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

Lecture – 60
Non Thermal Processing (Contd.)

Hello everyone, welcome to the NPTEL online certification course on Fundamentals of Food Process Engineering. So, this is our last class on Non Thermal Processing.

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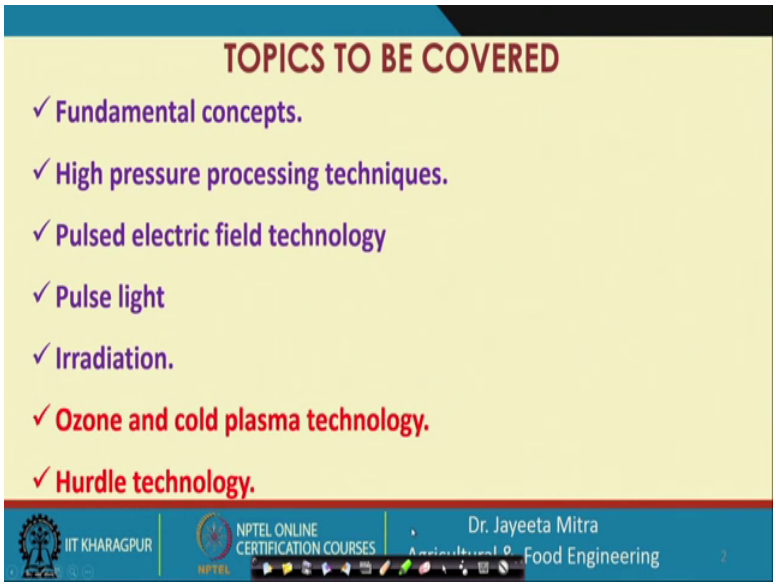

We have by now discussed many non thermal processing method, which are helpful in preserving the fruits and vegetables without the thermal effect of conventional treatment. So, we have discussed the high pressure processing, pulse electric field and irradiation. Now, we will discuss the ozone and cold plasma technology followed by hurdle technology.

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So, ozone in food processing; By now, ozone technique is a very much familiar with most of the people because, we normally use now ozone to disinfectant the water treatment plant or portable water or for the you know surface cleaning of the vegetables because, we when their surface are contaminated by some insecticides or pesticides or some microbes. So, we normally use the exposure to ozone and the main advantage of ozone is that ozone, does not give any you know adverse effect or some residue that to be remove from the from the surfaces. So, it is totally free because, when it get dissociated, it produce oxygen and that is not harmful. So, this is very effective.

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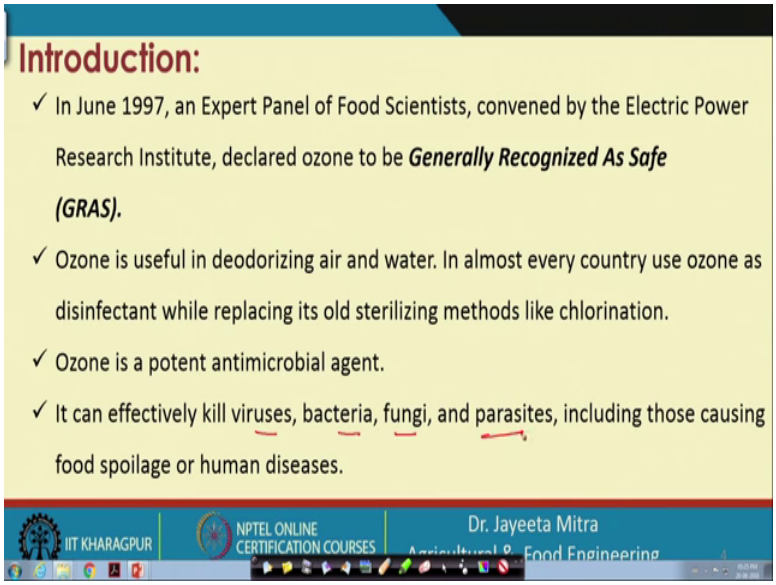

In June 1997, an Expert Panel of Food Scientists convened by the electric power research institute declared ozone to be generally recognized as safe GRAS. So, this is we know the food people, the people related to food industry or food processing know that before using any kind of chemical, we need to have this GRAS tag or the certification so, that we can safely use for the food. Ozone is useful in deodorizing air and water. So, this is already in practice and is in almost every country use ozone as disinfectant, while replacing it is old sterilizing method like chlorination because, when we use this kind of chemical methods like chlorination they have some ill effect because, they leave some residue ok.

So, either we have to remove that residue or we have to bear the ill effect of those in food or in the surface of the food contact materials. So, this is one thing and not only that, it it reduce the use of water also because, when we use ozone and that can be retreated or reutilized for the next batch because, that does not have any ill effect on the food or any residue that is harmful to the food. So, that is why these are now becoming popular, ozone is a potent antimicrobial agent, it can effectively kill virus, bacteria, fungi and parasites including, those causing the food spoilage or human disease that is the pathogenic.

So, ozone can effectively kill, we can see that the broad spectrum of microbes are there, it can kill virus, bacteria, fungi and parasite.

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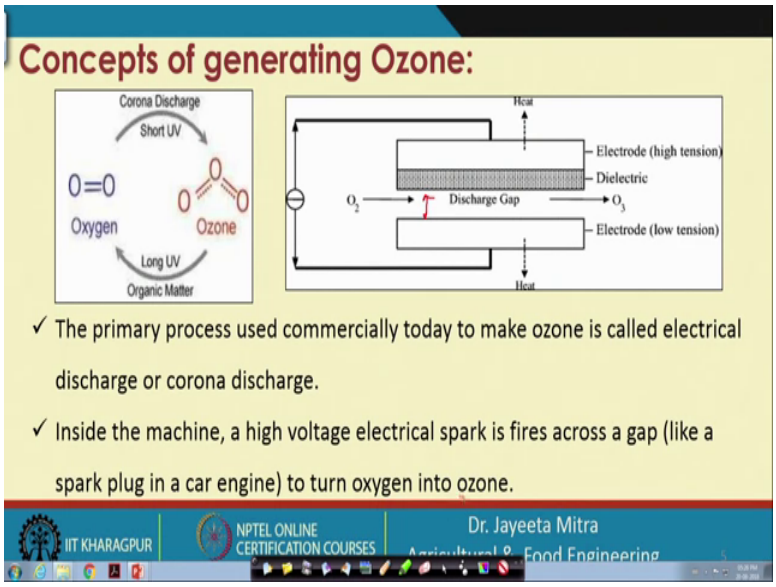

The concept of generating ozone. So basically, we develop ozone from oxygen by corona discharge method by applying the short UV and then we can reframe it from the ozone to oxygen also, this is also possible. And there are more than one method, there are many method by now for this you know generating ozone. The primary process use commercially, today to make ozone is call the electrical discharge or corona discharge method. So in fact, the machine high voltage electrical spark is fires across a gap ok, like there is a gap across which, the electrical spark is fires to turn the oxygen into ozone.

So, while going through this high spark the O 2 converts to O 3 right. So, these are the electrode the upper one is high tension electrode and the lower one is low tension electrode, there is a dielectric material there and O 2 is transferred across the gap ok. So, this is how we generate the ozone. So, this is one method very common method.

