Fundamentals of Food Process Engineering

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Lecture - 56
Non Thermal Processing

Hello everyone, welcome to the NPTEL online certification program on Fundamentals of Food Process Engineering ok. So, today we will start a new chapter on Non Thermal Processing, which is our last chapter of this course. By now we have discussed the various processing methods and preservation methods and mostly they are by some thermal treatments for example, we have discussed the sterilization pasteurization.

We have discussed the drain mechanism by which we can reduce the water activity and preserve the food for longer duration. There is evaporation there are many techniques by which we can reduce the moisture content or water activity. And specifically we do sterilization and pasteurization to inactivate the microorganism by thermal treatments.

But we have mention that because of this thermal effect, many important quality of the food may damage for example, the flavour, colour may hamper a bit may the quality may be hampered. So, there are new technologies coming into which are based on without heat treatment ok. So, we keep them in a category of non thermal processing and there are many non thermal processing are you know coming into pictures nowadays some of them as been practised in industry and all though there are cost high cost involvement is there in some of the non thermal technique.

So, these are inconstant you know improvement are going on so, that these methods can be used in a industry food industry in a efficient way and there cost of production may also decrease. So, in today's class and in the subsequent classes we will discuss some of the non thermal preservation techniques.

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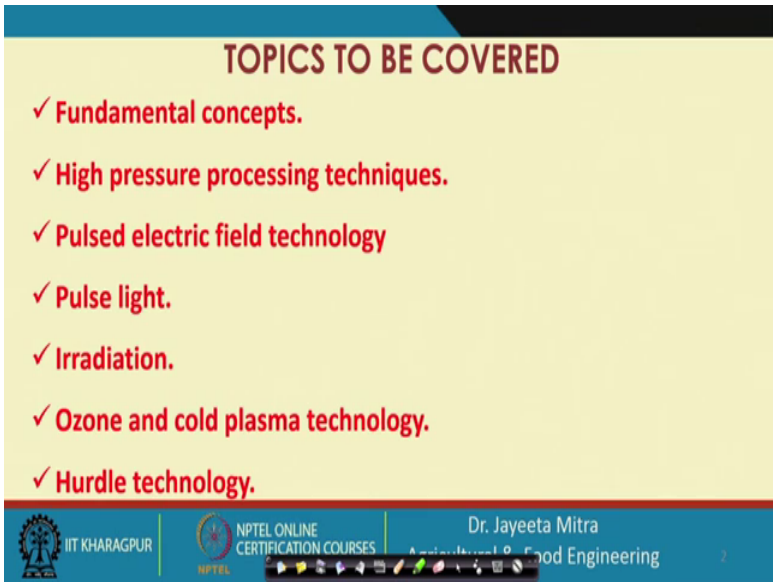

So, basically the fundamental concept behind this non thermal we will cover in the high pressure processing, which is one non thermal preservation technique pulse electric field technology, pulse light technology, irradiation, ozone and cold plasma technology all this we will discuss. And at the end we will discuss a bit on hurdle technology, which is actually a combination of more than one methods and combinely those methods can cause very well inactivation of microorganism and can produce the safe and quality food product.

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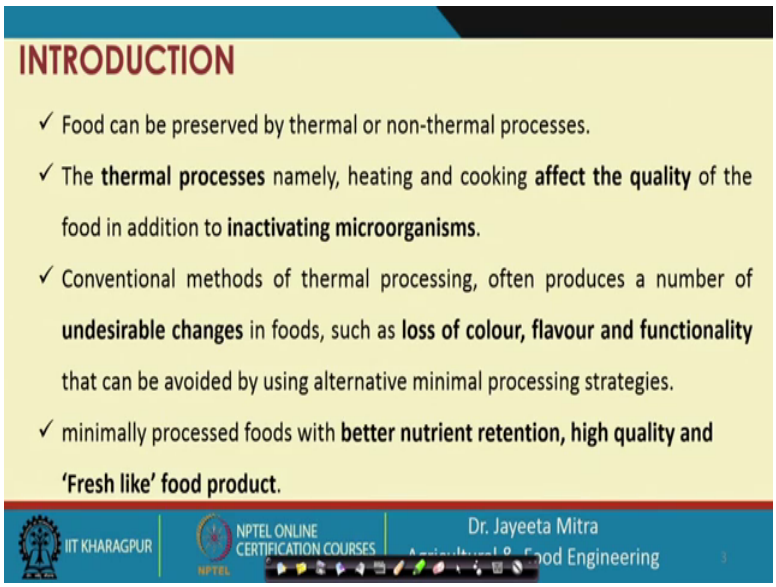

So, let us start. So, first of all we can mention that food can be preserved by thermal or non thermal process; before the you know the invention of this non thermal technique the common perception was that for inactivation of microorganism only the thermal treatment will be effective. So, this thermal process such as heating and cooking affect the quality of the food in addition to inactivating the microorganism. So, they do inactivate the microorganism, but with that there are some heat sensitive element that also are getting affected.

Conventional methods of thermal processing often produces a number of undesirable changes in the food as I mentioned that colour, flavour and functionality can be avoided ok. Even some nutritional components is there which will be damaged for example, vitamin C it is highly damaged because of you know temperature fluctuation or storage etcetera. So, minimally processed foods with better nutrient retention, high quality and fresh like food product this is the demand of the consumer now a days. So, they want a minimally processed food so, that the initial quality, which we get during the harvesting will not be altered much and the fresh like quality will be intact.

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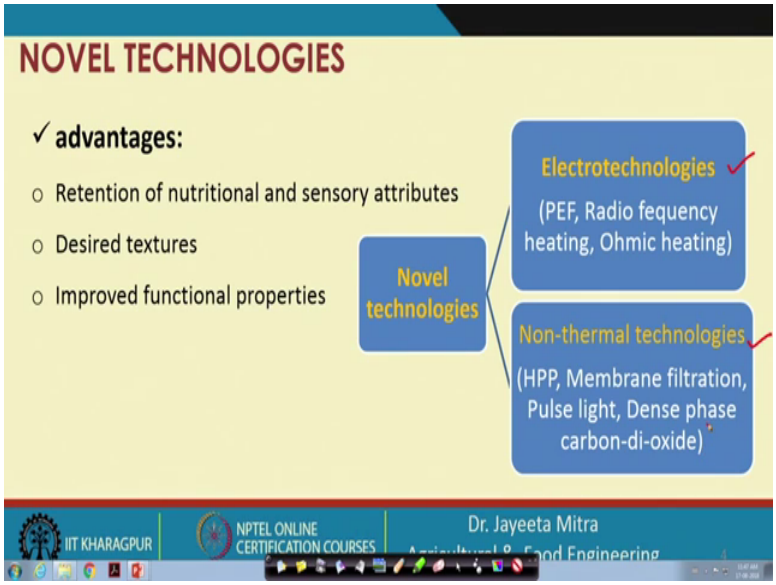

So, the novel technologies that came in due course of time when the scientist thought about some alternative way to preserve the food in a different way than the thermal processing because there are certain advantage associated with that. So, first is retention of nutritional and sensory attributes, then the desired texture sometime because of heat

treatment the proper texture of the food will get damage; sometime shrinkage may happen that is not required or that give some you know undesirable appearance to the product, they even form the some brown spot because of some browning action may have occur there and improved functional properties.

