Thermal Processing of Foods
Professor R.Anandalakshmi
Chemical Engineering Department
Indian Institute of Technology, Guwahati
Lecture No. 5
Canning Operations

Good afternoon all. Today we are going to see about canning operations.

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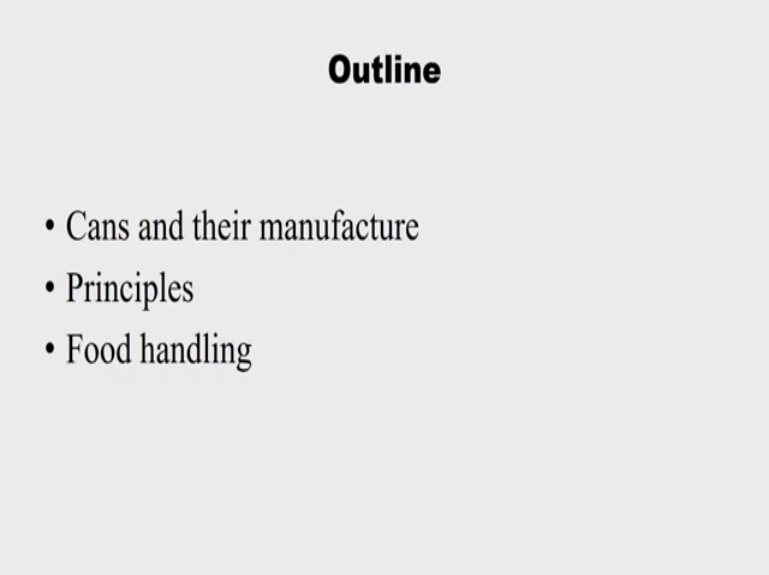

So the outline goes like this- Cans and their manufacture and the principles of canning operations and food handling in canning operations.

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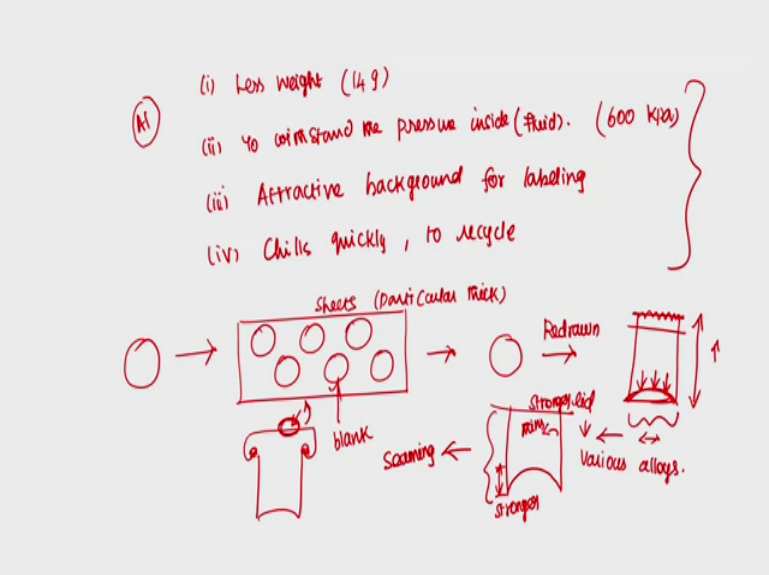

So the first thing is - Cans and their manufacture. So before filling the food for thermal processing, so how normally the cans are being manufactured, We are going to just discuss very briefly, because though the course is on thermal processing, so we do not concentrate much on material processing.

So the manufacturing of cans, the process is called two-piece drawing and wall ironing. So the procedure goes like this; first the cutting the blank. Then redrawing the cup, then trimming the ears and the lid and filling and seaming. So this two-piece drawing and wall ironing process is nothing but first if you see any cans, the cans the moment we talk about the canning operations, the cans means, the first thing that comes to our mind is either steel cans or aluminium cans.

So steel cans, normally it started with the, canning industry started with the steels. But they, over the years they understood the premium qualities of the aluminium over the steel. So the aluminium, the advantage is actually any canning; we we require two basic properties. One should be less weight. The another is nothing but to withstand the pressure; to withstand the pressure inside, inside that is due to the fluid, which contains in the can.

If you are seeing in normal carbonated drinks cans, then you must be understanding that CO_2 pressure that the can should be able to withstand. So the less weight as far as aluminium is concerned, so it withstand the weight is about 14 grams, less than 14 grams. And it can withstand, these thin walls can withstand around 600 Kpa of pressure. Not only that one, then it also offers an attractive background.

It offers attractive background for labelling because this is another one of the main criteria

because now a days customers want to see the labelling and buy the things. And the labelling also should be attractive and the can should provide the background which is in coherence for decorative labelling. And also it chills quickly, aluminium and also it is, to recycle it is easy.

So all these properties makes aluminium superior than the steel cans. So, what the can manufacturing process, first we will get the aluminium ingot. So this aluminium ingot will be formed into sheets of particular thick. So these sheets again made into blanks. So these are all called blanks of particular diameter. So this we call it as a blank. So if you see that is cutting the blank.

From the sheets they produce the blanks and they are redrawing the cup. So this cup of particular diameter, so will be redrawn to cans of this size. So your height will be increased and your diameter of the can will be decreased. So that is the way it draws. So after redrawn, the next process is trimming the airs. Not only the drawing to a particular height.

So this bottom part should also be made by the punch in this way to contract the pressure from the inside lid. So it will be bulged kind of this one. So then after that when the redrawing happens, you will not get a particular shape of the can here. So it will be something of this kind. So this is being trimmed to get the proper shape of the can. So after the trimming is done, so then the lid is kept above the can.

So in the lid, maximum maybe of various alloys. It need not be of the same as that of the aluminium. It may be various alloys maybe used for the lid. And lid normally stronger than the thin walled can. So the walls are thin here. And also if you see along the length, so the bottom portion will be bit stronger than the top portion one, top one. So it is drawn in such a way a way that your bottom portion of the cans will be stronger than the upper portion of the can.

So after the lid is done, then they will have that opening lid. So that opening lid will be of very thin compared to that lid material. So then after the lid is done, then there is a seaming process. So the seaming process is when the cup is drawn, after the trimming, so this top portion of the can will be having a flanch outside. So when the lid is made, it will be made in such a way, this kind of thing.