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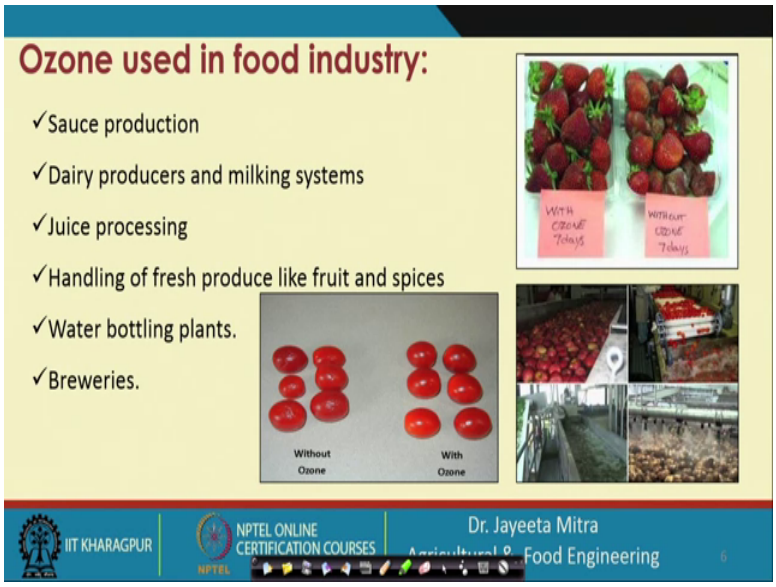

Now, ozone because of this so much beneficial effect that it can act on micro organism, it has a very broad spectrum effect because, it can kill starting from the virus, bacteria, mold and pathogenic organism then, spoilage organism, it can have a varied effect on the microorganism. It can have the surface disinfestation effect and also see, there are some process, where we want the sterilization effect and for that we normally conventionally implement the sterilizer or pasteurizer, where we need high you know heat treatment, hot water or steam, we utilize for that.

Now, if we use ozone. So, we reduce the energy intake to a higher amount because, we do not want them the you know the like the plate heat exchangers or different kind of heat exchangers that part, we can omit and the effect of that sterilization, we can get only by applying the ozone. So, we are reducing some machinery, we are reducing some utilization of steam or energy or water that, we can reduce.

So, by use of ozone we can significantly reduce, the cost of production as well, thereby it is very beneficial in sauce production dairy. Dairy producers and milking system, it can be used juice processing. So, everywhere for that heat transfer part for that sterilization part, pasteurization part we can replace by this, ozone technique.

Handling of fresh produce like fruits and spices, this can also be done by applying ozone treatment. So, that no contamination will come, water bottling plant here also the sterilization, we can perform by ozone, breweries also here, the you know the destruction of the microorganism, this part can be done by the ozone treatment.

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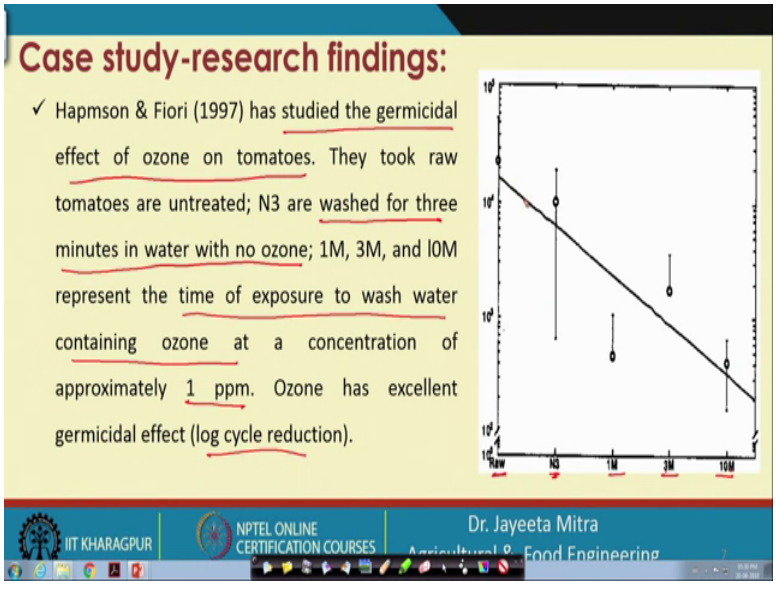

So, different studies has been conducted to have or to see the effect of this ozone treatment on the food products. So, one such study, we have reported here, it says that Hapmson and Fiori in 1997 has studied the germicidal effect of ozone on tomatoes and they, what they found? There are certain sample if you see, in the x direction and y direction, we have raw tomatoes then the N 3, which is washed for 3 minutes in water with no ozone ok.

So, this is N 3 then, we have 1 M, 3 M and 10 M, these are time of exposure to wash water, containing the ozone; that means, 1 minute, 3 minute and 10 minute, we have exposed the tomatoes to wash water, which is having ozone and a concentration of approximately 1 pulse per million ok. So, ozone has excellent germicidal effect; that means, the log cycle reduction because, log cycle here we have plotted in y axis and we can see that how much reduction it has it has occurred? Ok. All though, we have we can see here one out layer, but that may be because of the experimental error. So because, other two are having some reducing effect. So, we can consider that it has some effect on the on the germs.

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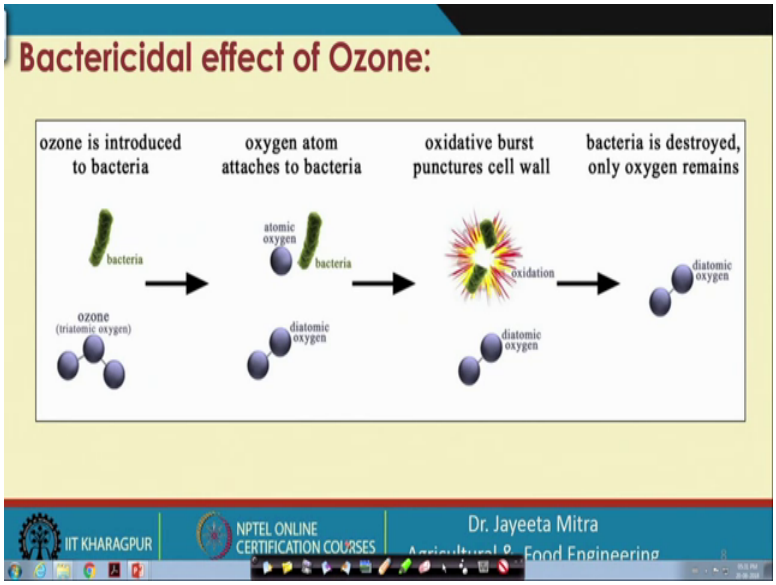

So, bactericidal effect of ozone, we have seen the germicidal effect, now there is a bactericidal effect. Ozone is introduced to bacteria so what will form the free radical or the atomic oxygen that will work on bacteria and eventually, kill the bacteria that that is that attached to the bacteria leaving the diatomic oxygen behind and oxidative burst will happen that puncture the cell wall ok, because atomic oxygen is highly reactive. So, it will break it and finally, the diatomic oxygen will be there, bacteria will destroy and this is not harmful for body. So, that is why treatment of ozone is very beneficial because, it does not leave any residue behind. So, it is very effective.

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There are certain equipment, because ozone treatment by now is commercially available and this is very popular nowadays. So, some systems are there you can see you can search in net also, these are market available systems OSU ozone based Shellegg sanitizer then, there is ozone based produce sanitizer. So, whatever the fresh produce, we can sanitize while passing through this channel and then at the end, we can collect them there is a hopper for sending that so, there is a ozone generating system. So, these kind of systems are available.

