Fundamentals of Food Process Engineering
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Lecture – 31
Freezing & Freeze Drying

Hello everyone, welcome to the NPTEL online certification course on Fundamentals of Food Process Engineering. Today we will start a new chapter on Freezing and Freeze Drying. We have just now seen the in the previous chapters one important unit operation that is drying. And drying is as we have mentioned that it is a method of preserving the food by lowering the water activity to the safe storage level. Similarly, freezing is also one very important operation by which we can store or preserve the food material for longer duration of time. However, the difference is that freezing is a low temperature preservation.

So, in today's class we will see that how this freezing operation is being done on different food material.

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So, if you have seen the various kind of fresh fruits and vegetable markets where, you know storage of fresh fruits and vegetable are being done. So, you might have seen that freezing is the most common operation and mostly in the shelf of the you know storage.

Frozen products are kept for longer duration and the advantages that when we freeze the material and after certain time of storage if you want to reuse it, so, we can get the initial quality and the structure of the food intact.

So, that is not available if we preserve them by drying. So, drying causes shrinkage and case hardening and the deterioration of the structure, quality, flavor, color etcetera. Whereas, freezing can preserve those quality very well; therefore, it is very important operation. And not only for you know fruits and vegetable, freezing is very common for the muscle foods such as fish, meat products etcetera. So, there by freezing is very important.

Now, another low temperature preservation that we sometime do the term is chilling, but the difference is that, chilling and freezing in both the cases we lower the temperature, but chilling is done above melting point and freezing is done below melting point. So, this is the you know a little bit overview of that.

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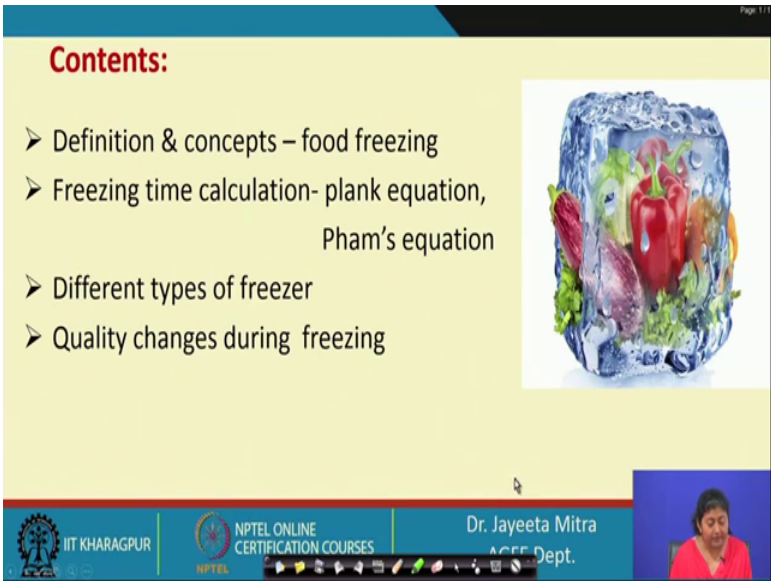

Now, in this chapter we will cover the concept of food freezing, freezing time calculation by planks equation and Pham equation, different types of freezer, quality changes during freezing. So, first we will see the definition and concept of food freezing.

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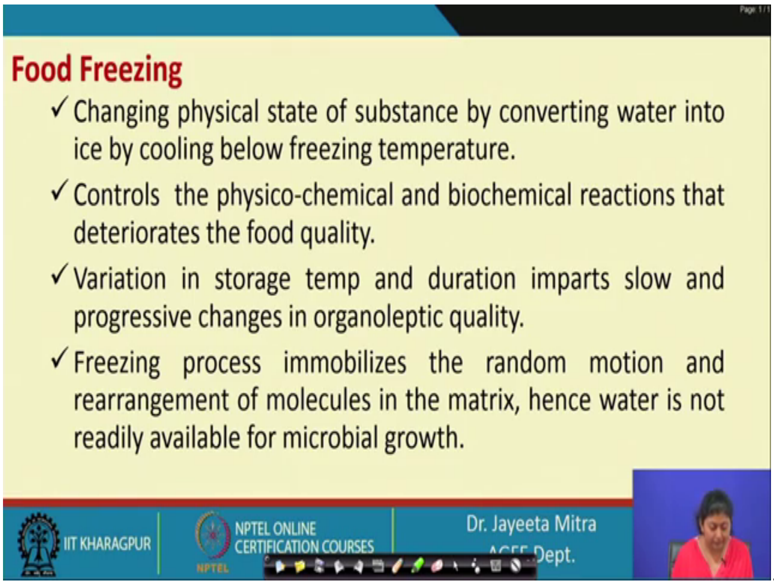

