Fundamentals of Food Process Engineering
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Lecture - 15
Thermal Processing and Kinetics of Microbial Death (Contd.)

Hello everyone, welcome to the NPTEL online certification course on Fundamentals of Food Process Engineering. Today this is our last class of chapter 3 that is Thermal Processing and Kinetics of Microbial Death. So, we have discussed about you know the thermal destruction curve and microbial survival curve D value z value and also certain problem.

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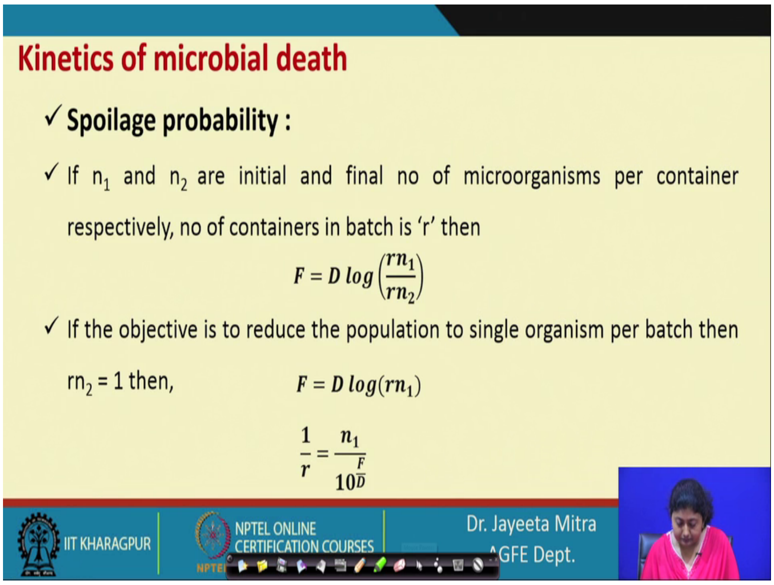

We have done now today we will continue with some more topic in that. So, first is spoilage probability.

So, you know spoilage probability is very important, whenever we want to process set of cans or any food material, because we want to make the probability always lower than 1, because if it is one; that means, there is a chance of contamination. So, we always want to lower it from the absolute value. So, we can calculated in this manner that if n 1 and n 2 are the initial and final number of microorganism viable microorganism per container respectively. So, number of containers in the batch is r.

So, then we can write it as F that is the process time will be D that is the decimal reduction time at that temperature, log r n 1 by r. N 2 n 1 and n 2 are the initial and final number of microorganism per container and there are number of containers in batch is r. So, r into n 1 that is the initial microbial load divided by r into n 2 that is the final microbial load ok. So, we can write in this way so the number of container in batch if it is r. So, out of r what is the probability of spoilage of can? So, what is the number of can that may be spoil after this treatment as well so that we need to find. Now if the objective is to reduce the population to single organism per batch right then, we can do the calculation in such away so, that r n 2 equal to 1.

Because, r n 2 is the final microbial load in each batch ok. R container in each batch and in each container there are n 2 number of microorganism. So, to a single organism per batch indicates r n 2 will be equal to 1. So, putting r into equal to 1 in this equation we can get F equal to D that is decimal reduction time into log r n 1, because r n 2 is 1. So, from here if we calculate 1 by r that indicates the chances of one container spoilage out of all r right. So that means finally, we want to calculate 1 by r; that means, the chances of spoilage of one can out of the r number of cans ok.

So, 1 by r from here we can write it as n 1; that is the number of initial microbial load per container divided by 10 to the power F by D total process time f divided by D that is decimal reduction time.