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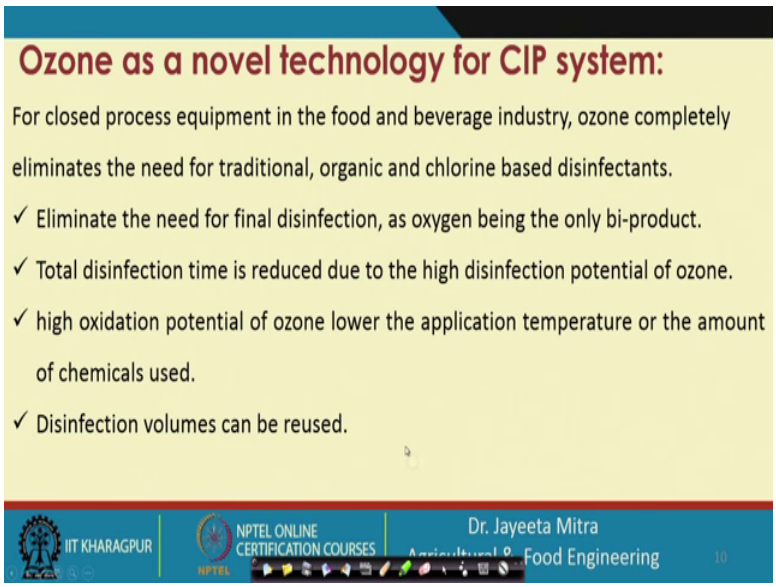

So, ozone has a novel technology for CIP system for closed process equipment for example, there are some pipe, some vessel some portions of the equipment, these are these are closed chambers and very not easy not very easy to clean them ok.

So, for closed process equipment in the food and beverage industry, ozone completely eliminate the need for traditional, organic and chlorine based disinfectant. So, this eliminate the need for final disinfections as oxygen being the only bi-product, because if we use this chlorine and other organic disinfectants, we what happen there are sometime some falling of the organic material deposited on the inner side of those closed equipments or closed parts of that food processing equipments.

So, that has to be cleaned nicely, but it is very tough to disinfectant those surfaces efficiently. So, if we use ozone. So, that is very beneficial because, the ozone treated water that we use instead of that disinfectant plus water that can be reutilized because, this does not give any kind of you know the contamination or any residue, it only give the oxygen as a bi-product. So, that water can be reused.

So, that is why for the CIP system, this has become very efficient, the ozone treatment has become very efficient day by day. Total disinfection time is reduced due to the high disinfection potential of ozone and high oxidation potential of ozone lower the application of temperature or the amount of chemicals used.

So, high oxidation potential of ozone lower the application of temperature because otherwise, we need to use the hot water or warm water to complete the half the disinfection. Disinfection volumes can be reused, as I said that the water that we are using for this can be reused.

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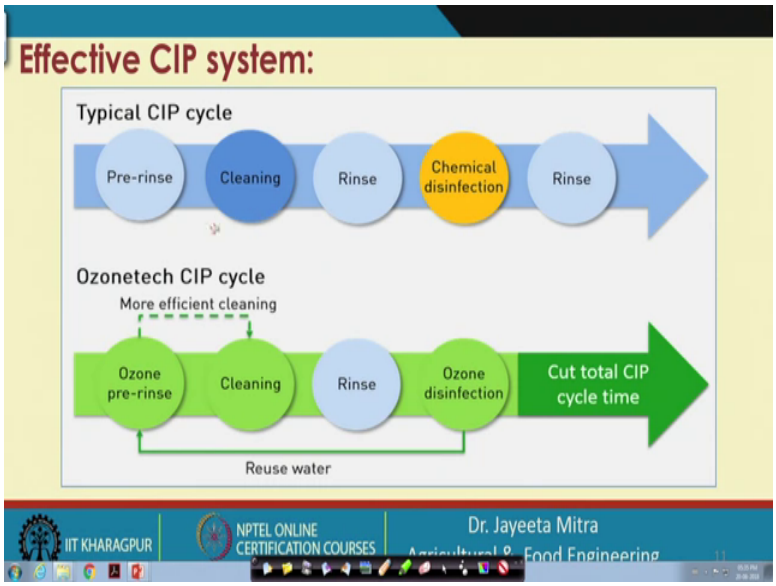

So previously, the typical CIP system was like that, first there is pre rinse and each step that water is discarded, then there is cleaning then, there is rinse thoroughly chemical disinfection. So again, this water should be thrown out or discarded and again rinse. So, pre-rinse, rinse and rinse, this 3 we have purely involving the water then cleaning and chemical disinfection here also we use that.

So, all this water have been wasted, now ozone takes CIP system. So, the ozone, pre rinse, cleaning rinse and ozone disinfection so all this water can be reused for cleaning ok. So, this more efficient cleaning for this is used. So, cut to the total CIP cycle time and the resources as well.

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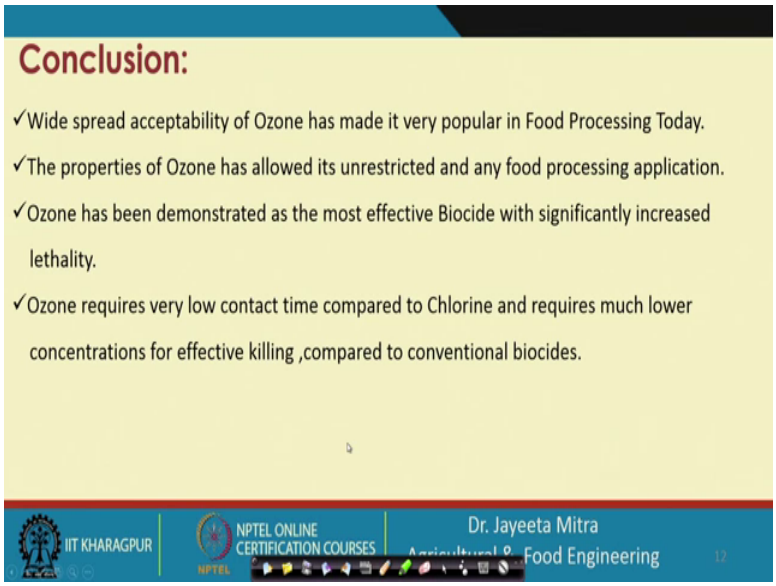

So, we have reached the conclusion part of ozone treatment, wide spread acceptability of ozone has made it very popular in food processing food processing today. So, the properties of ozone has allowed it is unrestricted and any food processing application. So, it can be used for any food processing application, ozone has been demonstrated as the most effective biocide with significantly increased lethality and we have checked that with many research oriented papers and works, ozone requires very low contact time compared to chlorine and requires much lower concentration for effective killing compared to the conventional biocide ok. So, very low dose it is effective.

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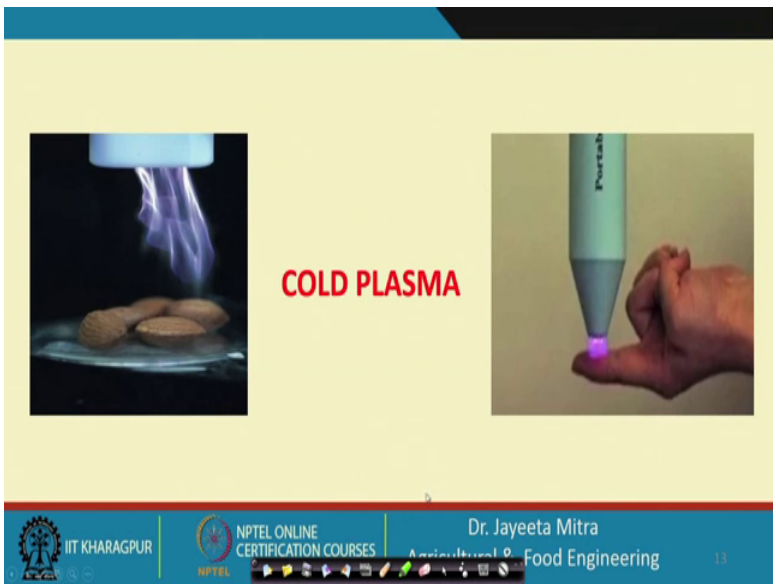

Now, next is cold plasma. Cold plasma is an upcoming technology that is nowadays used for basically surface sterilization.