So, freezing involve changing physical state of substance by converting water into ice by cooling below the freezing temperature ok. And also one thing I must mention here is that you know when we do drying and after that we can preserve the product at normal ambient temperature right.

Because the water activity is so, low. So, generally the contamination does not take place and also we can keep at certain temperature and relative humidity and based on that combination we can decide what is the safe storage moisture and we can dry after that level. However, if we dry by this method if we you know preserved by freezing ok, so, then we need to keep the condition or the temperature intact till we consume the product. If the fluctuation of temperature happens then the again the ice switch to water phase conversion will be there and it will cause some undesirable changes in the quality of food. Therefore, for frozen storage we need to maintain the cold chain throughout the you know production processing to the consumption.

Now, by freezing we can control the physical chemical and biochemical reaction that deteriorate the food quality. Now this reaction minimize because by conversion of water to ice, we restrict the mobility of the liquid water. And along with the liquid water what are the dissolved solid and enzymes. So, all those you know restricted to some certain locations. So, there mobility is restricted and because of that the changes will be minimal.

However, variation in storage temperature and duration imparts slow and progressive changes in organoleptic quality. That means, while performing the freezing operation if we you know perform the slow freezing or we perform fast freezing quick freezing.

So, both the cases formation of ice crystal or the structure will be different and they will affect the food quality in different way. So, freezing process immobilize immobilizes the random motion and rearrangement of molecules in the matrix, hence water is not readily available for microbial growth. So, not only chemical reaction, but microbiological reaction is also minimized. So, the difference from the previous method is that, in case of freezing we are not removing the water, but here restricting the mobility of the water by converting the water phase to ice phase and thereby we can keeping the moisture of the product intact.

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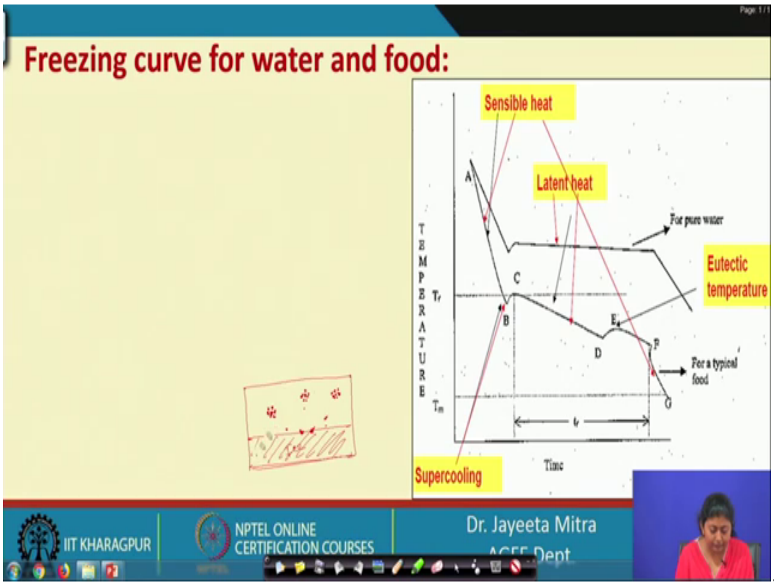

So, when we want to consume it with all the product we bring it to the normal ambient temperature and then we can get the initial quality almost the initial quality of the food. Freezing curve for water and food ok.

Now, before describing the curve where we have plotted the temperature versus time ok and how this changes happen from one stage to the other let me first explain you that how this phenomena of freezing normally takes place that. Lus say let us say this is a container where this part is ice and here the liquid water is there right. So, liquid water molecule will liquid water and this ice in this closed chamber will try to come to an equilibrium situation. So, what will happen that the liquid will come to the interface this ice and water interface and it will try to convert to ice.