The seaming is nothing but the pressing these two, so that the leakage will be avoided and also during thermal processing. So it will reduce the expansion of the material. So that is the way the seaming is being done. So then you will have this opening. This opening may be of different

material than the lid. So when you pull it up, it opens and give you the passage to drink your beverages or whatever the material you can take it out.

So this is normally overall process of cans manufacture. Anyway, we are not going to get into detail because the material processing is not of our interest in this course. So the processes are, this whole process is called two-piece drawing and wall ironing because both your body portion as well as the bottom portion of the can is being manufactured in a single blank what you cut it from the sheet. So then cut the blank, then redrawing the cup, then trimming the ears to get the same size, then lid, then fill and seaming. After filling, this is this happens during thermal processing itself. So after filling, the seaming is done.

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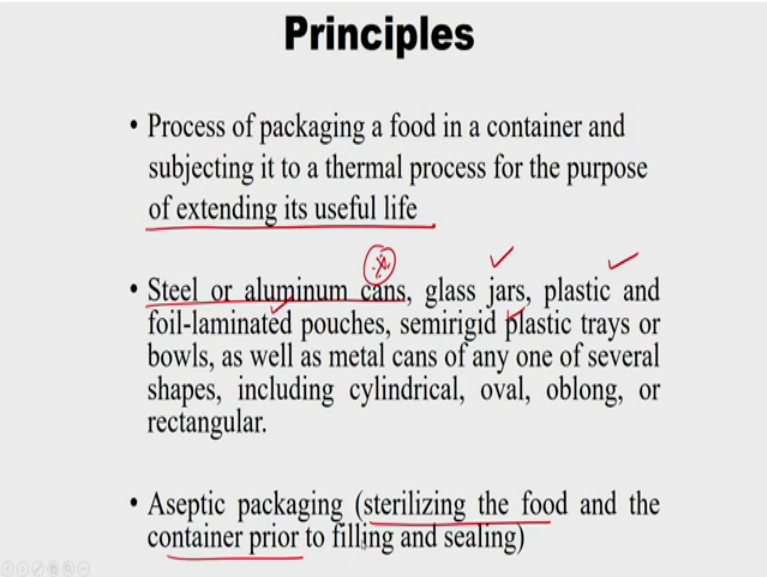

So now we are going to discuss about what are all the canning principles. So the first one is the process of packaging a food in a container and subjecting it to a thermal process for the purpose of extending its life, useful life. So normally all thermal processes are being done just to extend its useful life. So how it can be done? There are two things associated with it because we wanted to kill the disease causing microorganisms. As well as it is also included with pathogenic organisms. And also to control the growth of any organisms at that particular temperature.

So if these two are taken care, then obviously the shelf life of the product would be increase. So the, the moment we talk about the cans, then normally this is coming into our memory. But the principles and operations, whatever we do, that is applicable for glass jars, plastics foil-laminated pouches, semi grid plastic trays, bowls as well as metal cans of any one of the several shapes, including a cylindrical cans, oval cans, oblong, and rectangular.

Whatever maybe the shape and whatever may be the material, the principles and operations are same. And also the same principles and operations are valid for aseptic packaging. So, aseptic packaging, you are sterilizing the food and the container, both will be done prior to filling and sealing, before itself. So here we do the filling and sterilization together, but aseptic processing, sterilizing the food and the container prior to filling and sealing. Sealing is nothing but seaming.

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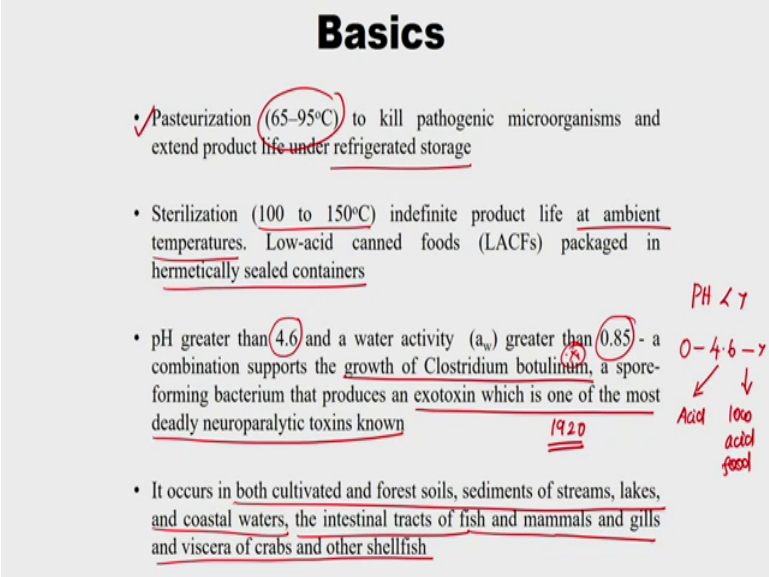

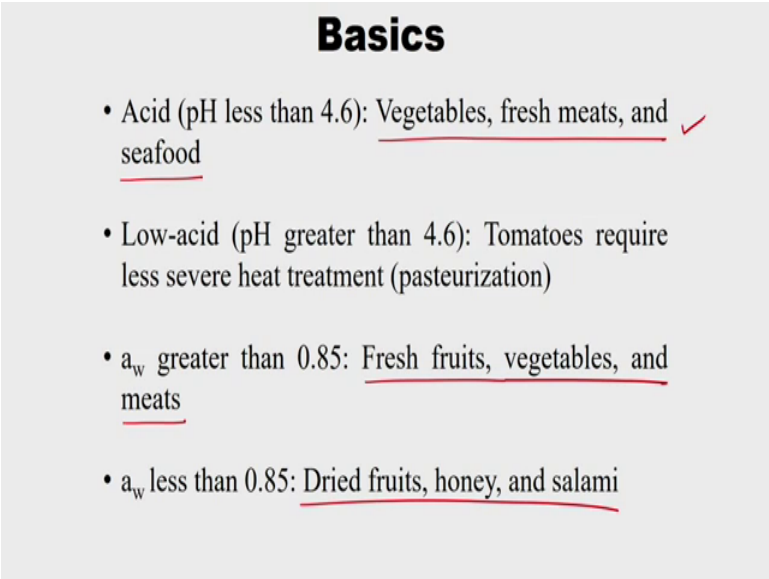

So the basics are, actually the thermal processing can be done in two ways. One is the pasteurization, so which accounts the temperature in between between 65 to 95 degree to kill pathogenic organisms which is nothing but a disease causing microorganism and extend the product lifetime and a refrigerated storage. So whenever you pasteurize, so you need to store it in a refrigerated condition, but whereas the sterilization is done in the temperature range between

100 to 150 degree.