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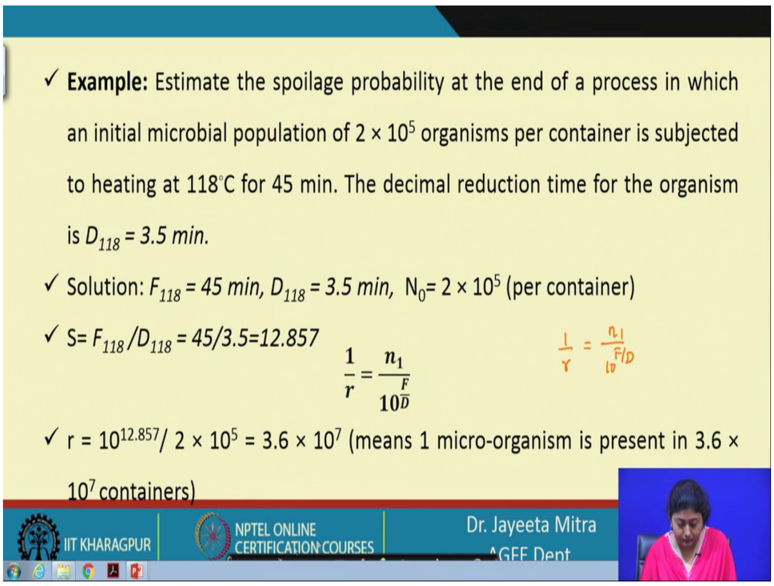

So, if we take one example on that, estimate the spoilage probability at the end of a process in which an initial microbial population of 2 into 10 to the power 5 organism per container is subjected to heating at 118 degree Celsius for 45 minute. The decimal reduction time for the organism is D 118 that is equal to 3.5 minute. So, we need to find the spoilage probability that is 1 by r an initial population of 2 into 10 to the power 5 organism per container that is this is n 1 small n 1 ok.

So, what we can do is F 118 that is the process time is given 45 minute. So, we are giving a processing to those containers for 45 minutes at 118 degree Celsius D 118 is 3.5 minute ok. So, what will be the final microbial load? So, F by D will perform F by D that is sterilization value: so 11 F 118 by D 118 that is 12.857. Now 1 by r we know that 1 by r is equal to 1 by r is equal to n 1 that is initial load divided by 10 to the power F by D; so then ok.

So, this is the case we need to find F by D and r is 10 to the power 12.857 divided by 2 into 10 to the power 5: so 3.6 into 10 to the power 7 right. That means, 1 micro organism is present in 3.6 into 10 to the power 7 container right. So, the probability is very low 3.6 into 10 to the power 7 container. So, there is a chance that 1 microorganism in those containers may be alive that can cause the contamination. So, the probability is very very low.

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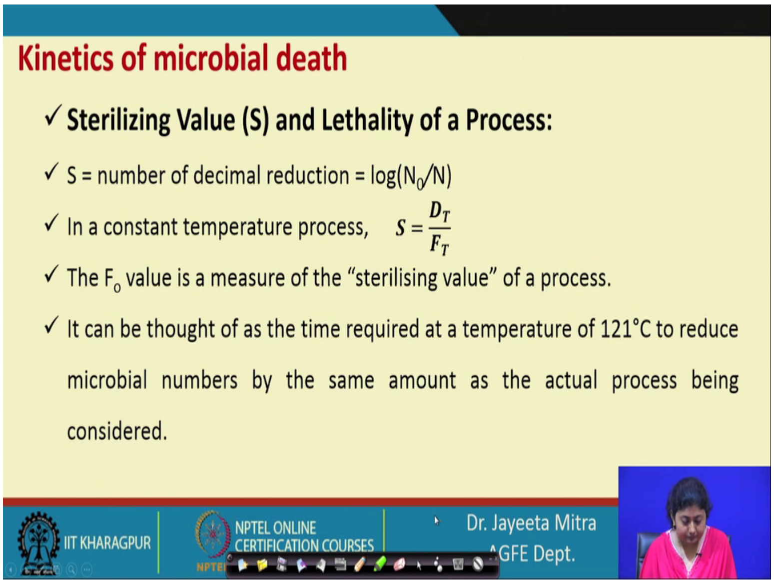

So, then sterilization value and lethality of a process; sterilization value we are discussing since the last class that is number of decimal reduction log of N 0 by N. aAnd in a constant temperature process sterilization value is D T by F T F 0 value is a measure of the sterilizing value of a process.