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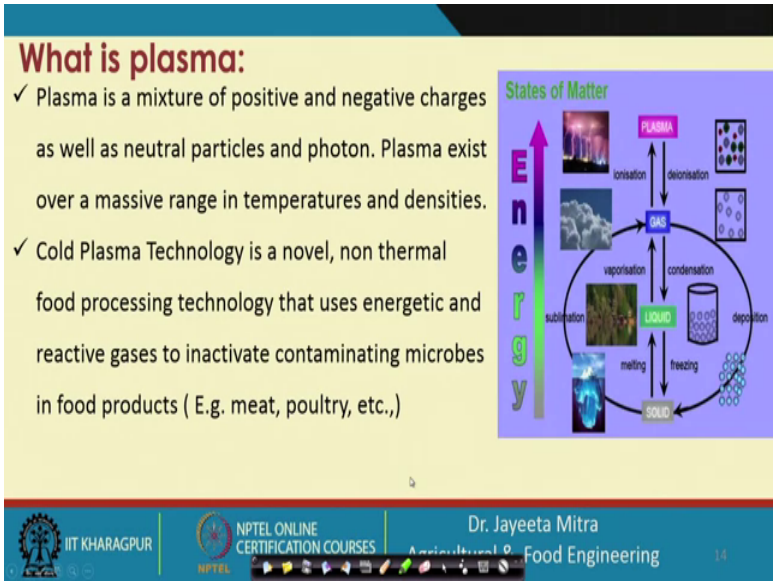

So, what is that? Plasma is a mixture of positive and negative charges as well as some neutral ions, neutral particle and photon. Plasma exist over a massive range in temperature and density ok. So, it actually have some mixed property of gas and the liquid and so from this solid, we if you provide energy to it, we are getting the liquid, if further, we provide energy, we are getting gas and again from the gas further we give energy. So, we get the plasma state ok.

So from the plasma state as from the gas, we organize it and we get the plasma and from the plasma to deionize it, so we are getting the gas back and then from the gas condensation liquid and from the freezing we are getting solid. So, this cycle is go on continuously, and this transition of energy from the lower to higher then, because of that the sublimation of ice to gas bypassing the liquid phase and from the gas to deposition to solid. So, all such exist ok. So, this basically, the states of the matter and how it can be transferred from one phase to the other ok.

Now, cold plasma technology is a novel, non thermal food processing technology that uses energetic and reactive gases to inactivate contaminating microbes. So, energize gas. So, when gas to plasma, it has become, it has become a energized gas. So, that can be

used to inactivate contaminating microbes in food product ok. As for example, meat, poultry, etcetera, there we can use it.

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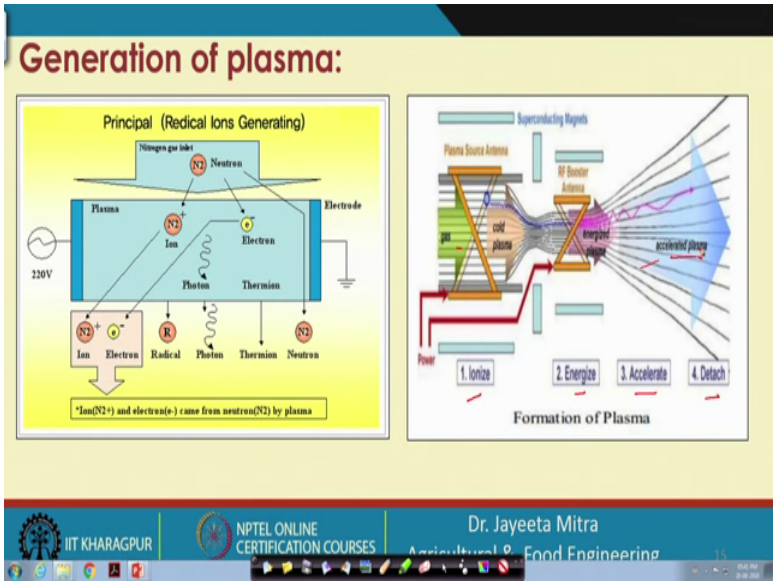

So, generation of plasma. So basically, the principle is first the redical ions generated, there is a nitrogen gas which is an inert gas from then, we are by applying the high energy, we are getting the ions and electrons and photons. So, plasma state having all of them that is positive ion then negative ion then electrons then photons everything and that ions that ions into nitrogen and electron came from the neutron by plasma ok, they form the radical photon thermion and neutron.

Now, we when we apply very high voltage to the gas this break down will form. So, here the formation of plasma we can see when the gas comes in contact with the plasma source antenna there is a plasma source antenna and when we give power to it when we give power to it generate cold plasma from the gas now this plasma again through a super conducting magnets this plasma move on to the radio frequency booster antenna where this plasma is energized and then it release.

So, it we are getting then the accelerated plasma ok. So, it is first ionized. So, gas to plasma then energize to this RF booster antenna and then accelerate and then detach. So now, the plasma has been detached. So, these are now ready for application.

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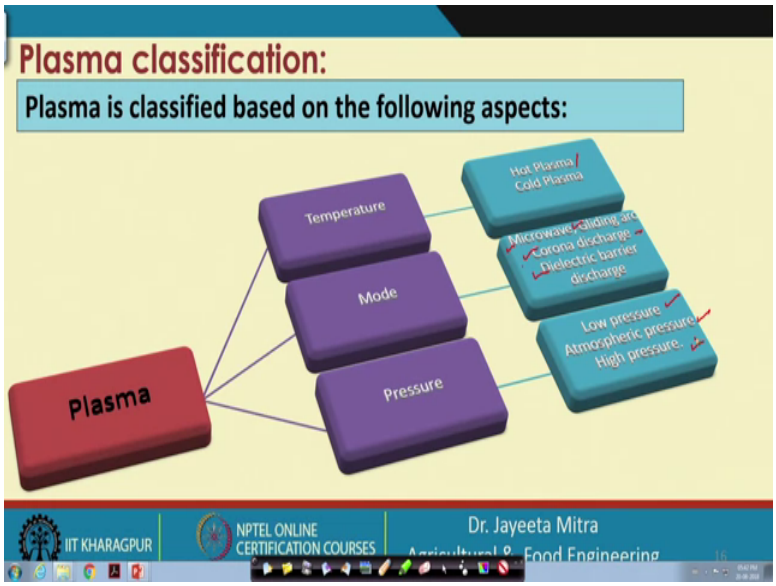

So, next is classification of plasma based on the following aspects. So, plasma can be classified based on temperature variation or based on the mode variation or because of the pressure variation. So, for temperature variation thermal plasma or cold hot plasma and cold or non thermal plasma, these 2 separation can be made hot plasma and cold plasma then, if we use the mode; that means, how we are generating the plasma. So based on that, we can have the micro wave plasma or gliding arc method or corona discharge method, dielectric barrier discharge method.

So, these are all corona is the very basic one and common one, but these are the methods by which, we can generate the plasma and pressure, because pressure will also initiate that amount of formation of the plasma. So, because of that the low pressure, atmospheric pressure and high pressure, these are the pressure mediated chain that causing the plasma.