So this indefinite product life at ambient temperature. So you can store it at ambient temperatures itself. So whatever the milk tetra pack you get, so that is sterile milk. And normally, low acid canned foods packaged in hermetically sealed containers. What we mean by low acid canned foods is nothing but the pH greater than 4.6 and water activity is greater than point 85. So this is called low acid food. So normally pH less than 7, 7 is a neutral, we call it as a acid, acid food. so in that, so this 4.6 is given, so below than that we call it as acid food. So maybe for example, 0 to 4.6, 4.6 to 7 we call it as a low acid food. So water activity is nothing but amount of water present in the food.

So if it is greater than 0.85. If pH is greater than 4.6 within 7, then we call it as a low acid food. So in this condition, combination supports the growth of Clostridium botulinum, we call it as a Cbot. So this is a spore forming bacterium that produces exotoxin which is one of the most deadly neuroparalytic toxins so till now it is known. It is almost found out in 1920s, if I am correct. So this is the basis for all the thermal processing. So this organism is nothing but a deadliest organisms. So at this condition, which is nothing but pH greater than 4.6 and water activity greater than 0.85, so it favors the condition of growth of Clostridium botulinum so which is nothing but a Cbot.

So it occurs both cultivated and forest soils. So Cbot appears in cultivated, forest soils, sediments of streams, lakes, coastal waters and intestinal tracts of fish, mammals and grills, crabs and other shell fish. So everywhere it is almost available, everywhere. But the favorable condition is this particular condition: pH is greater than 4.6 and water activity is greater than 0.85. So based on the acid nature of the food if it is 4.6, then most of the vegetables, fresh meats, and seafood comes under this category.

Low acid food, already we talked about but tomatoes require less severe, so all these conditions, if it less than, then we do not require sterilization condition. Less severe pasteurization itself is can be done. But in that tomatoes also require less severe treatment, which is nothing but a pasteurization. But if pH is greater than 4.6, that definitely requires sterilization condition. And water activity greater than 0.85, fresh fruit, vegetables, and meats all come under this category. So less than 0.85, we all know it is a dried food, honey, and salami. This is another kind of variety.

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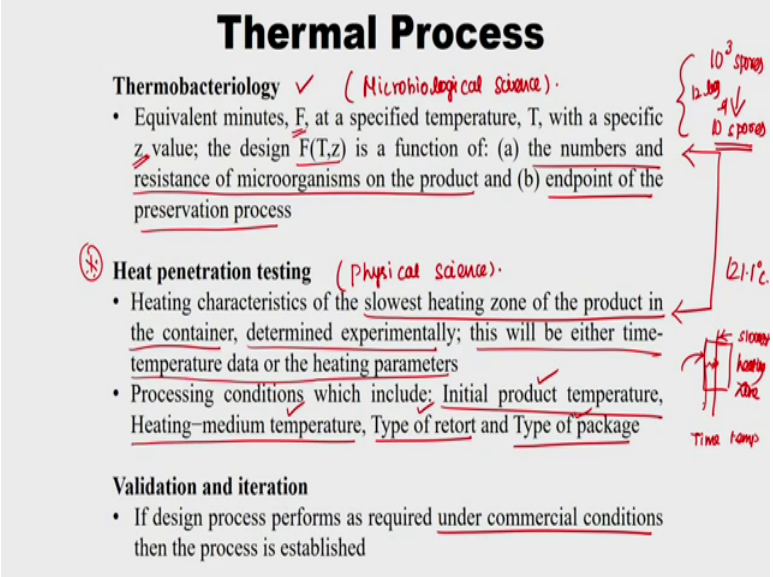

So when we talk about thermal processing, there are 3 major boxes to be ticked. One is thermobacteriology, so which talks about microbiological science. So another is heat penetration testing. So this is our domain that is nothing but physical science which talks about all thermal processing. And both combined together, and it should be validated and alterated. Otherwise for example, these both are interlinked together.

So we already told why we are doing any thermal processing, or pasteurization or sterilization to kill pathogenic organisms or to control the food spoilage organisms. So we require information from the microbiological science to fix any thermal processing parameters. So when we do so, we normally do not try everything in the commercial production, commercial production in the industrial level. So what we do, most of them are laboratory experiments. So when it goes to commercial plants, before going into that, we need to do validation and alteration.

So what thermobacteriology talks about, thermobacteriology talks about equivalent minutes in F at a specified temperature T with a specific z value. So this F value, and z value. So we will be seeing in our subsequent lectures which is nothing but kinetic parameter estimation. So as of now, we call it as F value, z value. So the design is F is a function of T, z value and temperature. So this again the function of the numbers and resistance of microorganisms on the product, I already told you. And end point of the preservation process. End point in the sense: so for example initially I have almost 10 to the power of 3 spores of Cbot in the food. So I reduce to 10 to the power minus 9 spores.

So this is nothing but 12 log reduction. So for this 12 log reduction, how long it takes. So end

point of the preservation. So end point which contains only 10 to the power minus 9 pores, spores. So F of (Tz) value, depends upon these 2 factors. The numbers and resistance of the microorganisms as well as the end point of the preservation process. When goes to heat penetration testing, so the heating characteristics of the slowest heating zone of the product in container. When we talk about the canning, if it a rectangular or cylindrical can of vertical shape kept in vertical line, so the axis, so the midpoint of the can is nothing but the slowest heating zone.

So what happens, when you keep it in the retort. Retort is nothing but a pressure vessel. So when the steam is on, the heating medium starts heating the can. So the heat has to penetrate from the wall, to the wall to inside. So the, this portion will be heated first then the slowest is nothing but midpoint. So determine experimentally, this will be either time temperature data or heating parameters. So to know how long it takes from it reaches to the sterilization temperature, which is nothing but; normally reference is 121.1 degree centigrade.

So how long does it take from outer wall to the slowest heating zone that is nothing but the time temperature data. So this can be done by experimental or that also can be done by modelling and simulation. So either it will be in terms of heating parameters, or it will be in terms of time and temperature data. And processing conditions which include initial product temperature, it it requires. And heating medium temperature, I told you, so heating medium is nothing but a steam. So that temperature initially my product is at what temperature and type of retort.

