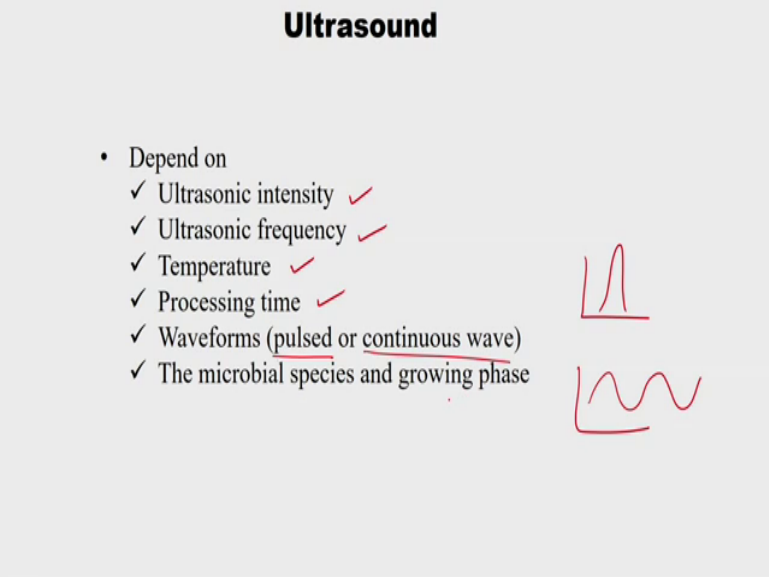

It depends upon the ultrasonic intensity, frequency, temperature, processing time, and which wave we use pulse or continuous wave from pulse I have explained you this is the one of the example continuous means so kind of sign view, and the microbial species and growing phase this is also important.

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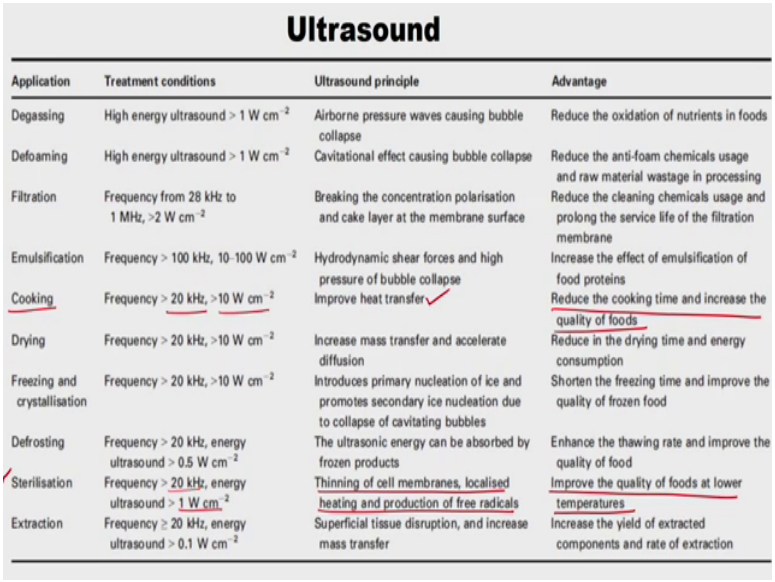

Ultrasound

Application	Treatment conditions	Ultrasound principle	Advantage
Degassing	High energy ultrasound > 1 W cm^{-2}	Airborne pressure waves causing bubble collapse	Reduce the oxidation of nutrients in foods
Defoaming	High energy ultrasound > 1 W cm^{-2}	Cavitational effect causing bubble collapse	Reduce the anti-foam chemicals usage and raw material wastage in processing
Filtration	Frequency from 28 kHz to 1 MHz, >2 W cm^{-2}	Breaking the concentration polarisation and cake layer at the membrane surface	Reduce the cleaning chemicals usage and prolong the service life of the filtration membrane
Emulsification	Frequency > 100 kHz, 10-100 W cm^{-2}	Hydrodynamic shear forces and high pressure of bubble collapse	Increase the effect of emulsification of food proteins
Cooking	Frequency > 20 kHz, >10 W cm^{-2}	Improve heat transfer	Reduce the cooking time and increase the quality of foods
Drying	Frequency > 20 kHz, >10 W cm^{-2}	Increase mass transfer and accelerate diffusion	Reduce in the drying time and energy consumption
Freezing and crystallisation	Frequency > 20 kHz, >10 W cm^{-2}	Introduces primary nucleation of ice and promotes secondary ice nucleation due to collapse of cavitating bubbles	Shorten the freezing time and improve the quality of frozen food
Defrosting	Frequency > 20 kHz, energy ultrasound > 0.5 W cm^{-2}	The ultrasonic energy can be absorbed by frozen products	Enhance the thawing rate and improve the quality of food
Sterilisation	Frequency > 20 kHz, energy ultrasound > 1 W cm^{-2}	Thinning of cell membranes, localised heating and production of free radicals	Improve the quality of foods at lower temperatures
Extraction	Frequency ≥ 20 kHz, energy ultrasound > 0.1 W cm^{-2}	Superficial tissue disruption, and increase mass transfer	Increase the yield of extracted components and rate of extraction