Now, it can be thought of as time required at a temperature of 121 degree Celsius to reduce the microbial number by the same amount as the actual process being considered ok. So, F 0 value it is thought of as the time required at a temperature of 121 because this is our reference temperature in a Celsius scale. So, at 121 to reduce the microbial number by the same amount as the actual process being considered; so if the actual process is being considered for example, let us say 114 degree celsius and the process time we have calculated. So, we want to calculate that F 0 value; that means, what is the time required to process it towards the same microbial destruction at 121 degree Celsius.

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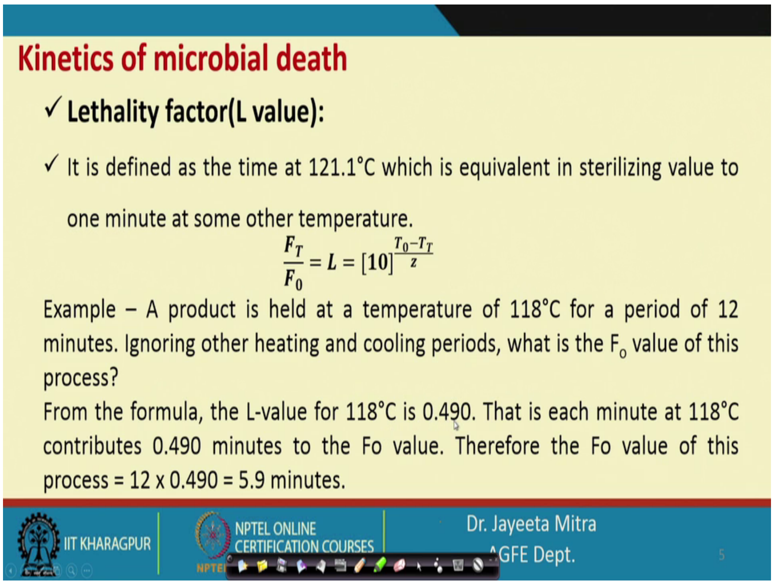

And what is lethality factor or L value? It is defined as the time at 121.1 degree Celsius, which is equivalent in sterilizing value to one minute at some other temperature.

That means if we want to you know destroy the number of micro organism at any temperature in such a ratio that is. So, log of N 0 by N in such a ratio. So, that the process time at that temperature is 1 minute only, so the same microbial destruction if we want to cause at 121 degree Celsius. So, this time required at 121 degree Celsius will be termed as lethality factor. So, F T by F 0; F T is the process time at any other temperature and F 0. So, F T by F 0 that is equal to lethality factor that is 10 to the power T 0 minus T T by z where T 0 is the reference temperature T T is the temperature at which the processing has been done for 1 minute, and z is the temperature dependence of that particular micro organism.

So, an example is that a product is held at a temperature of 118 degree Celsius for a period of 12 minutes. Ignoring other heating and cooling periods what is the F 0 value of this process. So, considering held at a temperature. That means this is only the holding time we know that for any kind of heat treatment we need to first heat it then we try to maintain that at a particular temperatures during holding period. And then, gradually it is being cooled. So, here ignoring the heating and cooling period we want to focus on only the holding period that is at 118 degree for 12 minute we need to find the F 0 value for this process.

So, the lethality value for 118 degree Celsius will be 0.490. So, we can calculate the L value L value is 0.490 that is each minute at 118 degree contribute to 0.490 minute to the Fvalue F 0 value. F 0 value means the processing if it is done at 121 degree Celsius. Therefore, the F 0 value of this process will be 12 into 0.490 that is 5.9 minute ok. So, if this product is held at a temperature of 118 degree for a period of 12 minute and if we want to do the same processing same destruction of microbes at 121 degree Celsius that is our reference temperature as Celsius scale we need 5.9 minutes.