So, this is also another desirable quality that we want to have. So, novel technologies have all this qualities, we can categories them into these two segment ok. So, first is the electro technologies and the non thermal technologies. In the electro technology there are pulse electric field PEF, radio frequency heating, Ohmic heating etcetera and in the non thermal technologies we have High Pressure Processing HPP, membrane filtration, pulse light treatment then says carbon dioxide and many more ok.

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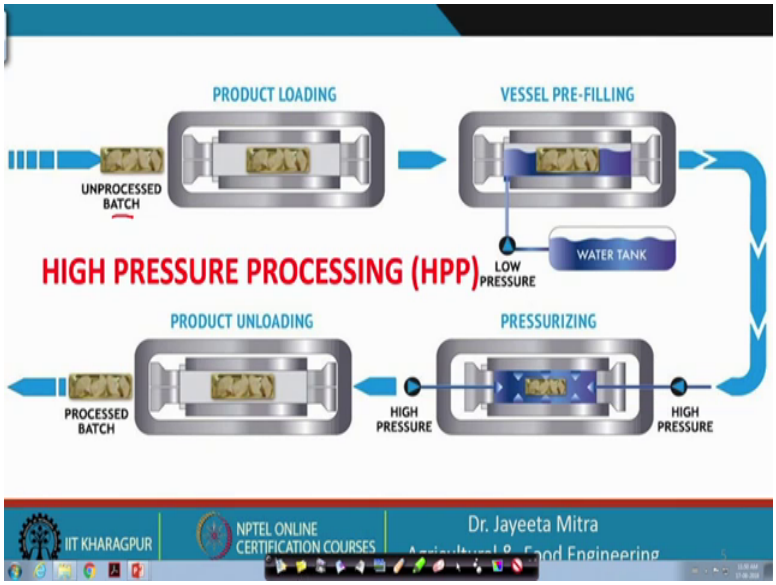

So, first will see high pressure processing. So, high pressure processing is not very new we can say because it has the first experimentation related to high pressure processing was invented around 1889; and that time it was not that much use only it has been established that high pressure processing is efficient in decreasing the microbial contamination. Now in a around 1999 again scientist started on a experimenting with HPP. So, that a to accesses effect on the food basically apart from the inactivation of microorganism what other changes the hyper processing can cause and still not much work has been done because of the high cost involvement of this high pressure processing.

So, as the in the picture we can see that the total process chain of the high pressure processing occurs as first the unprocessed batch of the food, this comes into the chamber where we perform the high pressure processing. So, the product is loaded into the high pressure chamber ok, after that the vessel pre filling is done. So, the water is entered from the low pressure channel to the chamber where it the pressure is intensified to a very high extent and the food is exposed to that high pressure. So, after this pre filling the high pressure generation starts ok.

So, this high pressure generation this high pressure generation causes an isostatic pressure distribution we can see from all the side the pressure seemed pressure is applicable on the food product and because of this mechanism the inactivation of microorganism and some enzymes occurs and because of that the food will be intact the pressure is from all the side we are providing. So, no damage visual damage or the physical damage to the product does not happen and it is very much in good quality and then the high pressure is released ok, and the product has been taken out the process high pressure process batch has been taken out.

So, mostly HPP is performed in a batch process or in semi continuous process also, but fully continuous high pressure processing has not been used and moreover it is not been sued in food as well. So, this is how it works ok.

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Now, what is HPP? And how it inactivate? How it works on the food products?

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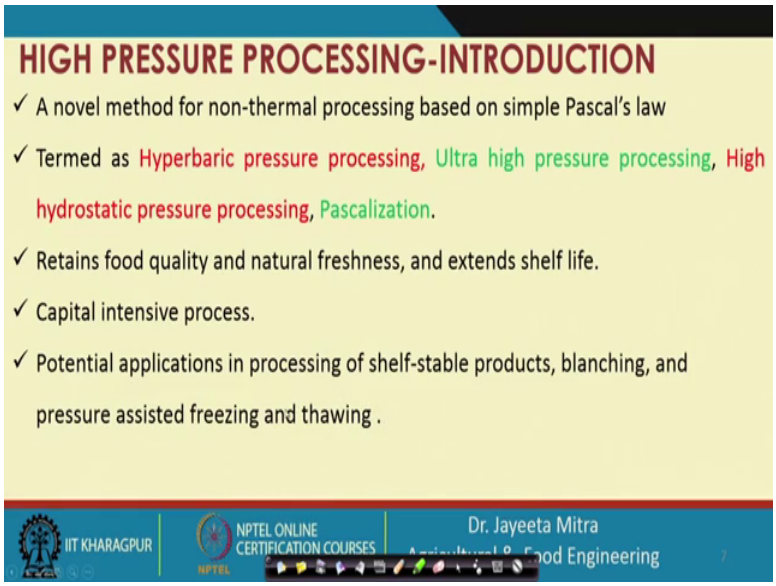

So, its method it is a novel method or non thermal processing method, which works on the principle of the Pascal's law and it also termed as hyperbaric pressure processing as a pressure is much much higher than the atmospheric pressure also called the ultra high pressure processing, high hydrostatic pressure processing, pascalization etcetera ok. It retain the food quality and natural freshness and extend the shelf life. So, these all are speciality of this method HPP and it is very much capital intensive process because the initial set up that we require and this pressurization and depressurization this cycle we have to perform for many times if we want to develop a system of industrial scale and that has to run for years. So, we need to design a very robust system ok.

So, capital intensive process it is an although we can we can perform only a small batch in every operation. So, these are the limitations of the process. Potential application in processing of shelf stable products blanching and pressure assisted freezing and thawing. So, there the application of high pressure processing is normally done.

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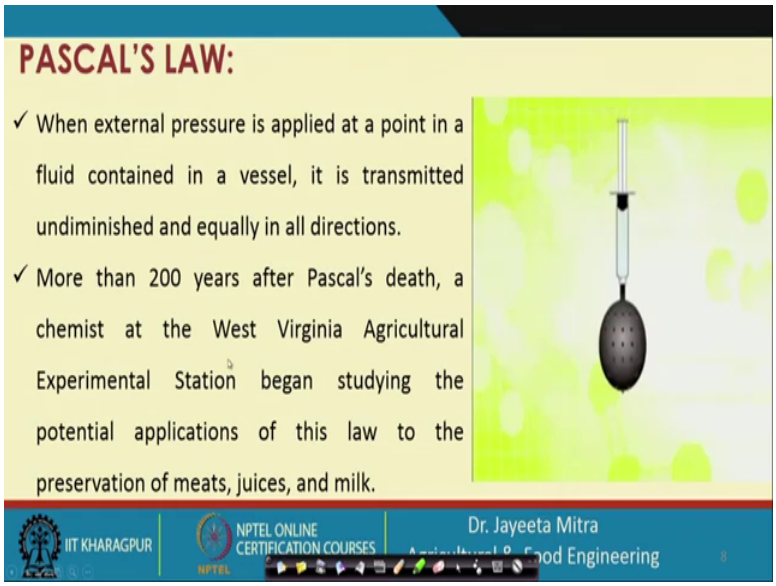

So, so, as we mentioned that it works on the principle of the Pascal's law, when an external pressure is applied at a point in a fluid contained in a vessel it is transmitted undiminished and equally in all direction right.