So, here are some application and treatment conditions and with which principle ultrasound works and are all the advantages. For example I will just take up two three one is I will take up the sterilization. The frequency of ultrasound used is 20 kilo hertz and the energy is ultrasound is greater than 1 watt per centimeter square. So, the principle is thinning of cell membrane localized heating and production of free radicals by which your microbial damage occurs. And, advantage wise it improves the quality of food at lower temperatures.

And, another example maybe we can take the cooking, cooking the frequency is same frequency 20 kilo hertz and energy is greater 10 watt per centimeter square. It improves the heat transfer in the cooking and reduce the cooking time and increase the quality of food for, example how we cooking the normal LPG stow and microwave. Here the ultrasound improves the heat transfer and reduce the cooking and increase the quality of the food. So, other applications and treatment conditions principle advantage you may refer the references what I have given from their only it is taken the table is taken.

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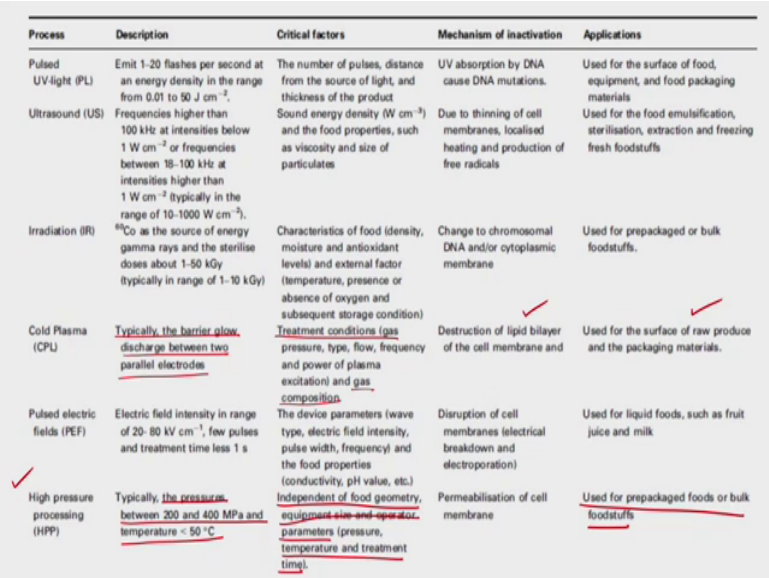