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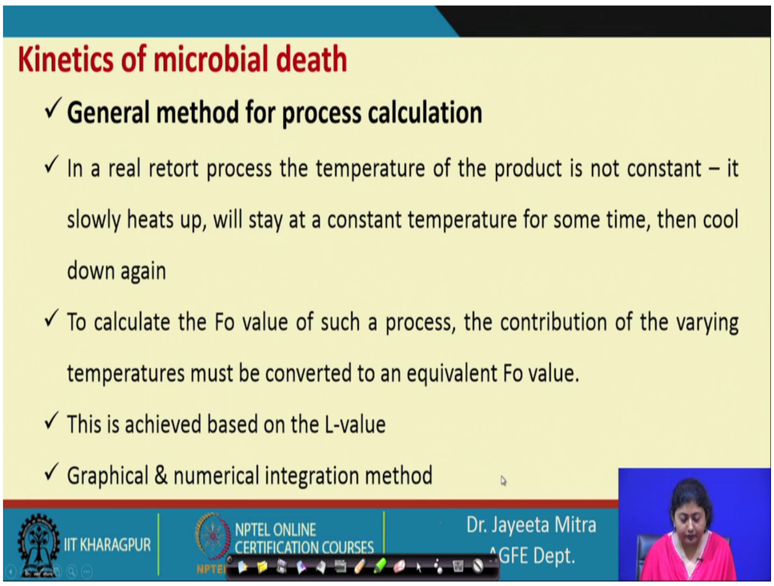

Now, coming to the general method for process calculation: in a real retort processes, the temperature of the product is not constant. We have mentioned that it first follow the unsteady state heat transfer, the temperature that is being given to the food material is first increase the temperature to the required temperature of the processing.

Then it is to be hold or maintained at that condition for certain period and then gradually it cools down ok. So, to calculate the F 0 value of such process, the contribution of the varying temperature must be converted to the equivalent F 0 value. That means, if you know the process is being gone through various temperature. And then we want to convert it to F 0 value so, what that all temperature time combination will mean or they will contribute to the F 0 value.

So, individually at each temperature we want to calculate them, and then we need to sum up them to get the final F 0 value. So, this is achieved by based on the L value that is the lethality value. So, graphical and numerical integration both method can be used to calculation of this lethality value.

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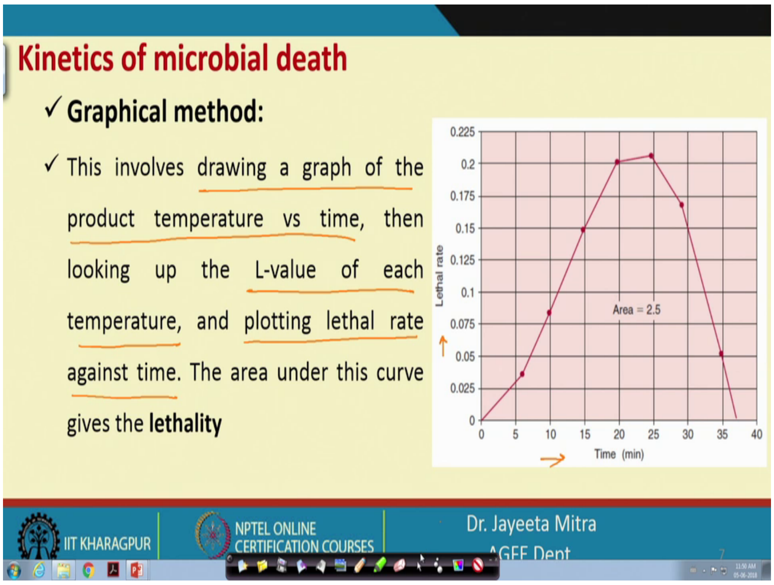

First we will see the graphical method. So, what we do is first we will draw a graph of the product temperature versus time ok. So, the first step is drawing a graph of the product temperature versus time. Now this temperature will be changing with respect to time as initially heating then holding and then the cooling period will be there. So, it will change with time. So, after that we will calculate the L value for each temperature.

So, lethality value that is what that is one minute processing at that temperature, will be equivalent to lethality value at 121 so, that we will calculate first and plotting the lethal rate against time ok. So, then we can produce this kind of a plot where we have plotted the lethal rate in y axis, and the time in minute in the x axis ok. And then calculating the area under this curve we can find the total process calculation or the total process time or F 0 value.