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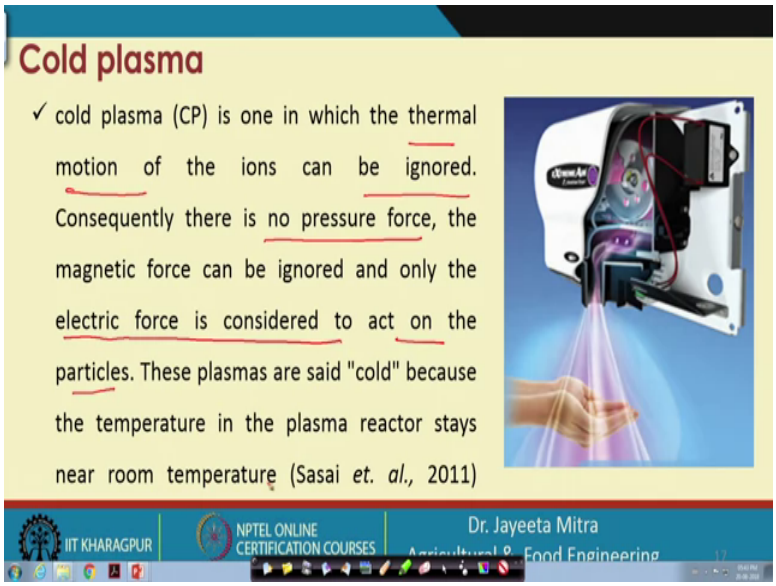

So, the cold plasma that is mostly used for the food process application is one in which, the thermal motion of the ions, this can be ignored or thermal motion is neglected. Consequently, there is no pressure force and the magnetic force can be ignored only the electric force is considered to act on the particle ok. So, the electric force is actually functioning for decreasing the microbes or for death of the microbes, this plasma, the cold plasma said cold because, the temperature in the plasma reactor stays near the room temperature that is why, the thermal motion those we can ignore.

So, this particular set up, where the cold plasma generation takes place.

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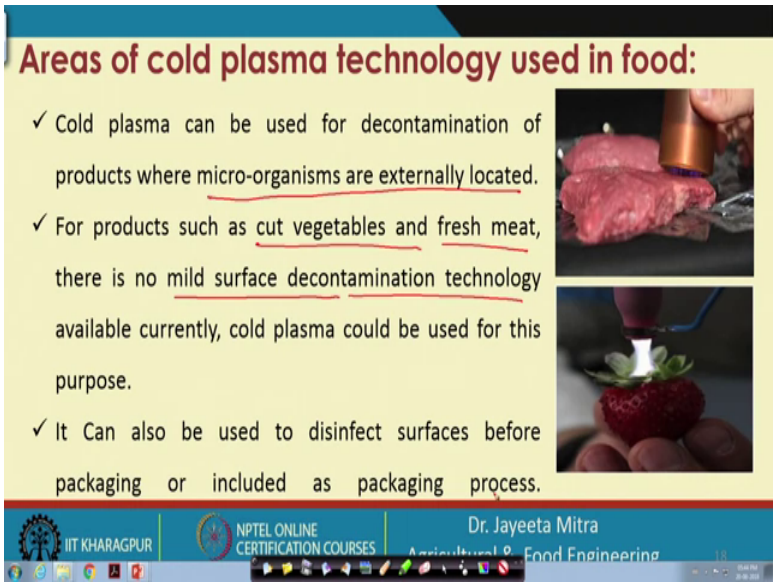

Now, areas of cold plasma technology used in food where so far cold plasma technology has been used. So, cold plasma can be used for decontamination of products, where microorganisms are externally located that means, the surface basically, again the surface can be exposed and surface disinfection or decontamination can be achieved. For products such as cut vegetable and fresh meat, there is no mild surface decontamination technology available currently. So, cold plasma can be used for this purpose. So, for the cut vegetable because normally, we have seen when the cut vegetables are there generally we reluctant to take that.

So, if we use this technique. So, the surface microorganism or the surface contamination can be prevented, then it can also be used to disinfect, the surface before packaging or included as packaging process. So, during the packaging process, if we include this one. So, no contamination will be there nor the surface of the package and neither on the food products. So, this is how we can use this.

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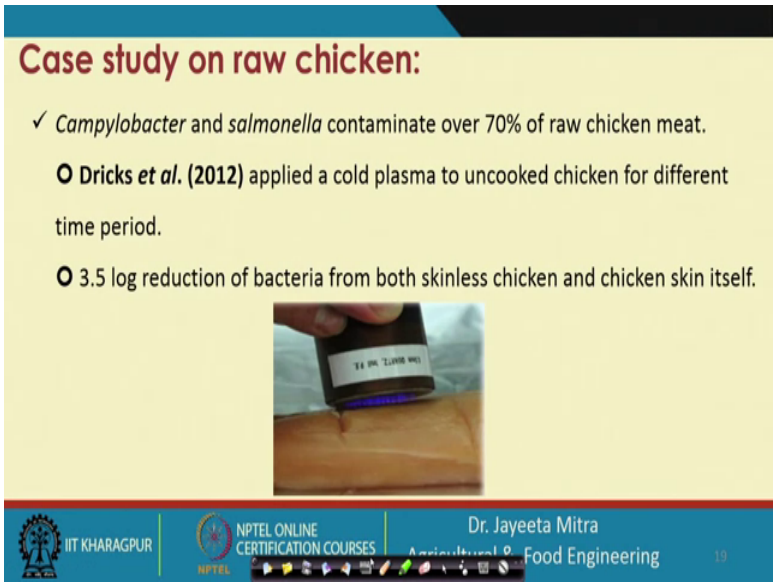

So, a case study has been done on the chicken, where campylobacter and salmonella, these 2 bacteria contaminate over 70 percent of raw chicken meat. So, raw chicken meat this was 70 percent contaminated by these 2 and Dricks et al in 2012 applied a cold plasma to uncooked chicken for different time period 3.5 log cycle reduction of bacteria from both the skinless chicken and the chicken skin, itself it has been found 3.5 log cycle reduction. So, these are effective.

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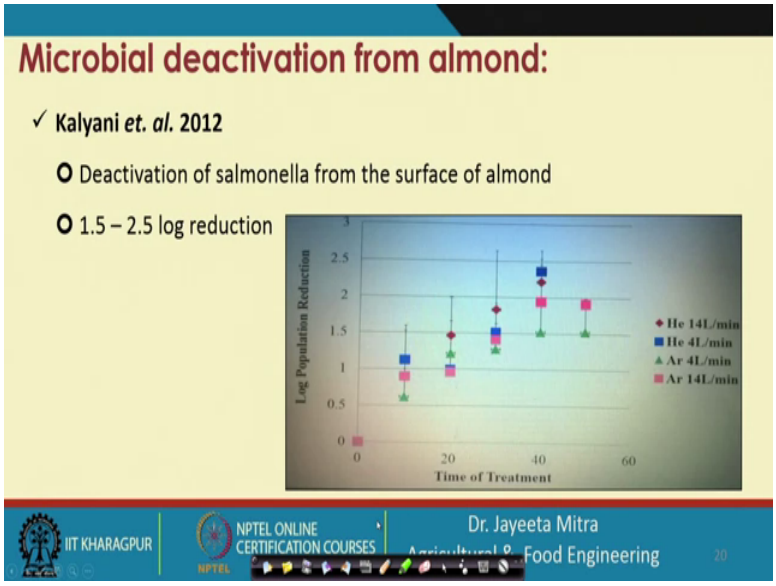

Another study has been seen where, deactivation of salmonella from the surface of almond has been seen where 1.5 to 2.5 log cycle reduction has been observed. So which time, when this treatment has been given? So, log of population reduction here has been plotted. So, we can get this much reduction.