Type of retort in the sense, the pressure vessel what we use and the type of packaging. The packaging does not mean that only cans. So the canning operations principles can be used for pouches and we have already seen. So these 4 are, 4 are very important parameters when you do the heat penetration testing. So the design process performs as required under commercial conditions. Whether when I scale up to commercial conditions, the same reduction of microorganisms happens at that particular temperature and particular time or not, that we need to validate.

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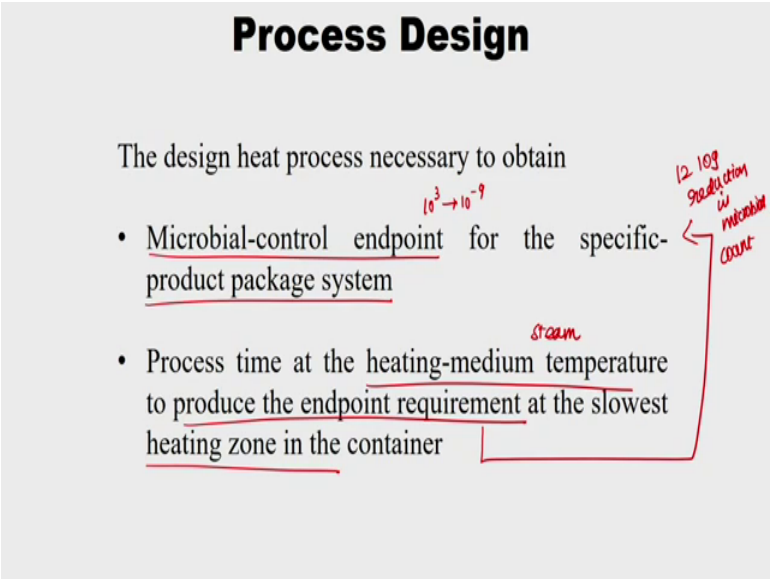

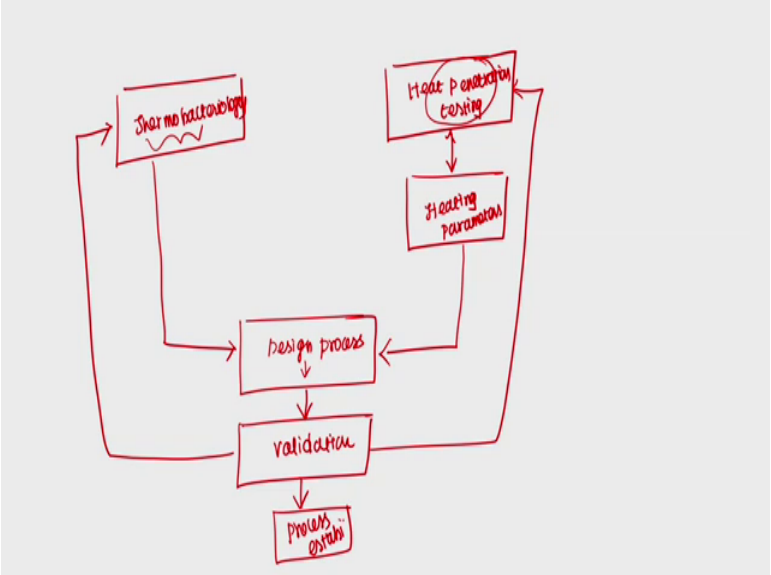

So then process design. The design of heating process is necessary to obtain microbial control endpoint for the specific product packaging system. Microbial control endpoint is I already told. I am getting it from 10 to the power of 3 to 10 to the power of minus 9. And process time at the heating medium temperature to produce the endpoint requirement at the slowest heating zone in the con,. So the heating medium here is steam. So I am using steam to sterilize my can. So to produce the endpoint requirement. Endpoint requirement is nothing but 12 log reduction in the microbial count in microbial count.

And at the slowest heating zone. So for example, to produce this 12 log reduction I need to maintain a 121 degree centigrade for 0.2 minutes means. so my slowest heating zone which is nothing but the axis of the cylindrical can should reach 121.1 degree centigrade, at that particular

time. So that is the way the process should be designed. So let me put it in this way. So here is your thermobacteriology which is nothing but a microbial science. So here is your heat penetration testing which is nothing but, so here this can be done in experimental way and or modelling also.

So which gives me the heating parameters, so this is interrelated because it can change. If it is a modelling, then you have the flexibility to change your initial temperature, and type of retort, and type of packaging, everything. So these both goes to the design processes. Sometimes it goes, both goes to design process, so then after that there is a validation before it goes to design process which combines thermobacteriology and heat penetration testing and come up with the particular endpoint. How much temperature to be maintained and how much is the time for the temperature to reach the slowest heating zone.

So then after that, it validates. Then if there is any, if that is not being followed in the commercial conditions, then it goes back. to change this condition and check, so that means that we have not understood probably the heat penetration testing parameters correctly. Or there may be a problem with the initial bacterial count. So that was not calibrated properly. So then then this goes on alteration. So then finally, if this is validated, then you go for process establishment. So this is the way, this is combined.

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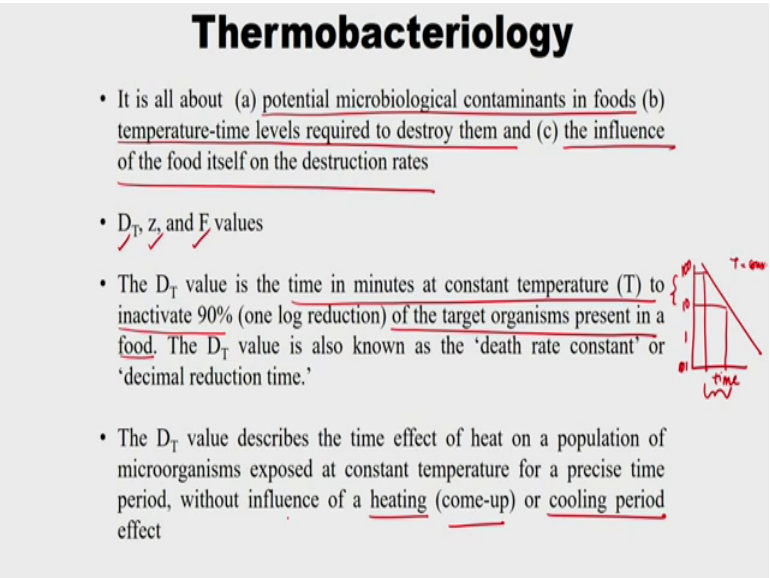