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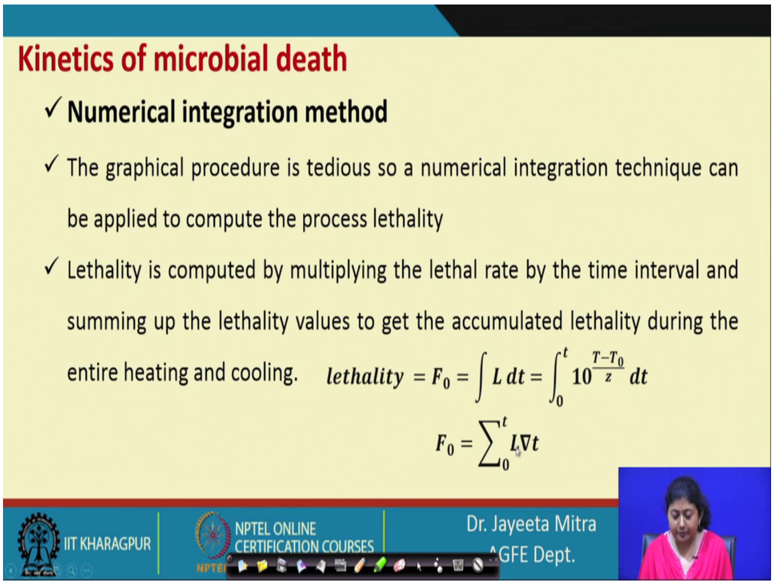

Now, since the graphical method is very tedious. So, the easy method for this calculation process calculation in case of this unsteady heat treatment method is numerical integration method ok. So, what we do is, lethality is computed by multiplying the lethal rate by the time interval ok.

So, we take very small small time interval, and lethality the average lethality at each temperature, each time combination is been multiplied with that to get the accumulated lethality during the entire heating and cooling. So, lethality can be calculated by F 0 that is integration L dt, that is the lethal rate into time small time interval that we take. So, L again can be written as 10 to the power T minus T 0 that is the temperature at which the processing has been done, minus T 0 that is the reference temperature divided by z value of that organism into dt ok. So, in this case we can do F 0 by summing up L into dt values.

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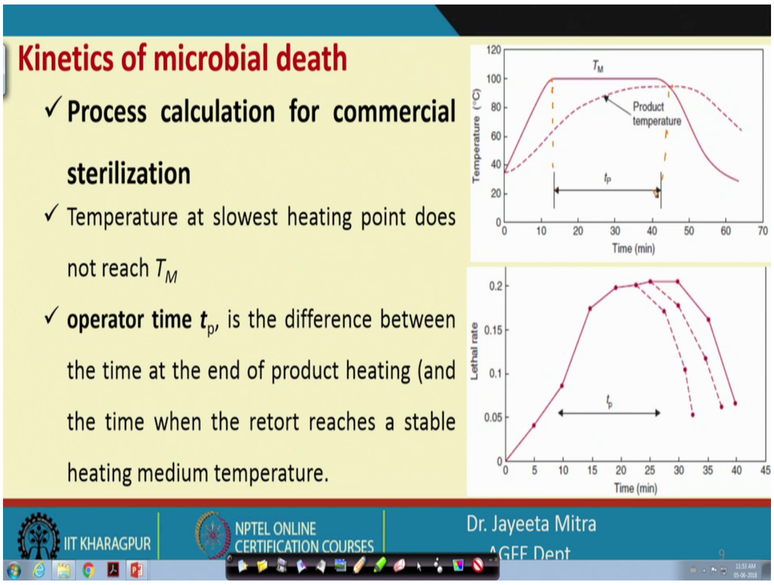

So, process calculation for commercial sterilization.