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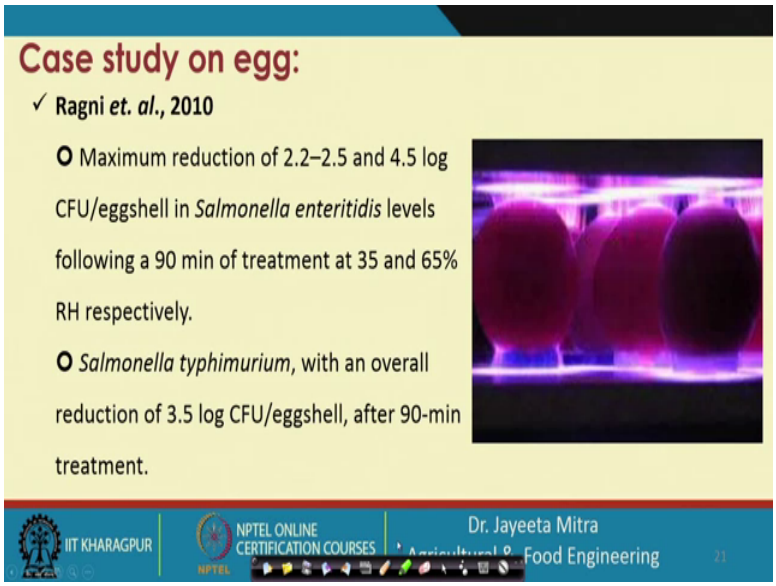

This is the another case study on egg to have the surface sterilization. So, maximum reduction of 2.2 to 2.5 times log cycle and 4.5 log CFU per eggshell. In Salmonella enteritidis level showing a 90 minute of treatment at 35 and 65 percent rh respectively.

So, when the high quality eggs are packed in the industry or the small entrepreneur shape, when people use this high quality of the eggs. So, the most common occurrence is Salmonella on the surface of the egg and that can be prevented, if the RH of the environment as we can see 35 percent and 65 percent.

So, almost 90 minute treatment time is required to reduce the micro organism load from 2.2 to 2.5 times and 4.5 times. So, if you know this much reduction, we want on the eggshell. So, this is the method that we can apply and this is very efficient method. Salmonella tyhimurium with an overall reduction of 3.5 log CFU per eggshell, after 90 minute treatment is observed ok.

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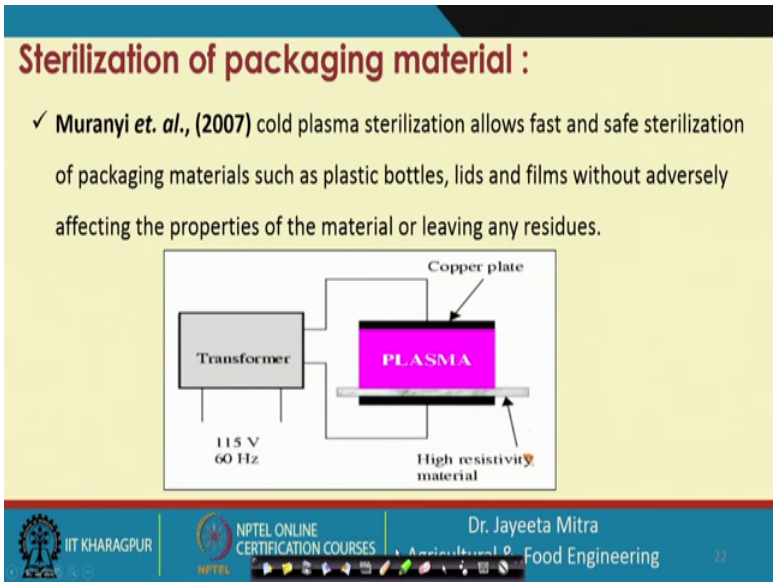

Then sterilization of packaging material, this has also been tried that the plasma has been exposed to the material in the packaging surface material, cold plasma sterilization allows fast and safe sterilization of packaging material such as plastic bottle, lids and films without adversely affecting the properties of the material or leaving any residue. So, that is why these methods are very helpful.

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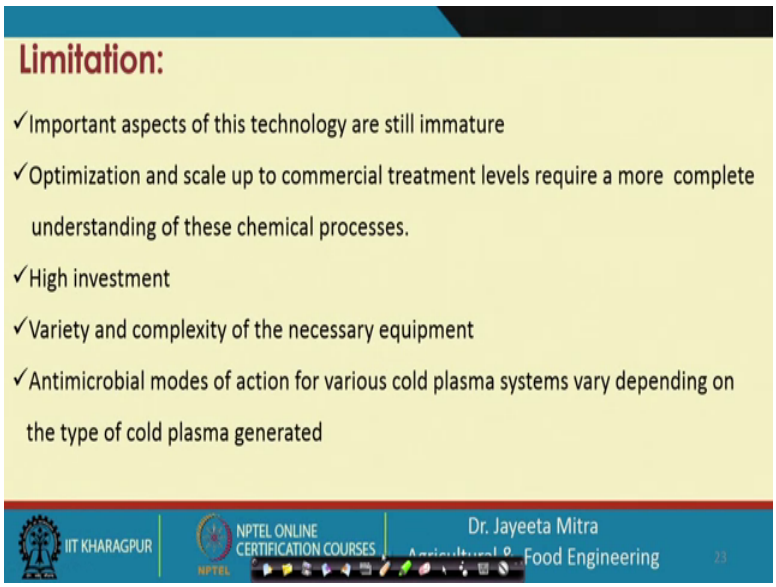

And there are certain limitations of this technique cold plasma technique. So, the limitations are first is the important aspect of this technology are still immature, we have

not gone too much deeper inside of this technique and by now only, the surface sterilization of few cases we use. So, the full potential of this technique is still to be exposed explored and what is the exact mechanism, how it destroy? So, that has to be defined properly.

Optimization and scale up of commercial treatment level require a more complete understanding of this chemical process. So, that has not been in done, this involve the high cost of production and installing the machines initially, variety and complexity of the necessary equipment. So, we have to work on this because, there are variety of the machines require for different cases. So, to make it uniform we have to work. Now anti microbial modes of action for various cold plasma systems vary depending on the type of cold plasma generated.

So, because of cold plasma also vary based on different parameter for example, the temperature the pressure ok. So, therefore, what kind of mode of action will be there? That also depends on the type by which, we prepare the cold plasma.

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Now, the last is hurdle technology. So, hurdle technology it means that there is there is not one method by which, we can inactivate all the type of microorganism ok. So, we have seen by now that some methods are there, that are effective only for the surface sterilization. Some are effective only for the gram positive micro organism, some may be effective for the east and mold ok. So, there are different ways. So, and some methods

are there, if we apply them may be all microorganism will be killed, but they will induce some undesirable changes in the sensory terms or the nutritional terms of the food material.

So, hurdle technology is combination of many technologies together that will have the destruction, complete destruction of the microbial contamination. As well as it will preserve the desired quality of the food.