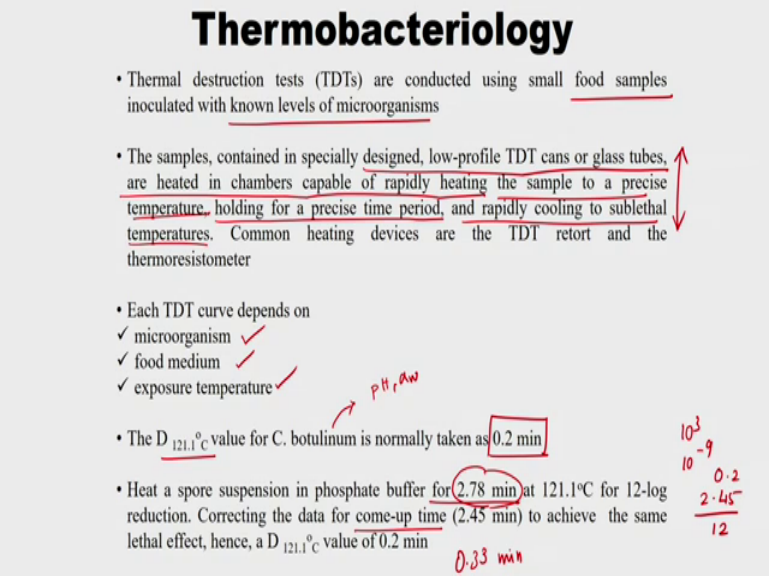

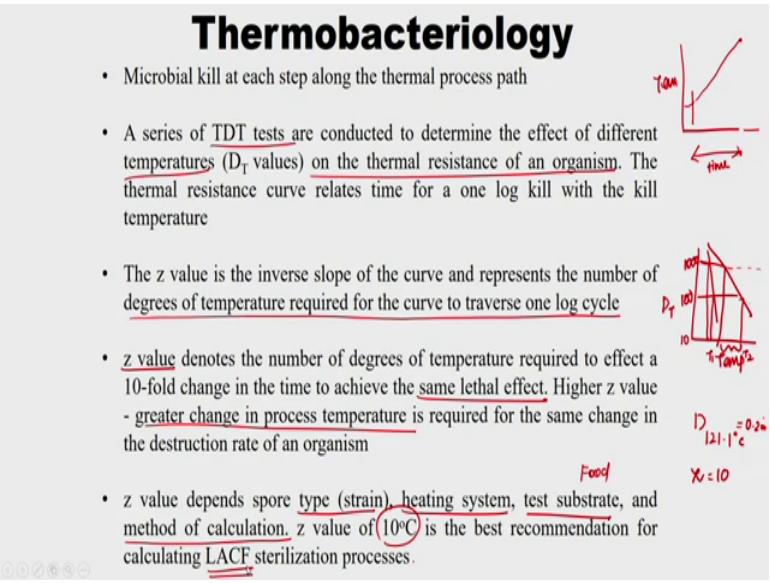

So the moment we talk about the thermobacteriology, it is all about the potential microbiological contaminants in the food and time temperature levels required to destroy them. The influence of food itself on the destruction rates. So these 3 combined together, to give the thermobacteriological science. So here as I said earlier z, F and one more is Dt values are important. Anyway we are going to see much in detail in the kinetic parameter calculation. So the Dt value is nothing but time in minutes at constant temperature to inactivate 90 percentage of the target organisms present in the food.

So this goes like this, so this is your constant T, T equal to constant. So this is nothing but time. So this is your log reduction, probably, 0.1, 1, 10, 100, something like this. So this is a linear line. So this is 1 and this is 1. So 1 log reduction is this, so what is the time taken. So that is nothing but a Dt. So this Dt value describes the time effect of heat on the population of

microorganisms exposed at a constant temperature to precise time period without influence of heating and cooling. So, what does it mean by heating and cooling here is so as I told earlier, when you keep the can in retort pressure vessel.

When the steam is on, it will take some time for the retort to reach the steam temperature. So that is nothing but a come up time. So that is the time taken for the retort to reach the heating medium temperature. And after once the sterilization is done at a particular temperature than it has to come back to the normal atmospheric temperature, so that is nothing but a cooling period. So this Dt is without the influence of heating or cooling period. So this means, immediately your retort is on for steam and at the end of the process the cooling is started. So the this time is without the influence of heating and cooling period.

And the, normally the thermal destruction test, how we conduct in the food sample is, first we use small amount of food samples and incubated with the known levels of microorganisms, so I know my initial count of organisms. Then the samples contained in a specifically designed, low profile TDT cans or glass tubes, are heated in chambers capable of rapidly heating the sample. Rapidly heating the sample in the sense, here we avoid that come up time. So the sample to a precise temperature, for example if it has to be maintained at 50 degree then I have, I will maintain at 50 degree. Holding the precise time period and rapidly cooling to sublethal temperatures, so that is nothing but back to normal temperature.

And common heating devices, so this I perform in the lab. So I will take a glass tube and put the small amount of food samples and the organisms with known levels, with the, with the known initial concentration. Then it will be rapidly heated, then cooled back to sublethal temperature. In between, for each time interval, we will take out a sample and check for how much microorganism count is there in that sample. So it depends upon the microorganisms taken, and food medium, and exposure temperature. This we already know. So actually the Dt, the D is nothing but the death rate constant.

At 121 degree centigrade, the value of C.botulinum, C C.bot, is normally taken as 0.2 minutes. So heat is spore suspension in a phosphate buffer. So why we use the phosphate buffer is to maintain the pH level because we already know it is always at what pH and what water activity. So normally it was taken as a, it was measured as 2.78 minute for 12 log reduction. 12 log reduction in the sense, if I take a initial spores of 10 to the power of 3, it will become 10 to the power minus 9. So this correcting the data to come up to, come up time. Come up time in the

sense the heating medium temperature reaches after this minus this.

Almost 73, okay, after 33 minute, sorry, 0.33 minutes. So this come up time reduced and (2.5) 2.45 to achieve the same lethal effect. Hence so 2.4 minutes for 12, 12 log reduction. So divided by 12. So this is nothing but 0.2 approximately. So this is the way normally how we calculate D in D using experimental temperatures. But the moment you see in the canning operations, when the steam is on, then slowly the temperature changes from the can wall to the lowest heating zone. So in that case, I would require the temperature, the time temperature curve because it is not a constant temperature, my temperature is kept on increasing, so I would require this D values at different temperatures to get my heating parameters done correctly.