So, the latent heat of fusion will be released and similar molecule will convert from ice to water. So, this process is going on when it comes in the equilibrium situation. But what happened the mobility in the in the liquid water is quite high molecular mobility in the liquid water is quite high ok. Now when we try to lower the temperature; when we try to lower the temperature then what happened? So, initially the molecules those were in random motion will try to restrict the velocity ok. As temperature will lower they will try to have minimal movement and come very close very close to each other and after certain time they will try to form aggregation ok.

So, what happen they will the molecule will form certain aggregate in places and that is the onset of nucleation; from where again when this aggregation will attain minimum amount of you know diameter. So, then further crystal growth will start from this place and as we lower the temperature, so, freezing will be there ok. So, this is how freezing takes place as we lower the temperature. So, from the liquid water to frozen state it will become.

So, now let us look into the plot of temperature versus time. So, this upper plot this is for the pure water and the lower one this is for the food material.

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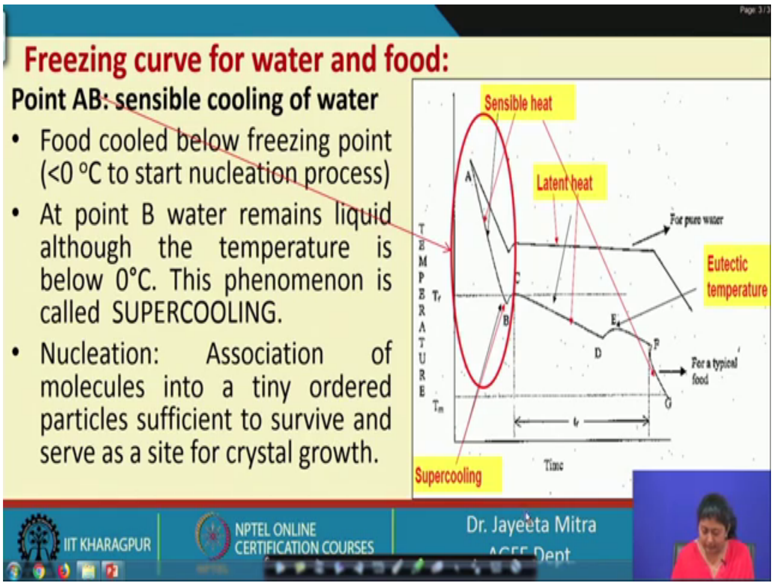

So, what will happen? First look into the point A to B. Initially, when we are taking liquid water and we are lowering the temperature of liquid water, so, sensible heat we are extracting. So, with time, the curve A to B showing the decrease in the temperature because of sensible heat removal and also the food is cool below freezing point that is lower than 0 degree and here the nucleation process starts. Nucleation has in the association of the molecules into tiny order particle sufficient to survive and serve as a site for the crystal growth. As I have just shown you that how those aggregation formed as lower temperature. So, at point B for in case of the food sample this nucleation starts.

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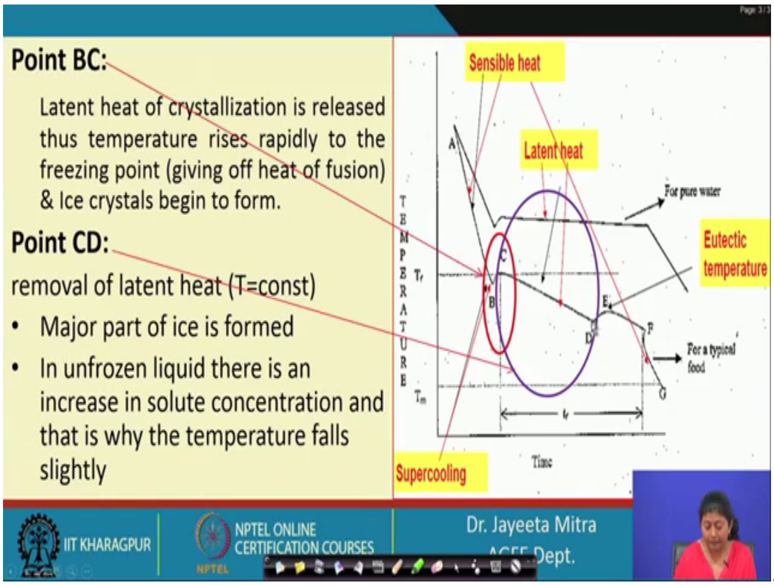

So, then we will go to the next section that is B to C. We can observe in both the plot for pure water and for the food sample there is a there is a little bit increase in the temperature from B to C zone this is because the latent heat of crystallization. So, as the crystal form heat will be released, latent heat of crystallization will be released and that will enhance the temperature of the food a little bit. So, slight increase in the temperature from B to C is observed here. So, latent heat of crystallization is released and that is temperature rises rapidly to the freezing point. Giving of the latent heat of fusion and ice now starts to form.