So, this is actually performed that when we apply the pressure isostatically. So, the pressure this distributed uniformly in the whole chamber and around the food. So, from everywhere the equal pressure is exerted on the product. More than 200 years after Pascal's death a chemist at the West Virginia agricultural experimental station began studying the potential application of this law to the preservation of meat, juices and milk.

So, we can see that this is the beauty of science that when some invention when it occurs we did not even think of that, it can be used for food processing in an efficient way, but nowadays this is very promising technology although it is cost intensive, but still since it gives a very good quality product. So, it has been mostly used in the juice processing and preservation etcetera.

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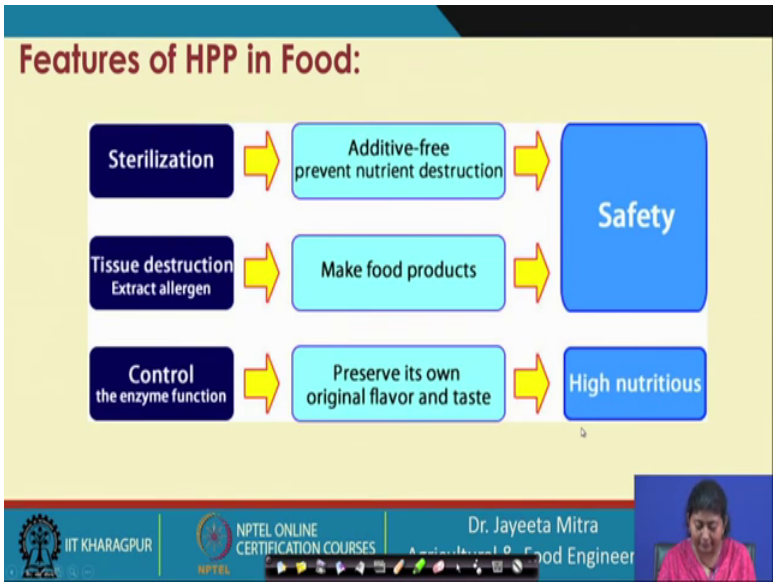

So, HPP performs the sterilization of food without having adding any additive to the food material. So, that way it is an additive free method and it prevent the nutrient distraction because no heat treatment we are applying to this, also because of tissue distraction the extract allergen that will be destroyed and make the food product safe.

So, the safety is the first concern that we can get by the HPP treatment second is the control of enzymes. So, by this method we can control the enzymatic activity so, that the food can preserve its original flavour and taste for example, if we apply the thermal method sometime there are enzymes in the food itself. So, that can cause some decolouration colour degradation and of flavour development. So, those can be omitted in the HPP treatment ok. So, therefore, the nutrition is also intact.

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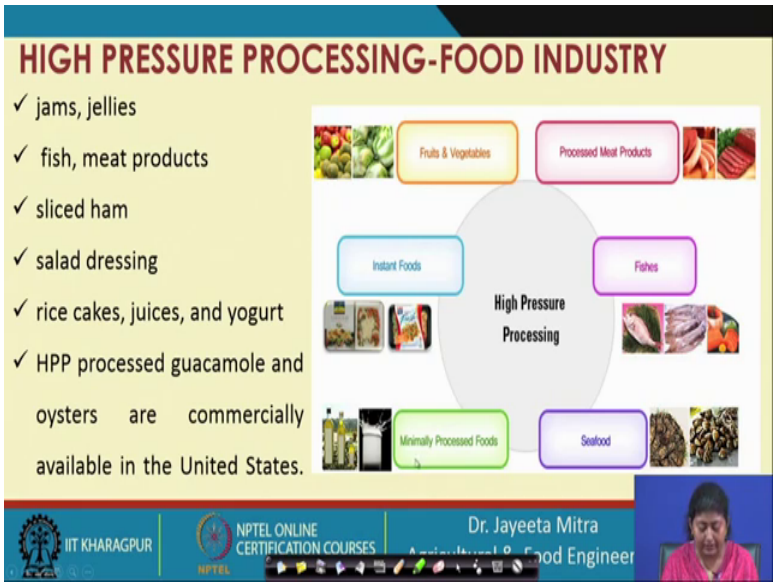

So, high pressure processing is applied to many cases in a in a food industry for example, fruits and vegetable then processed meat products, fish then sea food minimally processed food then instant food fruits and vegetable. So, all these are area including the sliced ham, salad dressing rice, cake, juices and yogurt. So, all these are you know the areas where the HPP is applied not in India may be it is not that much popular now only for very high cost product preparation we use HPP all though in our in a research oriented works are going on HPP, but in industrially not much utilization we have seen here, but in other countries it is in use now a days.

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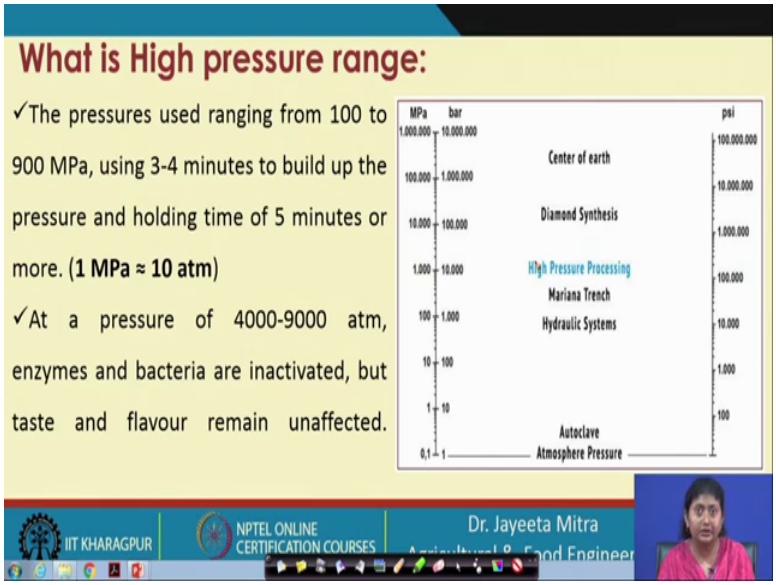

So, let us see how much high pressure is required to cause the degradation of the microorganisms or or distraction of the microorganism. So, very high pressure is required here the pressure used ranges from 100 to 900 mega pascal even 1000 mega pascal in some cases using 3 to 4 minutes to build up the pressure and holding time up to 5 minutes or more ok.

And as a pressure of 4000 to 9000 atmosphere enzymes and bacteria are inactivated, but taste and flavour remain unaffected. So, there are range of the pressure not you know for every microorganism the destruction level or the pressure requirement for which they can be inactivated is not same, that may vary from microorganism to microorganism even for bacteria or mold those may vary and generally the enzymes are resistant more.

So, for them the high pressure is required that is around 4000 to 9000 atmosphere ok, I was still the taste and flavour are not affected. So, we have see; we have a chart here that can show you that how the pressure varies from atmospheric pressure to autoclaving, hydraulic systems then Mariana Trench, which is the you know the deepest point where we can in under the sea level in the world where we can measure the pressure and that is still the little higher than the 100 mega pascal and high pressure processing is even higher than that. So, you can imagine that, how much strong system you have to build? How much strong pressure chamber you have to build for the processing of high pressure?