So then another value which uses is nothing but z value. So here a series of TDT tests are conducted to determine the effect of different temperatures. So that is why my thermal process path. We already told. this is the temperature. So when the steam is on, it will take some time for come up then it starts increasing to the endpoint temperature. So I would require for the time versus temperature. So what is my D value. So for that on the thermal resistance of an organisms. The thermal resistance curve relates time for 1 log kill with the kill temperature.

So the z value is inverse slope of the curve and represent the number of degrees of temperature required for the curve to transverse 1 log cycle. So the z value is nothing but, here is my, so this is a temperature. So this is nothing but 100 degree something. So this is, so how long it, what is the temperature range. So z value is the inverse slope of the curve represents the number of degrees of temperature required for the curve to transverse 1 log cycle. So this is nothing but Dt value. So for this T1 temperature, so this is my Dt value. For T2 temperature, this is my Dt value. So to 1 log reduction in the Dt value, so what is the temperature difference.

So that is nothing but z value. z value denotes number of degrees of temperature required to effect a 10 fold change in time to achieve the same lethal effect. So higher z value means we know already, the greater change in process temperature is required for the same change in destruction of organisms. So higher temperature means this slope is something like this. So this 10 and this will go bit. Let me put it, something of this kind. So the second one requires less temperature change.

So that is a way and z value depends spore type which strain we use and heating system, test substrate, that is nothing but a food on which it grows, and method of calculation. So everything, z value also depends upon. Z value of 10 degree centigrade is the best recommendation for

calculating LACF, LACF in the sense low acid food sterilization process. So now we understood that for C.bot, the D, the reference temperature is 121. degrees centigrade. And which is nothing but 0.2 minute for 1 log reduction. And also z value is nothing but 10. So LACF the main organism which grows is our C.bot.

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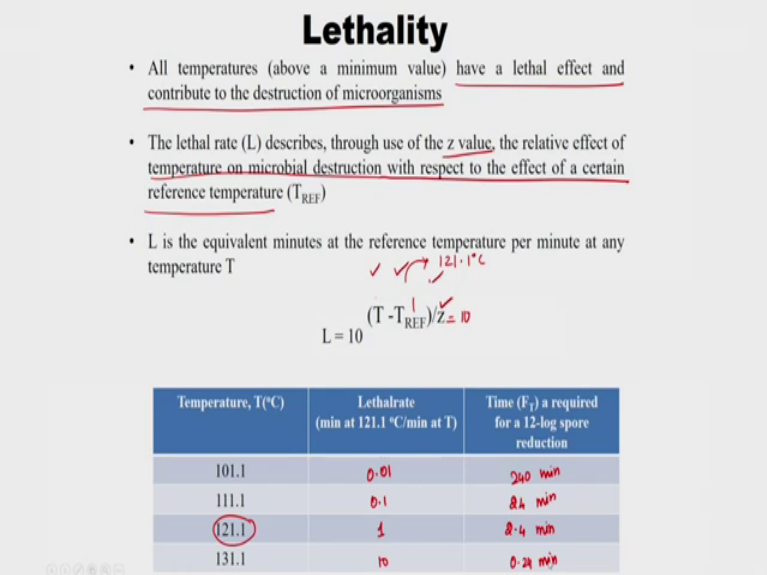

So then the lethality. All temperatures above the minimum value have lethal effect. And it contributes to the destruction of the microorganisms. So the lethal rate describes through thorough use of z value. z value you require and reference temperature. And this T is nothing but time temperature history of the heating process. Effect of temperature on the microbial destruction with respect to the effect of a certain reference temperature. So the formula goes like this, L equal to 10 to the power of T minus T reference divided by z. For example, we know this is the reference temperature. So at this one, this becomes 1.

So this becomes 1, so this becomes 0.1. This is 0.01 maybe. So this becomes 10.. This Ft is nothing but 12 log reduction. So 12 log reduction, so we already know for 121 for C.bot., at z value of 10, your reference value is nothing but 121.1 degree. So we know what is the value. This is nothing but 2.4 minute. We already calculated before. So this becomes 24 minutes. So this becomes 240 minutes, because 10-fold increase, 10 fold increase. So this probably becomes 0.24 minute.

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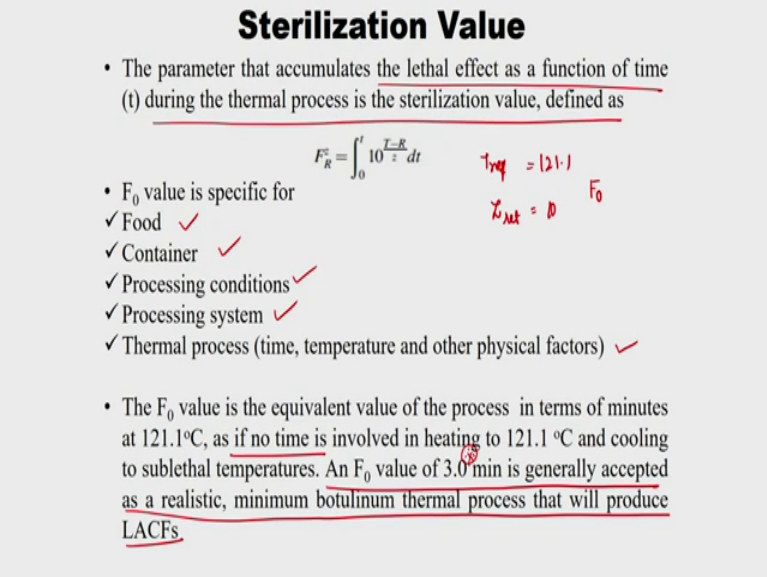

So that is lethality and sterilization value is nothing but, we will integrate over total time t, 0 to t. The parameter that accumulates lethal effect does the function of time during the thermal process in the sterilization value. So F naught value is specific for food, container, processing condition, processing system and thermal processes. So we cannot say this this F naught value for example, some food samples I found it or the canned process F value is so and so. F naught is nothing but when my T reference is 121.1 and my z reference is 10, then only it is called F naught. So this F naught is specific for container food.