So, once nucleation happened, that is a first crystal formation is being done then it start increasing as we further lower the temperature. Now ideally the phase transition should happen at constant temperature that is zero degree for pure water. So, if you look into the pure water plot, there is not much change in the temperature. However, in the case of food material we can observe a gradual decrease in the temperature. This is because you can remember that while discussing evaporation, we have mention that boiling point elevation occurs when the solutes are dissolved into the water.

Similarly, here what happened that, when the liquid will convert to ice. So, as the concentration of the solutes in the food material, they will start increasing because less water available and solute concentration were the same ok. So, water has been converted from liquid to ice. So, that remaining liquid become concentrated in the solution that in the you know solute concentration because concentration will be similar. So, because of that the freezing point of the water will be lower

So, that is why freezing point depression occurs in this case for the food material. So, C to D major part of ice formed here in unfrozen liquid there is an increase in the solute concentration that is why temperature falls slightly.

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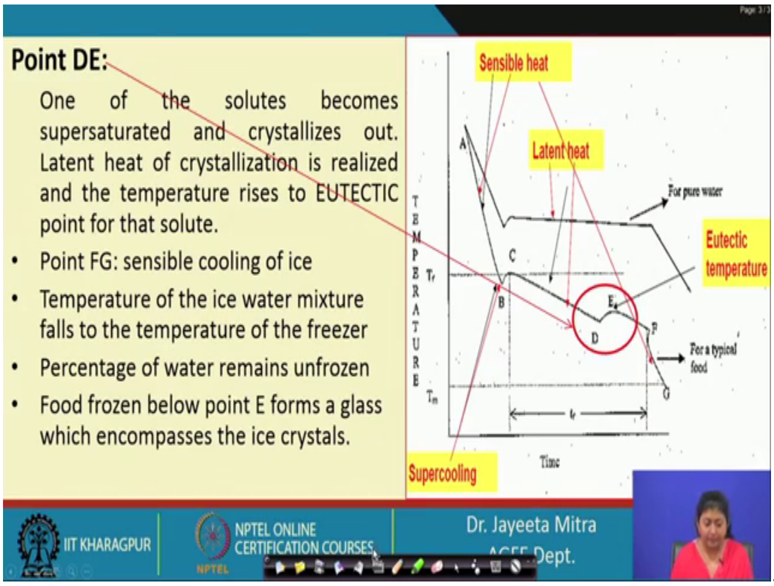

Now, coming to the point D to E; see this kind of thing is not available in the pure water. So, this property that is because of only the food material or a mixture kind of material we can observed this kind of behavior. So, one of the solute become supersaturated and crystallizes out. Latent heat of crystallization is realized and the temperature rises to the eutectic point of the solute.

So, eutectic point means lowest melting point of the eutectic mixture and what is the eutectic mixture? It is that when we mix two component and those are not reacting with each other, but they can mix properly and create an uniform mixture, in that case if we try to freeze it. So, what will happen that the minimum temperature that at which the melting locker. So, that temperature is considered as the eutectic temperature. So, we can observe at point E this eutectic temperature and then point F to G. So, till F all the food has been all the water has been frozen and then from F to G shows the sensible cooling of the frozen material ok.

So, temperature of the ice water mixture falls to the temperature of the freezer and percentage of water remain unfrozen. So, if a little bit of unfrozen water remains because it has become so, much concentrated. So, its freezing point will be lower to a higher extent and food frozen below point E forms a glass which encompasses the ice crystal.