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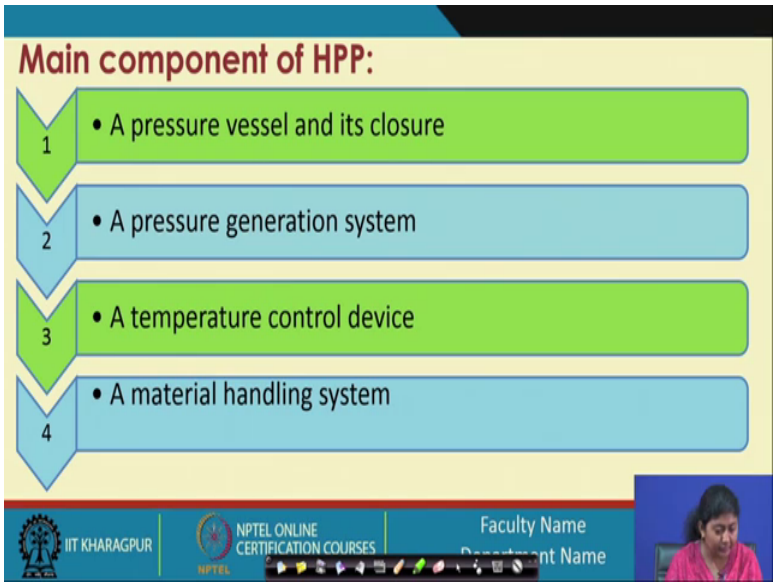

Let us see the main component of high pressure processing first we require a pressure vessel and it is closure ok. So, top and bottom closure and the pressure vessel we need then a pressure generation system, that is a very important component of the whole system and the temperature control device although our target is to reduce the temperature we do not want high temperature in case of HPP processing, but what happen that these are thermodynamic parameter pressure and temperature and these are have some synergistic effects.

So, when we expose very high pressure some increase in the temperature is inevitable and we want to control that. So, we provided and sometime there are there are few application not much in food, but in other application of HPP where temperature is also associated with the pressure and we need a material handling system just to make the inflow and out flow of the product from the chamber. So, the material handling system is also required.

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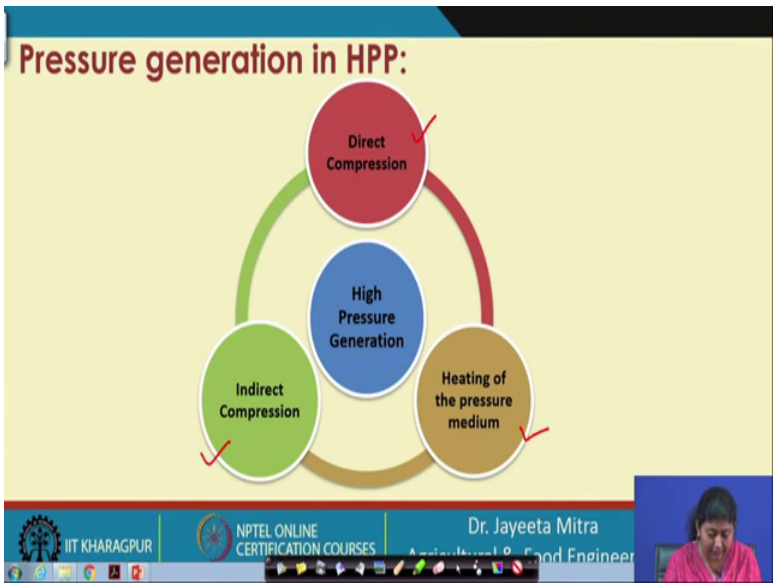

Pressure generation in HPP can have by three different mechanism ok. So, for this much high pressure generation either we can go for this direct compression method or indirect compression method and the third one is the heating of the pressure medium. Now let us see individually that. What are these methods? The direct compression indirect compression and the heating of the pressure medium.

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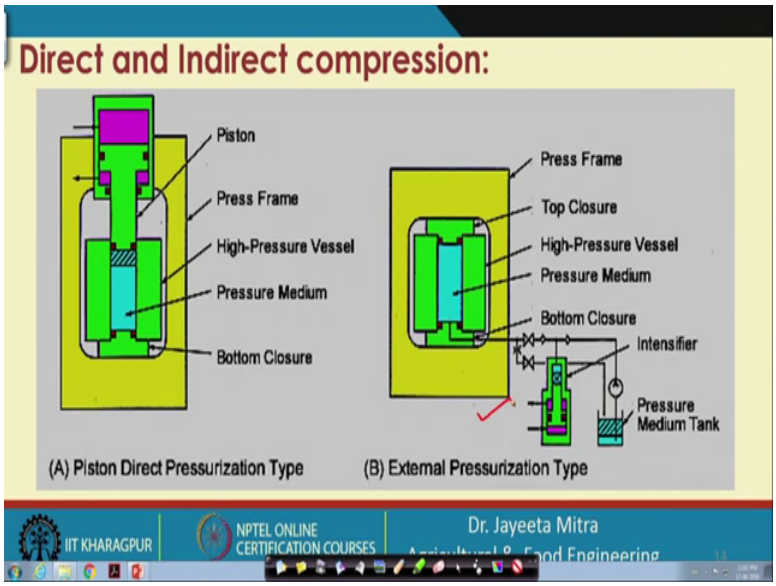

So, direct and indirect compression is you can see the diagram A, which shows the direct compression direct compression. So, here the piston is used to direct pressurize the fluid or the pressure medium which is here and there is a bottom closure will be there the piston will be there, there is a press frame and a high pressure vessel ok.

So, in the large scale there is a this kind of system development is a bit tough because of the problem of ceiling of the piston head and the chamber. So, there is a problem for generating this kind of a system in a small large scale therefore, it is not much used for the food processing in a large scale equipment and there is another system, which is the external pressurization or indirect type system. Here also the geometry is bit seem that we have a press frame we have a top closure and bottom closure in the previous one we had only the bottom closure because from the top the piston is coming and in this system we had the direct system we have the intensifier within the chamber right.

However in the in the eugenic pressurization we have the pressure medium here we have the high pressure vessel top and bottom closure and we have a different separate pressure medium tank and we have an intensifier externally. So, this is fill the pressurize liquid is filled into this and then the pressure is increasing indirectly by the intensifier ok. So, this two kind of systems, we can observe mostly this system is used in the laboratory scale or the batch food processing equipment.