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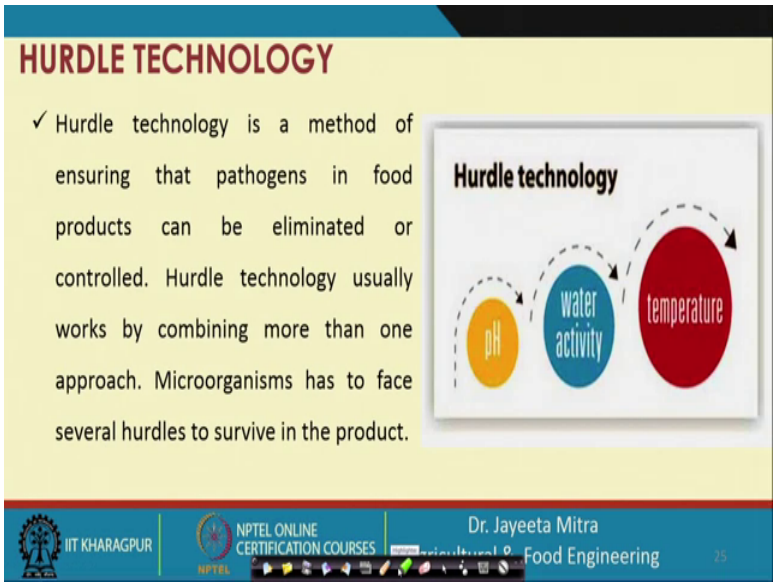

So, hurdle technology is a method of ensuring that pathogens in food products can be eliminated or controlled. Hurdle technology usually works by combining more than one approach. Microorganism has to face several hurdles to survive in the product. So finally, what will the hurdle will be you know taken such a way. So, that it will be even become tougher gradually and so finally, they cannot survive.

For example, we have seen here the pH is 1 trigger, the pH is 1 method by which, we can give some obstacle to growth of the microorganism, because if we control the pH, then some microorganism are there that can grow in the normal ph range, some can in the basic pH and some in the acidic.

So, if we control the pH. So, some microorganism, we can omit coming to the water activity again, we know that the different water activity is required for survival of the microorganism, if we lower the water activity. So, many of the microorganism will not

survive and finally, we can impose the temperature effect. So, that the level effect of the temperature or it can kill the any remaining micro microbes. If it present we can give this temperature for very short period of time so that, no loss in the nutrition can takes place.

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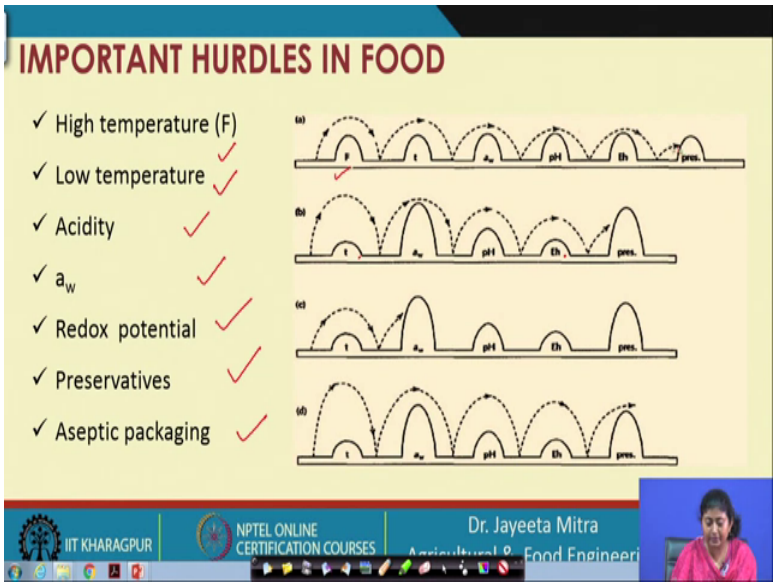

So, these are some common, what we can say that hurdles that, we normally apply one is the high temperature ok. One is the high temperature then low temperature also because, if we reduce the temperature to very low degree frozen condition ok. So, in that way also we can produce the activity of the microbes.

Acidity that is one then water activity, 1 hurdle redox potential that, we can control, we can add some preservative if required and that is fully regarded as GRAS, then aseptic packaging that is while packaging no contamination will arise. So, so that we can give some cold plasma treatment or irradiation or pulse light treatment like that so, we can perform the aseptic packaging.

So together, we can design that which one in what combination, if we can put? For example, in the second one, we have we have given that the temperature effect, low temperature effect then water activity then pH then redox potential preservative like that, some microbes are there that can go up to you know the maximum x chain of the combination.

Some management can be done where it cannot reach cannot cover 1 hurdle ok. It can also be made in such a way so that with 1 or 2 hurdle only it can stop. So, there are many methods and by we have to design based on the type of the product that we are dealing.

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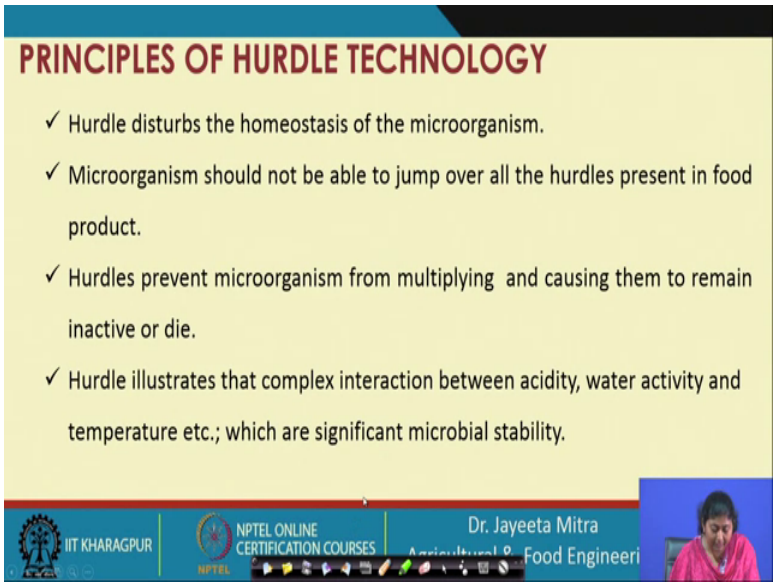

So, principle of hurdle technology, hurdle disturbs the homeostasis of the microorganism. Microorganism should not be able to jump over all the hurdle present in the product, hurdles prevent microorganism from multiplying and causing them to remain inactive or die.

Hurdles illustrate the complex interaction between acidity, water activity, temperature, etcetera with which are significant in microbial stability.

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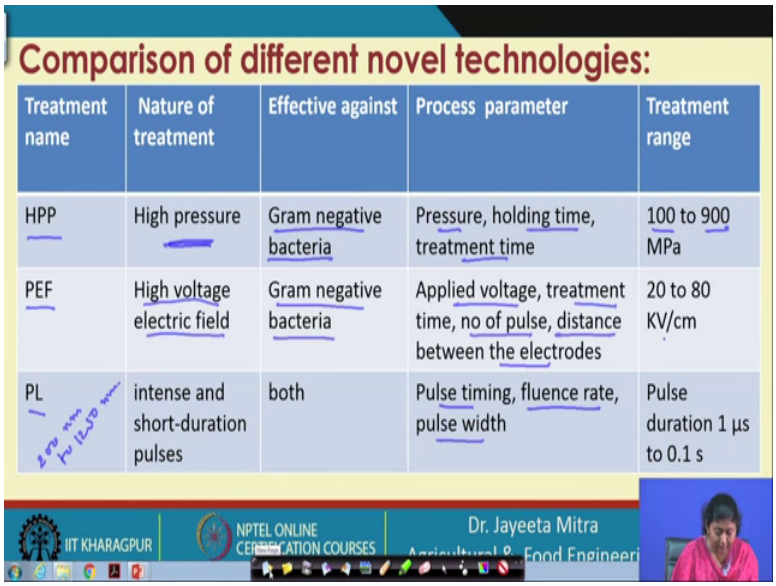

Finally, since in the non thermal processing we have we gave many method like HPP, PEF, pulse light, irradiation then ozone. So, I would like to give you a comparative table. So, that you can understand and you can clearly remind that which methods are helpful in inactivating in what case or what are the parameters related to them? So, this is the last part that, I would like to cover in this particular chapter. Here, we have 1 table ok. So, we have comparison of different novel technologies or non thermal technologies. One is HPP then pulse electric field, pulse light.