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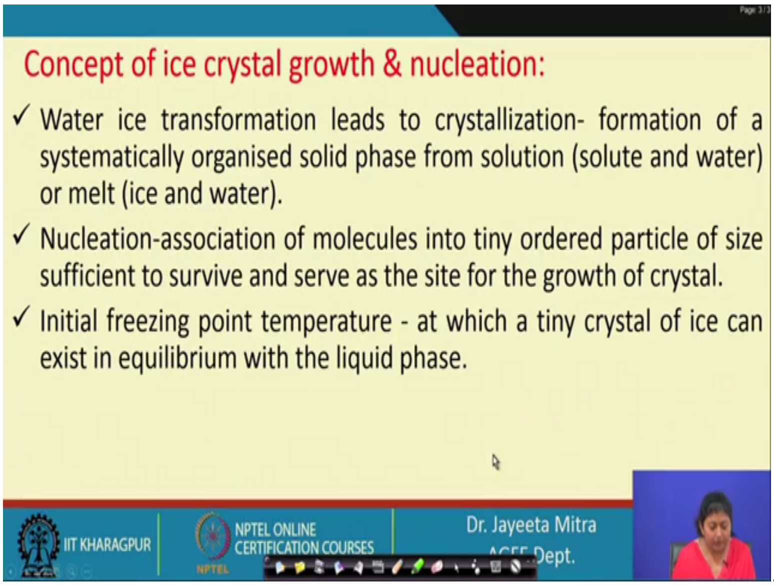

So, the concept of ice crystal growth and nucleation if we want to understand that; so, water ice transformation leads to crystallization that is, formation of systematically organized solid phase from the solution that is basically of the solute and water. Nucleation as we mentioned that these are the molecules into tiny ordered particle, of size sufficient to create the growth of the crystal over their surface. And initial freezing point temperature is such that at the temperature a tiny crystal of ice can exist in equilibrium with the liquid phase.

So, as i mentioned in the in that diagram that, initial freezing point; that means, at which the crystal of ice can exist in equilibrium; that means, how much liquid will convert to the crystal, the similar amount is you know converting to the liquid water. So, that condition arise and then we further lower the temperature and then the ice formation will increase.

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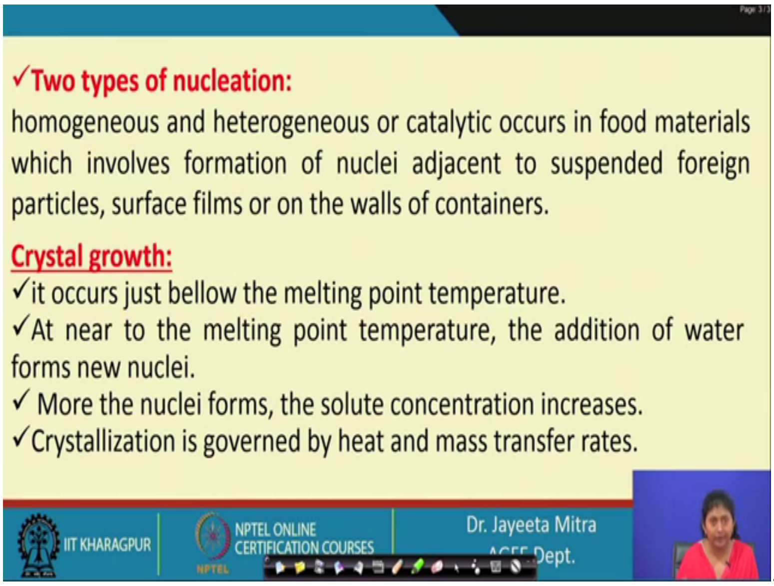

So, two types of nucleation we can observe homogenous and heterogeneous or catalytic nucleation, that occurs in food materials, which involve formation of nuclei adjacent to the suspended foreign particle surface film on the wall of the container.

So, these are the places where you know some induced nucleation may happen. Crystal growth it occurs just below the melting temperature. And at near to the melting point because crystal growth happens below the melting temperature that is why we have receive one super cooling before formation of the ice crystals ok.

So, then crystal formation will start and little bit temperature rise we have observed. So, at near to the melting point temperature the addition of the water forms new nuclei and more the nuclei forms the solute concentration increases. Crystallization is governed by heat and mass transfer rate.

So, because heat transferred is important because the rate at which we remove the heat or the lower the temperature. So, that causes that causes the nucleation and crystal growth and if we visualize that rate of nucleation with temperature.