So this is specifically for C.bot. So these are all the factors which depends upon, so the F naught value is equivalent value of the process in terms of minutes if no time is involved in heating to 120. So no time in heating is involved means come up timeSo which means the retort to become the steam temperature, and cooling to sublethal temperatures. And F naught value of 3 minute is generally accepted as a realistic, minimum botulinum thermal process that will produce LACFs. So I already told C.bot is most toxic one. So that 2.4 is rounded off to 3 minute. So this is the reference value being followed.

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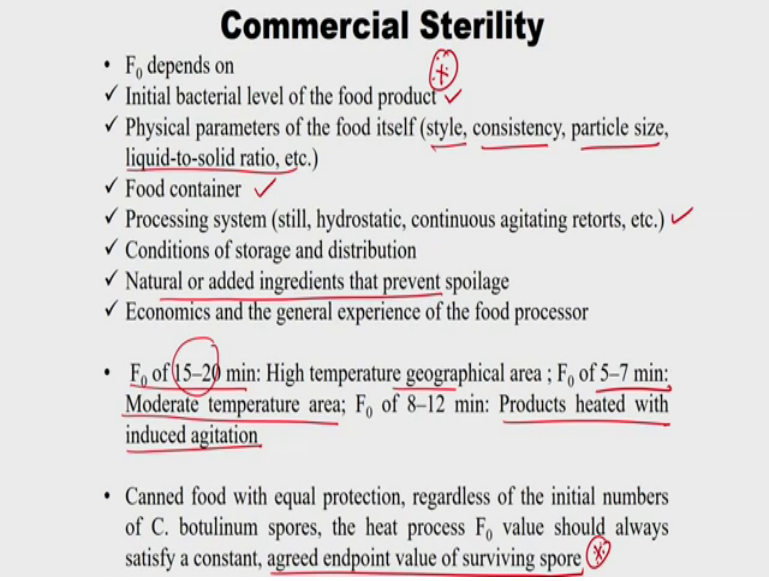

And also when it goes to commercial sterility, we need to be specific with the conditions what we use. The 3 minute may not be sufficient enough for if the 3 minute how we calculate it is 12 log reduction. 12 log reduction when my initial spores were 10 to the power of 3. But here the F naught depends on the initial bacterial level of the food. And also physical parameters, the style, consistency, particle size which is in the food, and liquid to solid ratio of the food, everything comes together when we calculate F naught.

And food container, whether it is a can or pouch and processing system. So whether you have any agitator inside. So that also comes into play. And conditions of the storage and distribution. Where do you want to store natural and added ingredients that prevents the spoilage. For example, I also took the example of beverage cans. But sometimes, they come up with the added ingredients, to prevent the spoilage of the food. So normally, that will not come under canning operations as well. And economics and the general experience of the food processor.

And for example, F naught of 15 to 20 minutes should be maintained, high temperature geographical area. For example, what happens here is, there are bacterias which are called thermopiles. So they are very much heat resistant. And also if they are present in the food which which escapes sterilization process. When it is stored in the high temperature geographical area, it starts growing. So that is why higher minutes, higher F naught values being used when the storage condition is high temperature geographical. 5 to 7 normally moderate temperature area and 8 to 12 minutes for products heated with induced agitation. Agitation improves the mixing.

Canned food with equal protection, regardless of the initial numbers of C.bot spores, the heat

process F naught value should always satisfy a constant agreed endpoint of the surviving spores. So this is very much important. Though we say 12 log reduction, there is no proper source for that, why I need to maintain 12 log and also as I said earlier, the initial bacterial level of the food product is also important when we use such a F naught value from the calculation.

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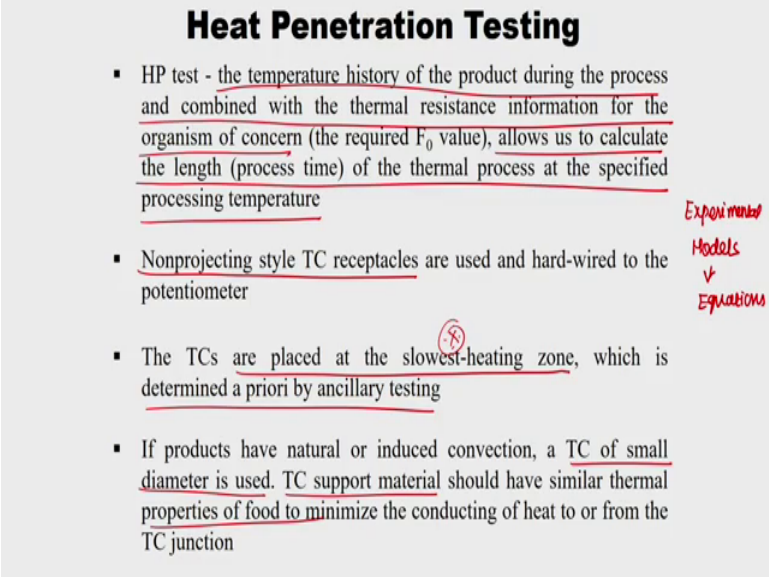

And heat penetration testing, normally, how it is being done in our laboratory is, the temperature history of the product during the process and combined with the thermal resistance information of the organism of concern allows us to calculate the length of the thermal process at the specified process temperature. So this we already discussed. I need a microbiological science to fix what is the temperature I would require for sterilization. And physical science will tell me how long it will take to reach that temperature, my coldest point of the food. To reach that particular sterilization temperature, how long does it take, that is nothing but a HP test. So normally how do I measure experi we told that there are 2 methods can be applied.

One is experimentally I can measure. And another is models, using equations. So normally non projecting style TC receptacles are used and it is hard-wired to the potentiometer. So it is nothing but a thermocouple based potentiometer is used to measure the temperature. And when we are using the thermocouples, we should be a bit careful about, how we are, where we are keeping the thermocouple and what kind of thermocouple we use. So normally it should be measure the slowest heating zone, and which is determined a priori. So sometimes we called it, because it is a regular shape of the gun, so I can tell that if it is only liquid food is there, so I can tell that access of the can is nothing but my slowest heating zone.

But if it has some solids, or it has some natural convection or forced convection, so these are all the also the parameters and whether the can is stacked vertically or horizontally, so that also comes to play to determine slowest heating zone. So that we will see in subsequent lectures. So that, this point, how I, one has to determine which is the slowest heating zone. There are some ancillary testing for that. And if the products have natural or induced convection, the TC, thermocouple of small diameter is used.