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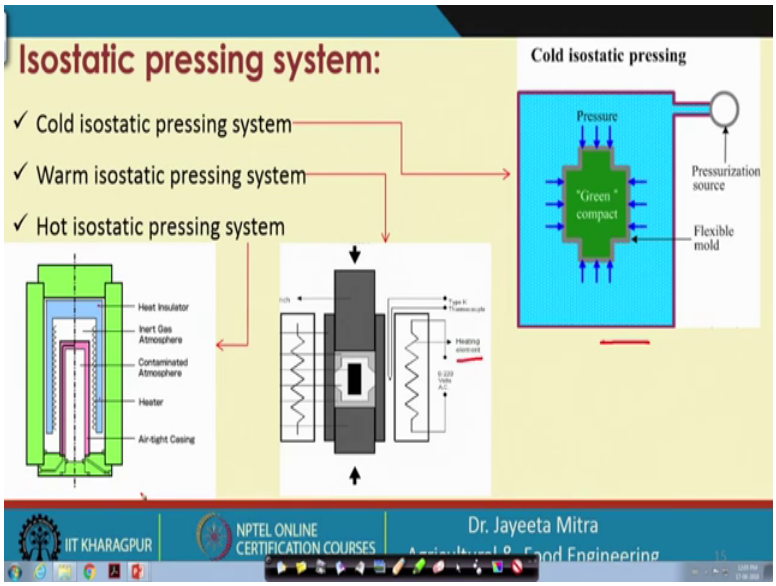

And the third one that I told that heating of a pressurized medium so, that is another method because we know that when we heat the you know the pressurize medium that the temperature will increase and also the pressure is increase and pressure is increase in terms of a vapour pressure actually. So, that is in this particular case we are not going to use that for HPP, but that is also one method.

Now isostatic pressing system isostatic pressing system can also be of three type first is the cold isostatic pressing also this is called the CIP system. So, cold isostatic pressing system is this diagram where the product is there and then the pressure is from all the side because it is isostatically filled by the product that we are keeping inside the pressurized medium. So, whatever pressure we are providing that pressure from the pressurization shows that is uniformly distributed on the flexible mold ok.

Now, in the other case when we see the warm isostatic pressing system there we have a heating element we have a heating element and across two electrode we are we are sending the electrical current and that heat this section there is a thermo couple attach, which control the temperature of this two heating section and the and the food is or the material is inside the pressurizing chamber. So, this is warm isostatic pressure ok.

So, this is another method and the third method is the hot isostatic pressing system, where we have a heater inside adjacent to the media and there is a heat insulator there is a heat insulator and the inert gas atmosphere is there where the where the heater is. So, in

this kind of a system we provide the hot isostatic pressing system. So; that means, with pressure we are having the effect of the high temperature as well, but normally for food we are using the cold isostatic pressing systems.

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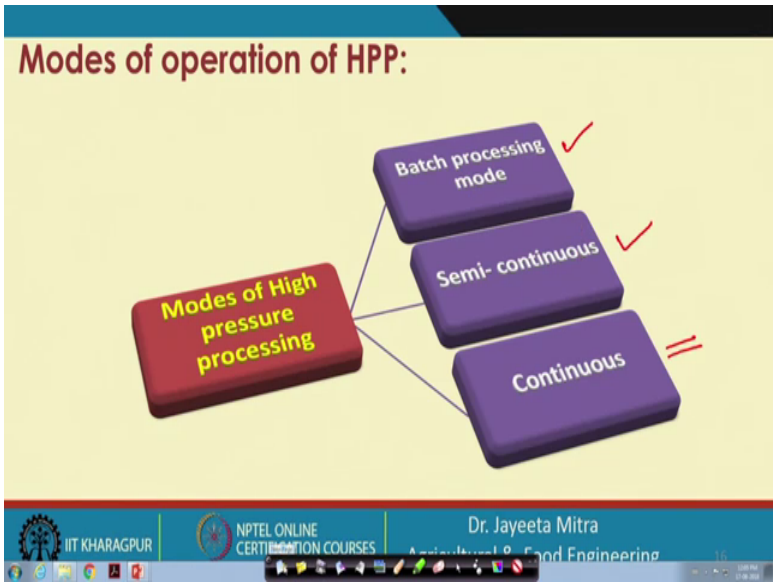

Modes of high pressure processing has I mentioned that we mostly get the batch processing module and somewhere we can see the semi continuous we hardly get the continuous module specifically for food we get very less.

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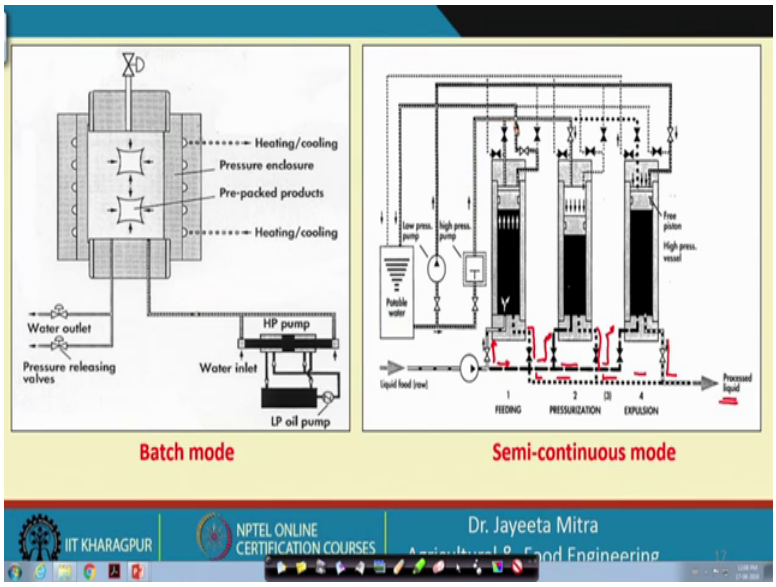

So, mostly this two we are we can observe and this is the batch mode kind of a system where there is a intensifier externally and there is a water inlet. So, this high pressure pump is sending this pressurized water into the chamber after the loading of the product is done. There is a pressure closure and there is a heating or cooling functional option is given and the water outlet is there when we wants the release of the pressure that time there should be some exist of this pressurized water so, there is a pressure release valve and the water outlet. So, this is kind of a system which is called the batch HPP system.

So, what is the other system? The other system is this semi continuous mode when what happen is that the liquid food we are sending by pump to the chambers and there are chambers in series ok. So, this is entered into this pressurize the liquid food is entered into the chamber and then after one set of processing this is entered to the process liquid section and the since it is in series. So, for all the consecutive pressure chamber the feed is entered ok, so, this is entered here and then it is going to this channel and then enter.

So, like that it is going and the after processing, this is coming to the common exit channel. So, the process liquid is going out and the high pressure pump is there which is sending the pressurize liquid here and that is again sending to the other consecutive lines ok.

So, what happens is we make a sequence here when one chamber is in pressurized condition the other chamber is in the depressurized condition ok. So, this sequence is maintained in all the condition all the consecutive section and that we call a semi continuous system. So, we continuously feeding the liquid food in all the chambers and we maintain the sequence of making one as pressurize the other as depressurize and the sequence is going on and the semi continuous operation is performed.