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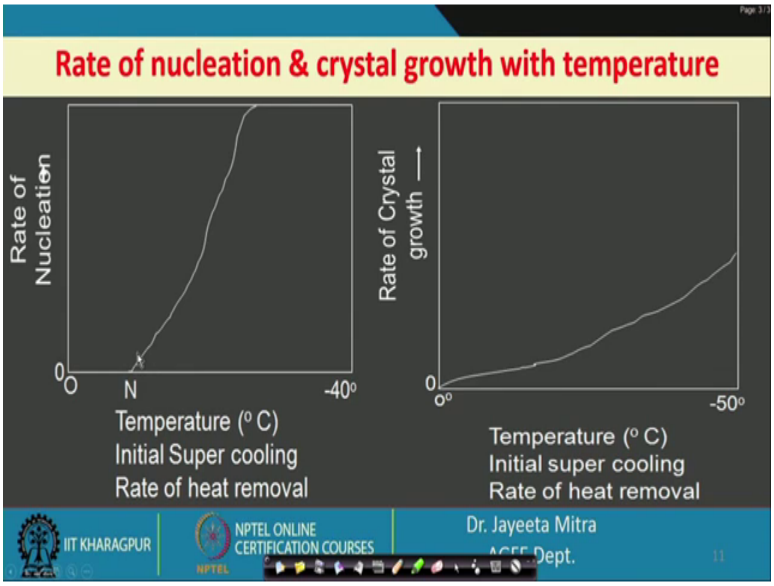

So, we can see that from 0 to minus 40; that means, we lower the temperature and at some point, when the rate of nucleation happens then this is the initial super cooling point. So, then rate of heat removal; that means, when the when this nucleation when this nucleation starts and then its rate will propagate has been move on to further lower temperature and here in the second picture we can see the rate of crystal growth with temperature

So, once the crystal growth has occurred because it has occurred not nucleation occurred lower than 0 degree; however, once the formation of ice has been done, it will start from the 0 degree and it will go up to as low as minus 40 or minus 50, because as the water will be freezing solute concentration increases. So, eventually the temperature will also you can know decrease.

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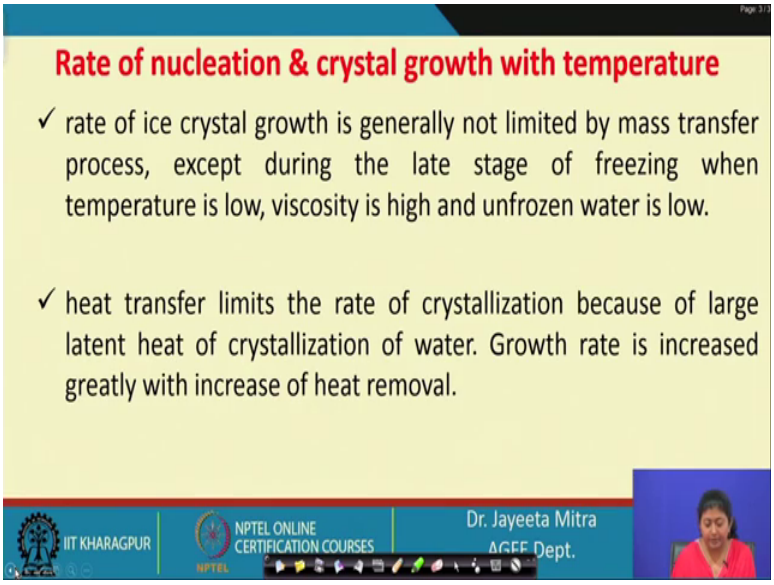

So, rate of nucleation and crystal growth with temperature; rate of ice crystal growth is generally not limited by mass transfer process except during the later stage of freezing. When temperature is low viscosity is high and unfrozen water is low; that means, initially we have mentioned that it is governed by both the transfer process.

Now, rate of ice crystal growth is generally not limited by mass transfer; however, this will be limited by the heat transfer process. Heat transfer limit the rate of crystallization because of large latent heat of crystallization of water needs to be extracted from the material to cause the freezing of the water. So, growth rate is increase greatly with increase in the heat removal therefore, at this stage heat transfer you know causes the higher effect compared to the mass transfer. So, will stop here will continue with the freezing process in the next class.

Thank you.