Ideally the temperature if we look into the profile of temperature, we know that it has to start from a certain product temperature and as the heating continues it should increase. Then, at the start of the holding it should maintain that particular temperature T M at which the processing should be done ideally. And then, it lowers again to cool it. However, the actual product temperature may deviate from that basically the center temperature, which is the slowest heating point. For example, if you are dealing with the can then the center axis of that can, may achieve the heat very slowly. So, that is the farthest point where the heat may reach at a later time and then the center point may be shown by this kind of a curve.

Where when the surface may attain the temperature of the processing, but the center may attain it at a later period of time or may not fully attain it may be slightly lower than that ok. So, the temperature of the slowest heating point does not reach to T M. So, the operator time t p is basically the difference between the time at the end of product heating, that is we have here we have stopped heating up to this point and then we have started holding. So, from here to when the retort reaches a stable heating medium temperature; that means, when the product core that is our slowest heating point has reach the stable temperature let us say as this section. So, that time is called the operator time t p ok.

Now beyond that when it attains it can again start decreasing or lowering that depends on the condition to condition.

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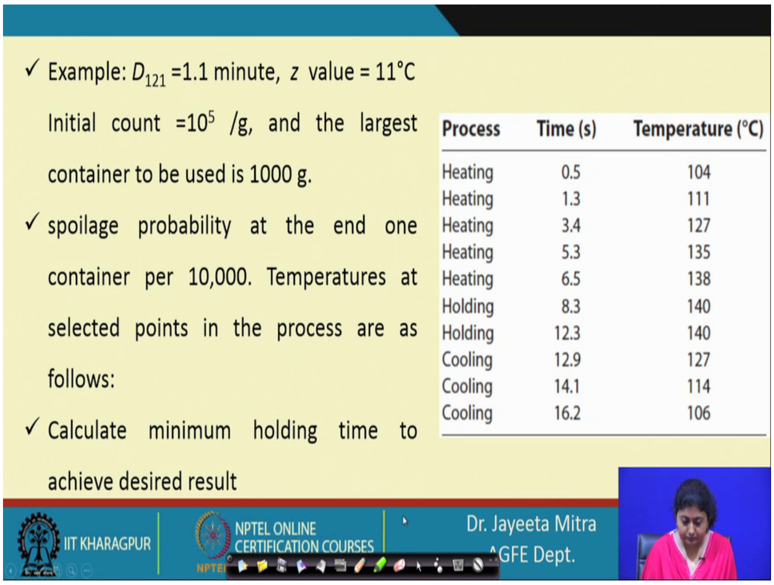

So, example that D 121 that is at 121 degree, decimal reduction time for a micro organism is 1.1 minute, for which the z value is 11 degree Celsius initial count 10 to the power 5 per gram, and the largest container to be used, is 1000 gram. So, spoilage probability; at the end one container per 10000 temperatures at selected points in the process are as follows.

So, this is the case that we need to calculate and heating first is being done, then holding, then cooling. Heating it has started from 0 to it has been measured around 0.5 second the temperature has reached to 104, and then temperature at 1.3 second is 111 like that when it is being done at 6.5 second it is 138 degree Celsius the temperature. When it reaches to the holding section 8.3 second and till it is it is hold up to 12.3 second the temperature is maintained here at 140, then cooling start from 12.9 second and goes up to 16.2 second where the temperature has reduced to 106.

So, calculate the minimum holding time to achieve the desired result. That means, the probability at the end of one container per 10000 container, and also each container is having 1000 gram product.

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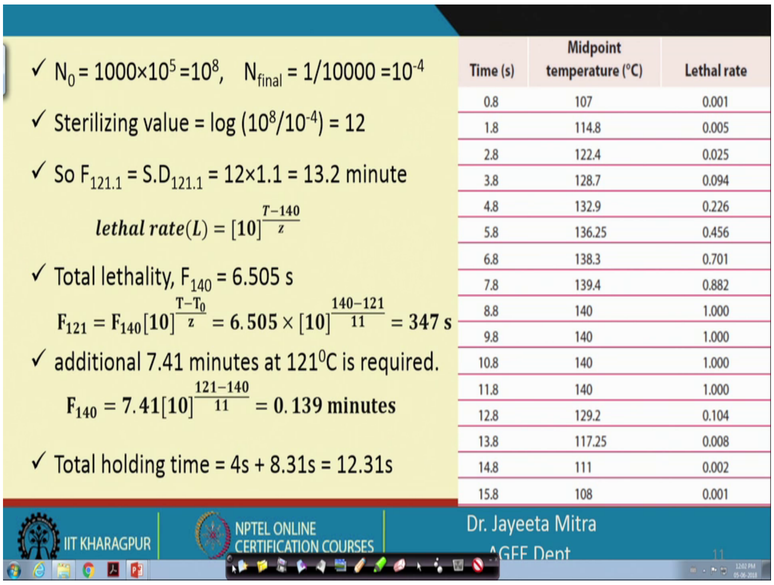