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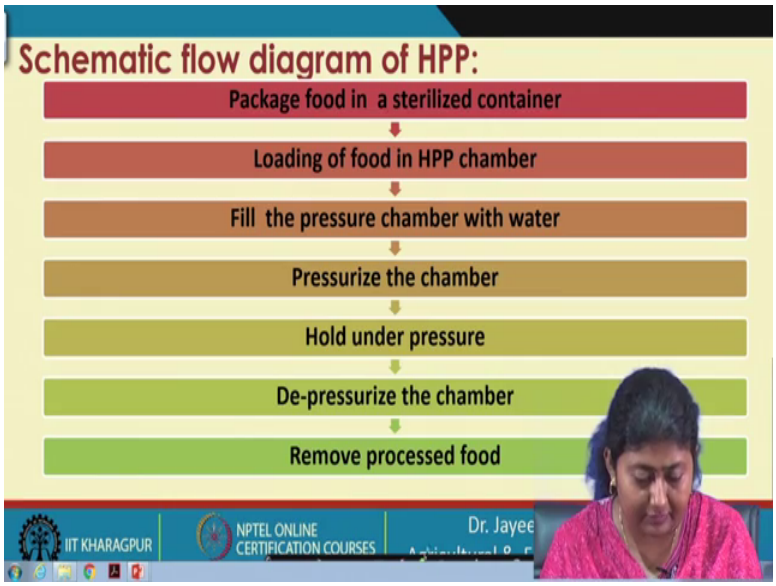

So, to summarize the process first the package food in a sterilized container is given then that is loaded to the HPP chamber, then fill the pressure chamber with water pressurize the chamber this is done by the intensifier then hold under that pressure for the for a required period of time then depressurize the chamber and remove the processed food. So, this is the whole chain that we perform in HPP system.

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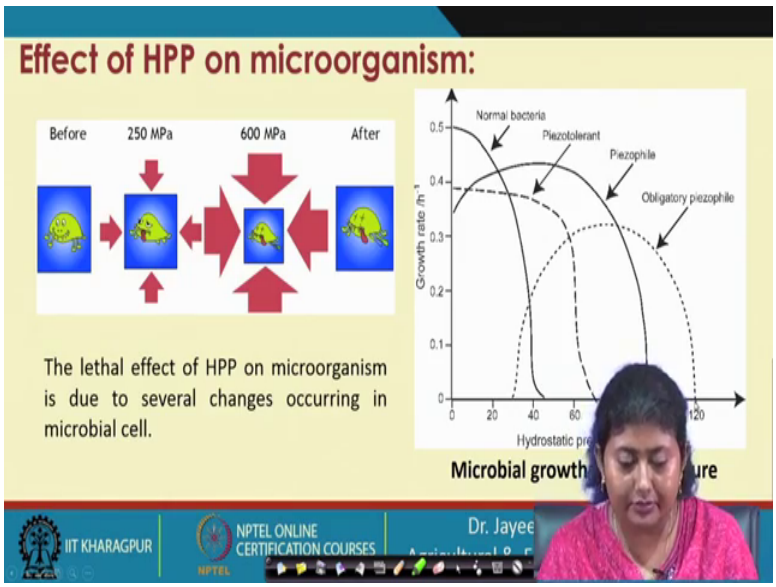

Now the most important thing that is what is the effect of high pressure processing on microorganism ok. So, microorganism which in the atmospheric pressure can very well

sustain as we increase the pressure up to 250 mega pascal they start you know start I mean their growth stops and they start to decreasing.

So, then what happen that when we increase the pressure up to 600 mega pascal. So, the complete inactivation or the destruction of the microorganism will be there. So, at 250 days start inactivate inactivating and at 600 mega pascal they fully destroyed. So, when we release then the pressure and bring it to the normal condition the microbes will not be again you know again can grow and contaminate the food. So, the Lethal effect of HPP on microorganism is due to the several changes occurring in the microbial cell.

So, if we see the microbial growth rate versus pressure. So, the growth rate per hour versus pressure if you can see. So, as we increase the pressure this is in mega pascal. So, as we increase the normal bacteria will destroy as we reach to the little bit higher than the 40-45 around ok. So, some bacteria are there they can withstand little bit of fresh air. So, those are called the piezotolerant there are piezophile. So, which can sustain even up to higher that is around 100 mega pascal and obligatory piezophile these are there is a range of this the bacteria. So, mostly they will destroyed beyond this pressure level.

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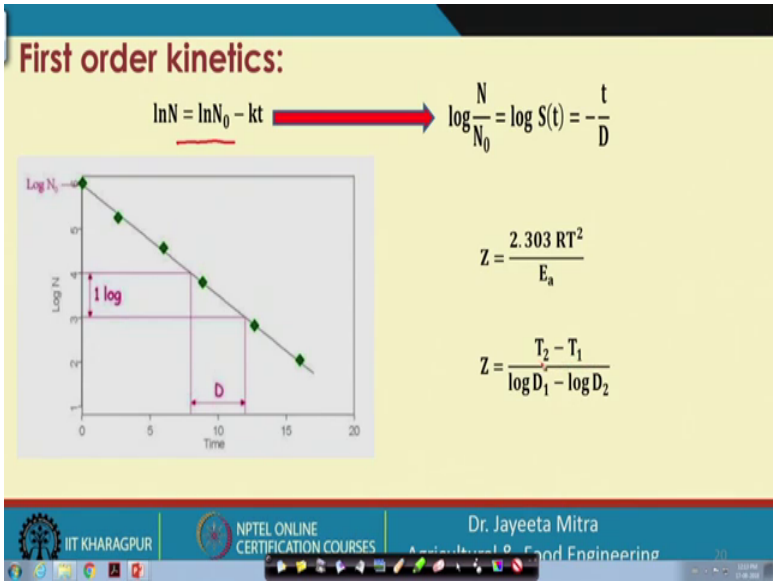

So, if we see destruction kinetics of the microbes as we have seen we have discussed this in some of our chapter in this course that microbial death kinetics how from the initial number of N02 N they are coming with the time T and how they decrease. So, here also the same principle is valid only the difference is that in that case the destruction

was because of the thermal effect and here the destruction is because of the pressure effect ok.

So, if we plot that the initial number of microorganism with time we can get the equation as this ln N equal to ln N 0 minus k t. So, log N by N 0 that is equal to log of S t that is equal to minus t by D. So, this is called the sterilizing sterilizing value if you remember. So, this way we can calculate where D is the decimal reduction time and t is the time taken to inactivate the microorganism and Z we know that Z is the is that by in case of the thermal effect we have discussed that Z value causes the increase in the temperature for that one log cycle reduction will be there ok.

So, this is the effect that Z equal to 2.303 R T square by E a and if we know the two temperature. So, Z is equal to T 2 minus T 1 by log of D 1 minus log of D 2 where D1 D2 are the inactivation D, D value of temperature corresponding T 1 and T 2.

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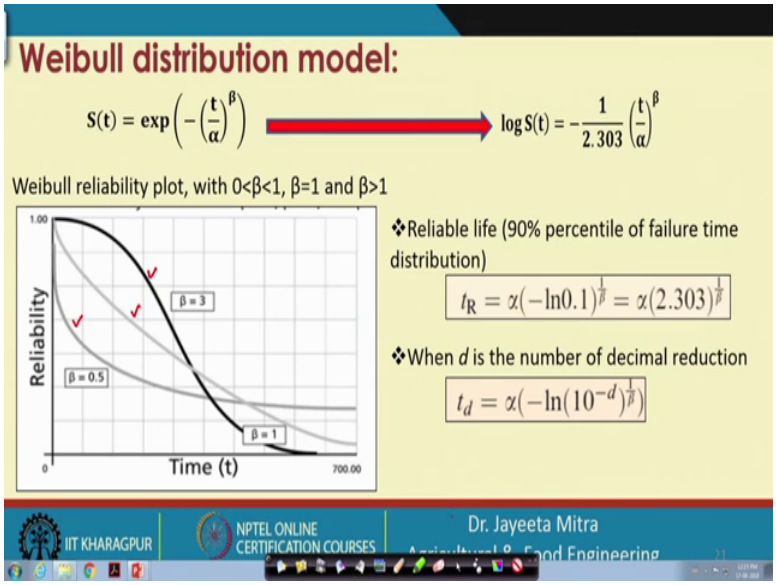

So, in this case in this case the destruction follows this kind of a pattern which will be explained by the Weibull distribution model. So, this is one model there are many such kind of model exists in high pressure processing that has been generated by you know empirical model development. So, S t is equal to exponential minus t by alpha to the power beta where Weibull reliability plot if we draw where beta varies from 0 to 1 which is which is this plot beta equal to 1 and beta greater than 1. So, for that it has been plotted as Weibull reliability with respect to time ok.