Process	Description	Critical factors	Mechanism of inactivation	Applications
Pulsed UV-light (PL)	Emit 1-20 flashes per second at an energy density in the range from 0.01 to 50 J cm^{-2}.	The number of pulses, distance from the source of light, and thickness of the product	UV absorption by DNA cause DNA mutations.	Used for the surface of food, equipment, and food packaging materials
Ultrasound (US)	Frequencies higher than 100 kHz at intensities below 1 W cm^{-2} or frequencies between 18-100 kHz at intensities higher than 1 W cm^{-2} (typically in the range of 10-1000 W cm^{-2}).	Sound energy density (W cm^{-3}) and the food properties, such as viscosity and size of particulates	Due to thinning of cell membranes, localised heating and production of free radicals	Used for the food emulsification, sterilisation, extraction and freezing fresh foodstuffs
Irradiation (IR)	^{60}Co as the source of energy gamma rays and the sterilise doses about 1-50 kGy (typically in range of 1-10 kGy)	Characteristics of food (density, moisture and antioxidant levels) and external factor (temperature, presence or absence of oxygen and subsequent storage condition)	Change to chromosomal DNA and/or cytoplasmic membrane	Used for prepackaged or bulk foodstuffs.
Cold Plasma (CPL)	Typically, the barrier glow discharge between two parallel electrodes	Treatment conditions (gas pressure, type, flow, frequency and power of plasma excitation) and gas composition.	Destruction of lipid bilayer of the cell membrane and	Used for the surface of raw produce and the packaging materials.
Pulsed electric fields (PEF)	Electric field intensity in range of 20- 80 kV cm^{-1}, few pulses and treatment time less 1 s	The device parameters (wave type, electric field intensity, pulse width, frequency) and the food properties (conductivity, pH value, etc.)	Disruption of cell membranes (electrical breakdown and electroporation)	Used for liquid foods, such as fruit juice and milk
High pressure processing (HPP)	Typically, the pressures between 200 and 400 MPa and temperature < 50 °C	Independent of food geometry, equipment size and operator parameters (pressure, temperature and treatment time).	Permeabilisation of cell membrane	Used for prepackaged foods or bulk foodstuffs

And this table compares all the technologies whatever we have discussed. For example, high pressure processing which is nothing but HPP. So, the typically the pressures between 200 and 400 and the temperature is less than 50 degree. So, this is the descriptions of the process and it is independent of food geometry. We have already told it is working under the principle of hydrostatic equilibrium. So it does not matter which food geometry we are applying and equipment size and operator parameters are important.

And temperature and treatment time is also important when we apply HPP. So, the permeabilization of the cell membrane is the mechanism by which the inactivation of microorganism occurs, used for packaged foods or bulk foodstuff the HHP is used. And, if you go for cold plasma it is typically the barrier glow discharge between the two parallel electrodes. So, we have seen between the electrodes the carrier gases flown. So, through which the plasma is generated.

The treatment conditions depends upon as pressure type of flow and frequency and power of plasma excitation everything are matters and gas composition also critical factor and destruction lipid buy layer of the cell membrane happens in this CPL. And, used for the surface of the raw products and packaging materials. So, you can see for other process as well though we have discuss in the class thus gives you, the shorten description of the process and critical fact is to be considered and mechanism of inactivation and their applications.

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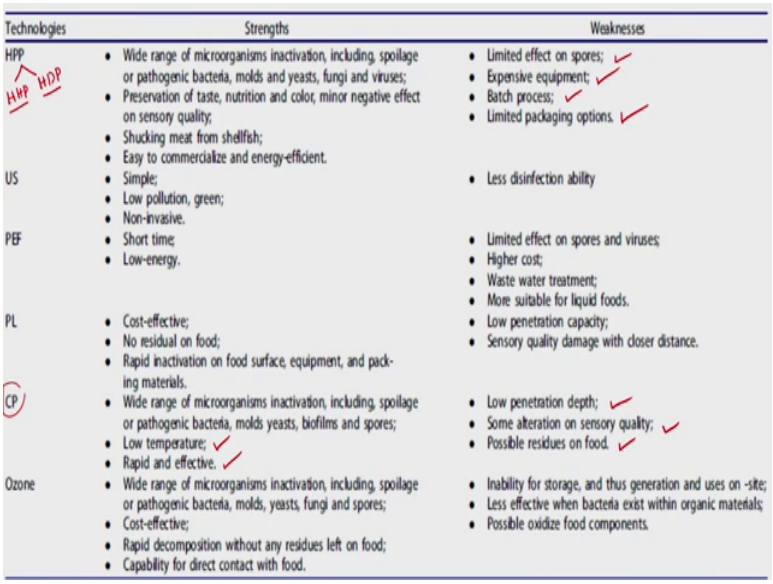