So, what we need to do first we calculate N 0 ok. So, N 0 is 1000 gram and initial load is 10 to the power of 5. So, initial load per container is 10 to the power 8. Now the final microbial population expected is 1 by 10000: so 10000 container; so 10 to the power minus 4.

So, sterilizing value will be log of 10 to the power 8 by 10 to the power minus 4 that is 12 ok. So, basically 12 log cycle reduction we want. Now F value at 121.1 is sterilizing value S into D 121.1. Now for this micro organism D 121.1 is given as 1.1 minute right. So, this is given D 1.1 minute and z is given 11 degree Celsius right. So, then we need to find out lethal rate that is 10 to the power T minus 140 by z. Now, the maximum lethality that will be offered in the holding section that is 140 degree Celsius z value 11 degree is been given already.

So, lethal rate we need to find ok. Now if we want to plot it starting from the midpoint of the can of each can, the midpoint we want to measure first, that with increasing time in second what is the condition of the midpoint ok. And based on that using this equation 10 to the power T minus 140 by z we will calculate the lethal rate first. So, we can see that at 7.8 it has reached to the temperature of the midpoint; at 7.8 the temperature has reach to 139.4 and then it has been constant or held at this temperature. So, 7.8 to 8.8 9.8 10.8 to 11.8.

So, till four second it has been hold at this condition and if we consider the total processing time starting from the heating to the cooling. So, the total lethality if we if we try to find we are getting that F 140 is 6.505 second. So, this total has been done at different temperature we have converted them all to the lethality of with respect to the 140 degree Celsius. So, this is coming 6.505 second if we you know calculate them all ok. If we if we calculate them all the total we will get the value as 6.505 second using this equation lethal rate.

Now, if 121 will be if 140 into 10 to the power T minus T 0 by z right. So, F 140 is 6.505 into 10 to the power 140 minus 121 by 11 that is 347 second. So, we have seen that 13.2 minute was given as F 121 right and ok. So, 13.2 minute is being given and here the additional 7.41 minute at 121 degree Celsius is still required right.

So, F 140 the process time for 7.41 minute at 120 degree will be 7.41 into 10 to the power 121 minus 140 by 11 that is 0.139 minute ok. So, what we have done? Then first lethal rate we have calculated total lethal rate at 140 degree than 140 degree of this much lethal rate will be equivalent to how much in the 121 degree ok. So, that is coming 347 second, but the F 121 for 12 D inactivation has come 13.2 minutes. So, then the remaining 7.41 minute at 121 we need to provide to the product heat treatment for this much time. Now this 121 degree Celsius temperature exposure for 7.41 minute is equivalent to 0.139 minute at 140 degree Celsius. So, total time will be total time will be 4 second that we have hold it plus 8.31 second that we are getting from here ok.

So, 0.139 will convert it to second. So, then we are getting that this is that time required for holding at this temperature of F 140 degree Celsius to achieve the destruction of 12 log cycle for this particular micro organism.

So, we will stop here chapter three has been completed and we have given the reference in our course outline. However, I would like mention that we have referred the book of Toledo for this section of the microbial death kinetics and also the Zekiberk and PG Smith. So, you can refer those problems has been taken from there, and there are lot many example problems and problems in the reference is also given. And we will also provide you some sets of numericals that you have to submit as assignments.

Thank you.