So, this equation S t is equal to exponential minus t by alpha to the power beta can be simplified as log S t that is equal to minus 1 by 2.303 into t by alpha to the power beta. Reliable life where the ninety percentile of failure time distribution can be expressed as t R that is equal to alpha into minus ln 0.1 to the power 1 by beta that is equal to alpha into 2.303 to the power 1 by beta and the d is the number of decimal reduction. So, number of decimal reduction t d that is equal to alpha into minus ln 10 to the power minus d to the power 1 by beta.

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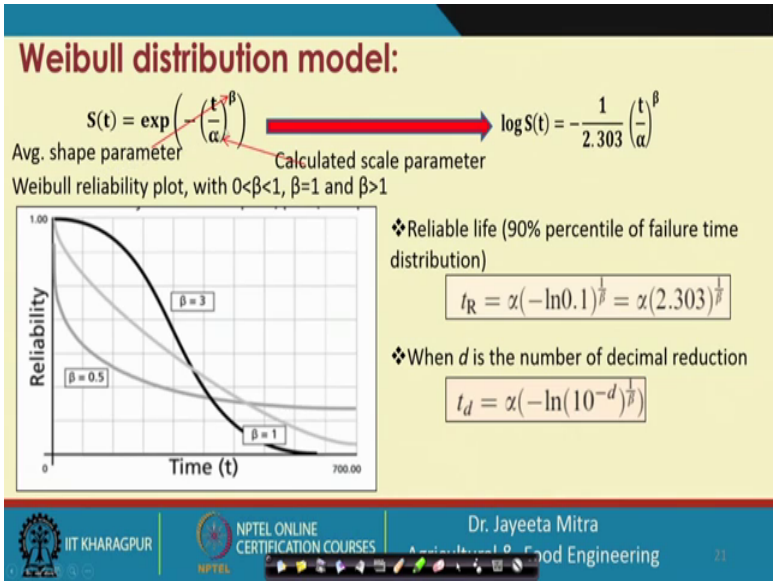

So, this is how the distraction the microbial distraction can happen for the different beta value and this values as depends on the average shape parameter that is the beta and the alpha is the calculated scale parameter.

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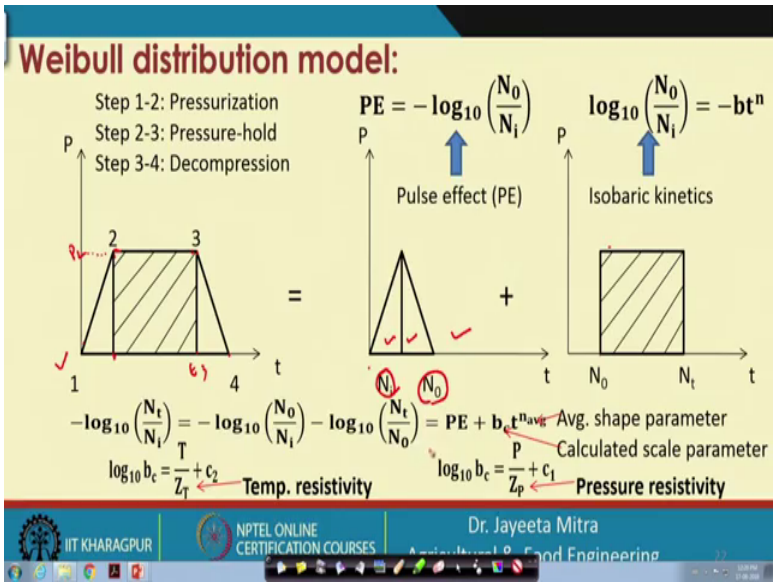

So, how that can be interpreted that that Weibull distribution model. So, as we mention that there is a pressurization initially then we have to hold it for a certain time and then again release of the pressure will be there. So, here in this pressure and temperature diagram this diagram we can see 1 to 2 the pressurization effect or the pressurization will occur. So, when we have reached time scale here then from 2 to 3 there is pressure hold. So, we will maintain the pressure whatever we have achieved at P 2 up to this time T 3 and then again it reduces to the atmospheric pressure.

So, this two effect we can categorize into two different graph one is considering the pulse effect that is increase of the pressure and decrease of the pressure ok. So, this is that and the other is showing the isobaric kinetic that is been constant pressure isostatically constant pressure was applied on the food that time what was the degradation. So, this is initially we had N i in initially we had N o microorganism sorry here N i is the initial and N o that we are attaining after certain time ok.

So, when we reach to N o then N o to N t initially it was N i then we have reached to N o and N o to N t that we hold it and after that the degradation will be. So, to model this part that is the pulse effect the equation is pulse effect equal to minus log 10 N 0 by N i and the other case the isobaric kinetics that effect is visible as log 10 N 0 by N i equal to minus b t to the power n right ok.

So, all together when the distraction is from the initial to the final one. So, minus log 10 N t by N i that is equal to this effect pulse effect N 0 by N i log 10 minus other isobaric kinetics so, this together. So, we can write P E plus B C into t to the power n average where n average is the average shape parameter and c is the calculated scale parameter; that means, the alpha that we have discussed there and n average is actually the resembles with the beta factor we can write this the calculated scale parameter b c. So, log 10 b c that is equal to T by Z T plus C 2 where Z T shows the temperature resistivity and log b c to the base 10 equal to P by Z P plus C 1. So, here Z P signifies the pressure resistivity ok.

So, temperature resistivity and pressure resistivity these two are the parameter by which we can assess that how much the distraction of the microorganism will takes place and using this combine equation we can assess that what will be the, I mean distraction of the microorganism. So, this is how the Weibull model is interpreted I hope we have reached almost the end of this HPP.

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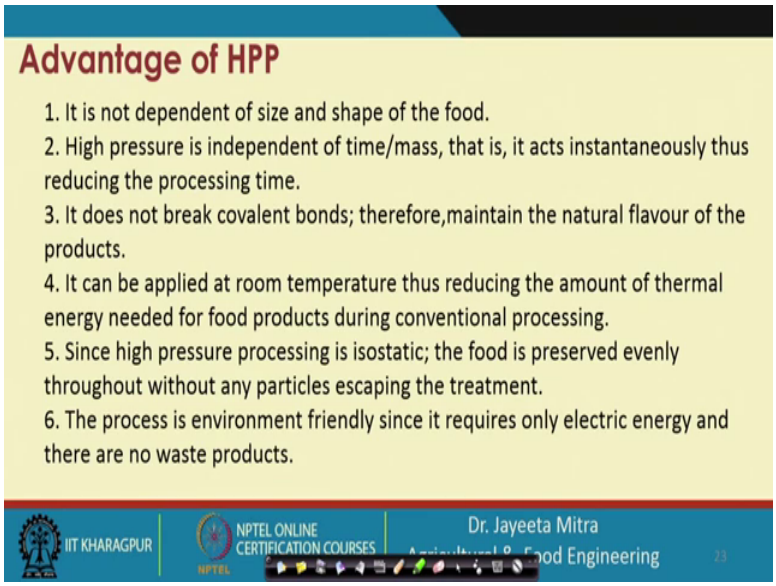

So, let us just summarize the advantage of HPP. It is not dependent on the size and shape of the food and because the shape does not matter in the sense, if you apply the pressure it is applicable on both the sides. So, all the particle of the food or all the section is exposed to exposed to the same pressure condition.