Technologies	Strengths	Weaknesses
HPP	• Wide range of microorganisms inactivation, including, spoilage or pathogenic bacteria, molds and yeasts, fungi and viruses; • Preservation of taste, nutrition and color, minor negative effect on sensory quality; • Shucking meat from shellfish; • Easy to commercialize and energy-efficient.	• Limited effect on spores; • Expensive equipment; • Batch process; • Limited packaging options.
US	• Simple; • Low pollution, green; • Non-invasive.	• Less disinfection ability
PEF	• Short time; • Low-energy.	• Limited effect on spores and viruses; • Higher cost; • Waste water treatment; • More suitable for liquid foods.
PL	• Cost-effective; • No residual on food; • Rapid inactivation on food surface, equipment, and packing materials.	• Low penetration capacity; • Sensory quality damage with closer distance.
CP	• Wide range of microorganisms inactivation, including, spoilage or pathogenic bacteria, molds yeasts, biofilms and spores; • Low temperature; • Rapid and effective.	• Low penetration depth; • Some alteration on sensory quality; • Possible residues on food.
Ozone	• Wide range of microorganisms inactivation, including, spoilage or pathogenic bacteria, molds, yeasts, fungi and spores; • Cost-effective; • Rapid decomposition without any residues left on food; • Capability for direct contact with food.	• Inability for storage, and thus generation and uses on -site; • Less effective when bacteria exist within organic materials; • Possible oxidize food components.

So, this compares the strength and weakness of the age factor. For example, if you take HPP it is high pressure processing somebody says the high pressure processing there are two categories one is high hydrostatic pressure and high hydro dynamic pressure technology. To please do not be confused with high pressure processing can be done is to with high hydro static pressure, that is mostly applied for static fluids and high hydro dynamic pressure technologies applied on motion of the fluids.

So this both comes under the category of HPP so, it does not matter whether it is the HPP or HHP or HDP. The principle behind is bit different. Because, HHP works on Pascal law HDP you are doing it in the flow of liquids. So, do not be confused with this three terminologies. The strength is wide range of microorganism inactivation including spoilage or pathogenic bacteria moles is fungal viruses. Preservation of taste, nutrients and color minor negative effect on sensory quality.

Shucking meat from shellfish, and easy to commercialize and energy efficient weakness wise limited on spores. Spores, nothing can be done and expensive equipment because, of high pressure and batch process and limited packaging option. And, if you see cold plasma this we already seen wide variety of microorganisms, low temperature, rapid and effective. So, if you see weaknesses low penetration death some alteration on sensory quality as well possible residues on the food.

Because we are using CP so forms the free radicals so, there may be a residues on the food as well so this is weakness. For all the technologies whatever we have discussed the strength and weakness are given so you may refer for each and every technology.

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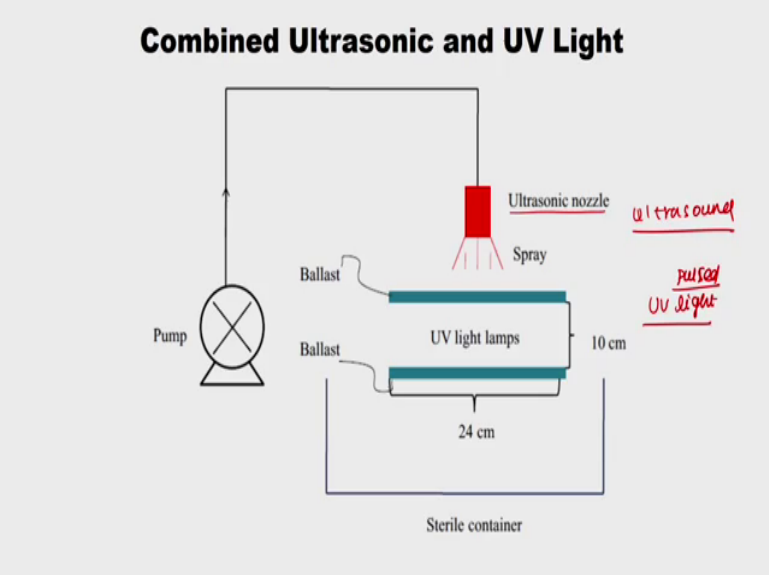

So, some times what happens we can combine two technologies as well, this is one of the such example. The product is pumped and it is sprayed using ultrasonic nozzle. So, this is what we have seen is ultrasonic technology. And, then your pulsed UV light technology is used, so combined both ultrasound as well as pulsed UV technology. So, this is the way you can increase death of microorganisms or, sometimes you wanted to maintained certain sensory qualities of the food. So, this way you can combined both the technologies to achieve your goal.

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So, this are additional references and resources which you would like to refer. Whatever we discussed in the class. And, mainly this tables were taken from those references thank you.