Nature of treatment, effective against the organism or the microorganism then process parameter and the treatment range so high pressure processing the nature of treatment actually by application of high pressure and it is most effective on gram negative bacteria. So, effective against this; that means, the gram positive is the bit resistant here. Process parameter, we can change the pressure holding time treatment time that, we can control 100 to 900 or 1000 mega pascal is the range of applying pressure here.

We have pulse electric field, which is actually the high voltage electric field that, we are putting across the food sample and this basically, works on the gram negative bacteria, this is effective against gram negative bacteria and the gram positives are bit resistant here. So; that means, it does not mean that we cannot use the use this method for inactivation of gram positive actually in that case, we need to increase the intensity to a higher extent the voltage and the duration to a higher extent or we can combine this with

some other hurdle to control this, the process parameter that we can change here is the applied voltage, treatment time, number of pulses, distance between the electrodes ok. Generally 20 to 80 kilo volt per semi, we use normally.

Third method is intense and short duration pulses that is pulse light, we have seen that basically, pulse light is active or effective for the surface sterilization, this effect effective on both that is gram positive as well as gram negative bacteria. So, it works on all and process parameter is, we can change the pulse timing, pulse width, fluence rate ok, pulse shape that can be changed, pulse duration ranges generally, from 1 micro second to 0.1 second and we have mentioned already, the broad spectrum light that is around 200 nanometer, 200 nanometer to 1250 nanometer, this is the range in the electromagnetic spectrum.

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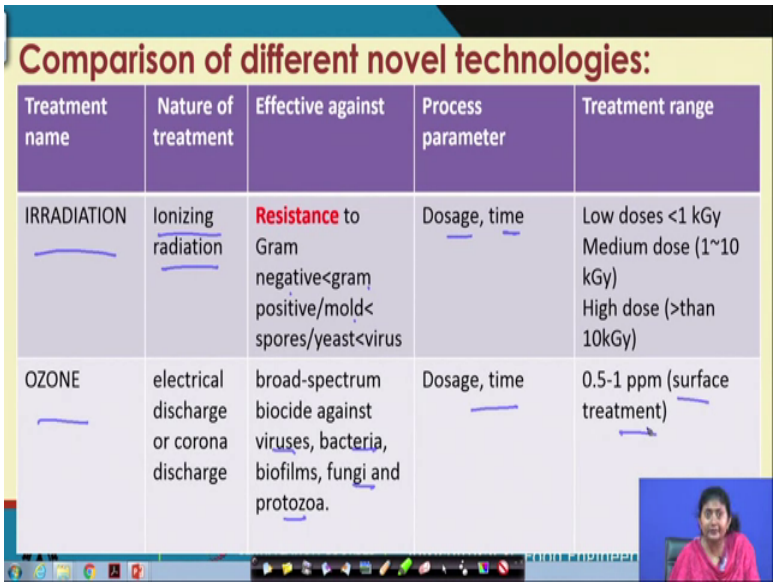

Next is we have irradiation and ozone. So, the irradiation the nature of treatment is actually the ionizing radiation that is the x ray, gamma ray and electronic radiation from the electron beam that we are using. So, these are the resistance, if we see it is high from gram negative to gram positive or mold and then to gram then to spore yeast and virus.

So; that means, the resistance of gram negative is very low, then the gram positive then this ok. So, it has action on all of them and the process parameter that is dose and time that can vary. So, low dose 1 kilo gray, we have seen this, we apply only for reducing the sprouting or ripening, degradation or disinfection of the pulses or storing of the of

decontamination of the spices, etcetera. Medium dose 1 to 10 kilo gray generally, we use for inactivation from the bacteria and high doses normally use for all the microorganism, when we want to kill.

Ozone this is the nature of treatment is electrical discharge or corona discharge method, ozone is a triatomic gas that that, we develop from the corona discharge method by using the oxygen, when we pass it through the high voltage discharge electrical discharge and ozone has a broad spectrum biocide against the virus bacteria, fungi, protozoa, etcetera. Both the you know spoilage and this is causing bacteria, this is causing organism on which the ozone can act, here also the dose and time that, we can change 0.5 to 1 PPM, this is required for the surface treatment.

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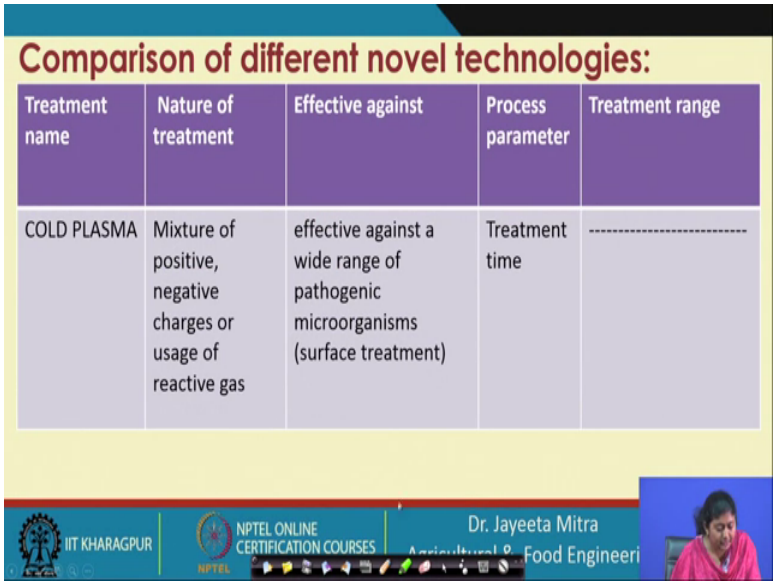

And finally, we have cold plasma treatment. So, this is the mixture of the nature of treatment actually is done by mixture of positive negative charges or usage of reactive gases.

This is the effective against, the wide range of pathogenic microorganism basically, used for a surface treatment and process parameter is treatment time only in this case, when the cold plasma generate and treatment range. So, there is not any specific range has been identified. So, cold plasma is 1 type of plasma, there are many kind of plasma can be generated based on the difference in the in the parameter of the mold or of the type by which, it is generated or application of temperature or not and based on all this the

effectiveness depends. So, that is why we cannot mention any, we use only cold plasma for the treatment of the food inactivation, surface microbial inactivation of the food.

So, this is all about the non thermal processing of the food through this course, through this particular chapter of fundamental of food process engineering, we tried to expose you people to this techniques. All this techniques can be can be dealt with in a broader way, having lot many practical applications equations and the problems, but since in our 12 week course actually, the non thermal was not part of all such unit operation that, we discussed initially.

This, we have intentionally kept because, these are all upcoming techniques that has very beneficial effect on the food and many of you may in future want to work with them for as an entrepreneur or as a farmer or as a business person. So, these are the efficient technique, you can explore this. So, that is why, we wanted to give a glimpse of all this technique in a brief way. So.

Thank you.