High pressure is independent of time mass that is it acts instantaneously thus reducing the processing time. So, it is not that suppose temperature you are giving an gradually the temperature is increasing from the or temperature has to reach from the surface to the centre, but here the pressure is instantly distributed throughout the whole section. It is not break the covalent bond therefore, maintain the natural flavour of the product. It can be applied at room temperature thus reducing the amount of thermal energy needed for food products during conventional processing.

Since high pressure processing is isostatic the food is preserved evenly throughout without any particle escaping the treatment and the process is environment friendly since it requires only electric energy and there are no waste product generated. So, that way it is very helpful.

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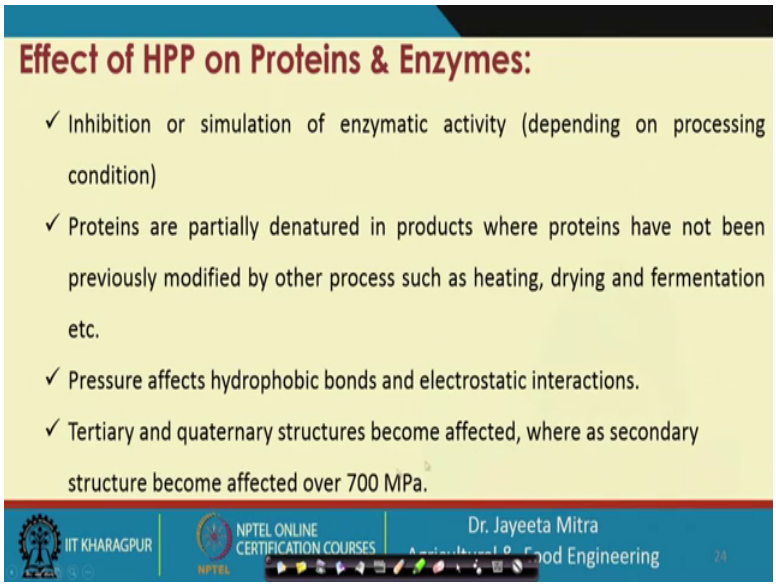

It has some specific effect on the proteins and enzymes inhibition or simulation of enzymatic activity. So, it depends on the processing condition that how much pressure we are providing, how long we are providing proteins are partially denatured in products were protein have not been previously modified by other process such as heating, drying and fermentation etcetera.

So, protein are partially denatured in this cases. Pressure effects hydrophobic bonds and electrostatic interactions. Tertiary and quaternary structure become affected whereas, the secondary structure become affected over 700 mega Pascal pressure.

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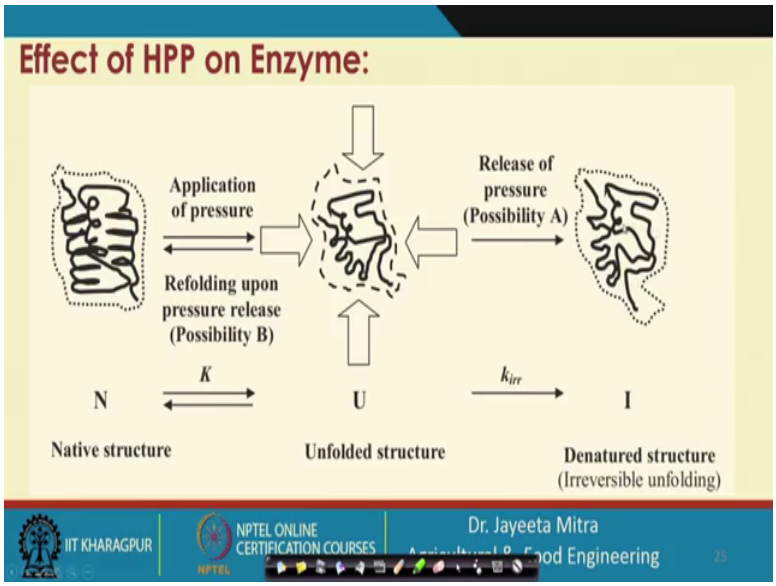

So, we can see that when unfolded structure enters into HPP chamber and we provide the isostatic pressure it may happen that the condition A arise that is release of the pressure will cause denatured structure of the protein or it may happen that the you know the release may cause the unfolding or from the unfolding state to the native state conversion will be there. So, native to unfold can happen because of the application of pressure and again the unfolding to native may also become because of the release of the pressure ok.

But in some cases when denaturation happen so, there it is not an reversible process ok. So, native to unfolding this part is reversible; however, from the unfolded to denatured part this part is not reversible ok.

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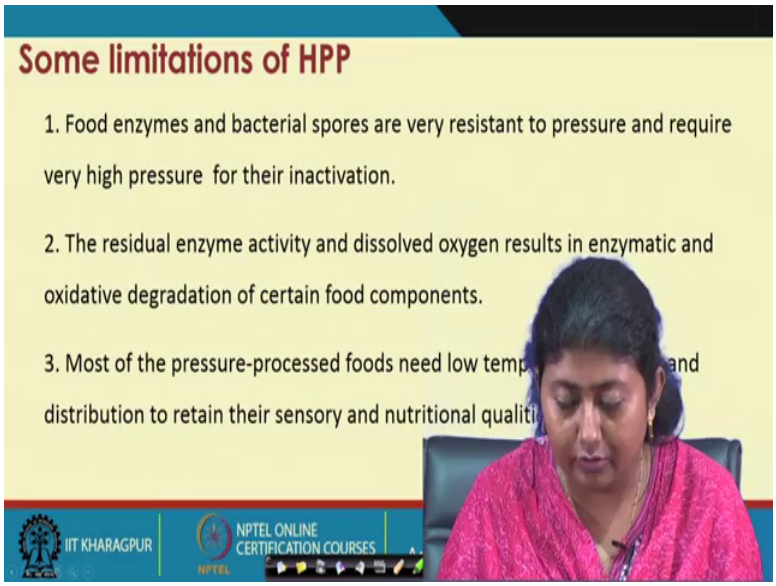

So, the limitations is that food enzymes and bacterial spores are very resistant to pressure and require very high pressure for their inactivation ok. So, spores inactivation of spore and enzyme require very high pressure. The residual enzyme activity and dissolved oxygen results in enzymatic and oxidative degradation of certain food component and most of the pressure processed foods need low temperature storage and distribution to retain there sensory and nutritional quality. So, will stop here and will continue with the next topic in a next class.

Thank you.