Because if the particles are induced by natural convection or forced convection, then you should not your thermocouple, what you keep inside the can to measure the temperature that should not hinder the particle moment. And also the TC support material should have similar thermal properties for the if the food is, if the heat transfer happens by conduction, then the TC material also should be having the same thermal properties of the solid food. Otherwise the conduction happens between the food to thermocouple. And normally it it it alters the TC junction. And whatever the temperature you are measuring, that may not be the correct temperature.

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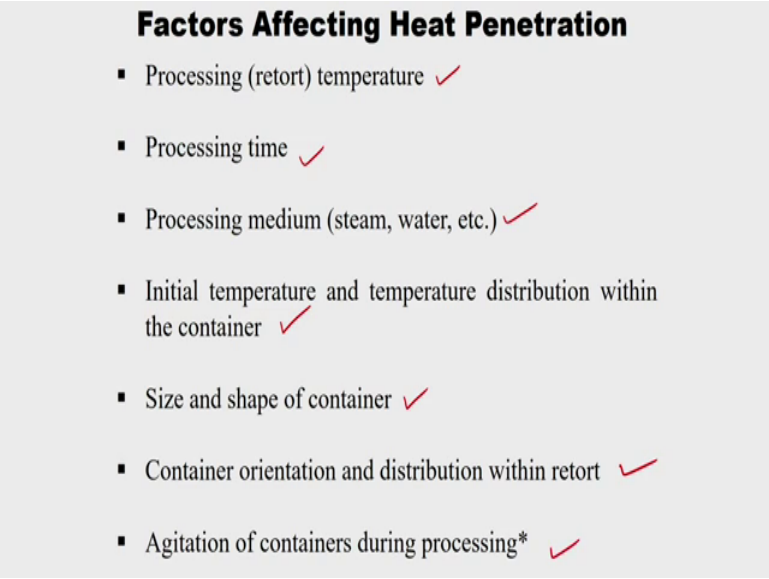

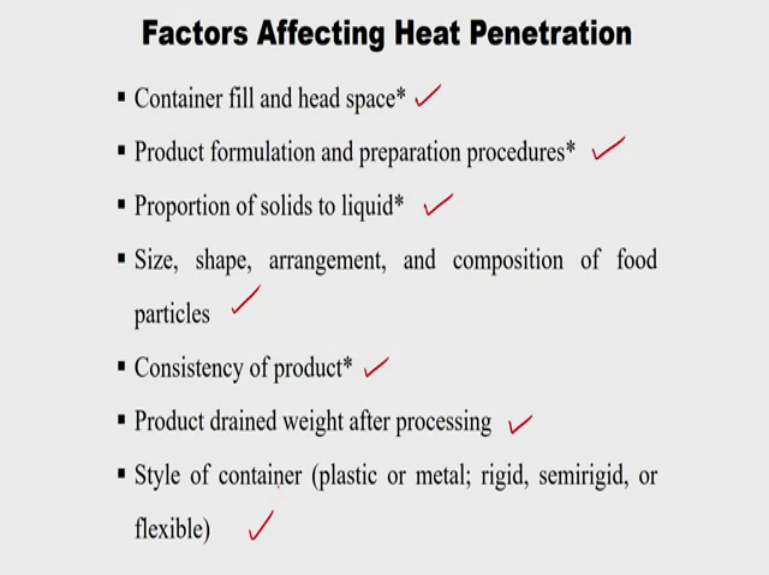

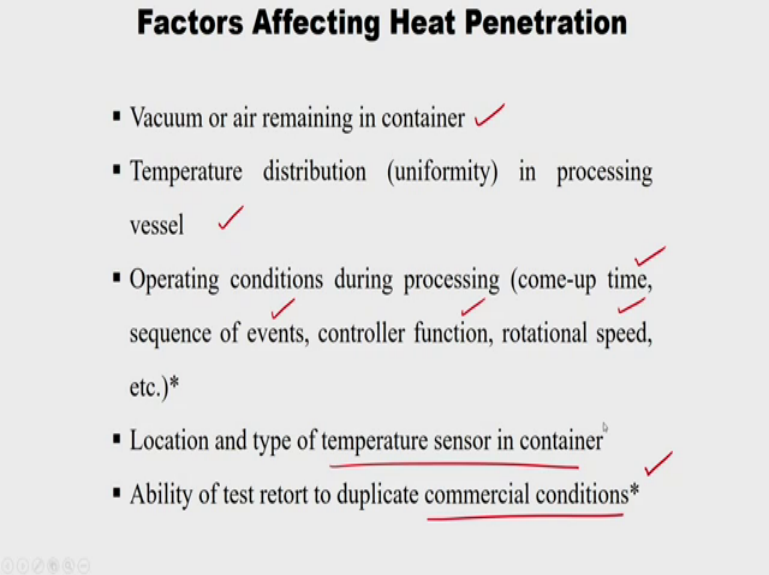

And these are all the various factors affecting heat penetration. So processing temperature we already told, processing time, processing media. This we will see when we talk about the heat penetration, heating curve. We will see what are all the different processing medium available. And initial temperature and temperature distribution within the container. And size and shape of the container we already told whether it is a cylindrical or a rectangular or oblong shape, everything. The container orientation and distribution, whether it is stacked vertically or horizontally.

And agitation of containers during process that I already told it the mixing improves the heat transfer. And what is the asterisk, asterisk means so this is different when without agitation and with agitation. Agitation we will have pedals inside it. The container fill and head space. So container we will not fill total cans with the food material, we will be having some head space. So

that also affects the heat penetration. Product formulation and preparation procedures and proportion of the solids in the liquids.

Solid to liquid of the food material and size, shape, arrangement, and composition of the food particles because the, if it is a liquid then natural convection will be different than liquid having the particles. And slowest heating zone also would be different when you have pure solid food or pure liquid food or suspended liquid food with suspended particles. And Consistency of the product, whether it is a liquid, or suspended solids, or emulsion, or pure solid food, it also affects.

And product drained weight after processing and style of the container, whether it is a metal container or plastic container. Vacuum or air remaining in the container, so this is nothing but related to head space and temperature distribution in processing vessel we already told. So processing vessel in the sense when you steam on, how long does it take for come and all those information. And operating conditions; come up time, sequence of events, and controller functions, and rotational speed, everything comes into play. Location and type of the temperature sensor, this just we discussed.

How, where you place the thermocouple and what kind of thermocouple you place, everything and ability to test retort to duplicate commercial conditions. So commercial conditions in the sense we already told how do we perform TDT, the test we just take small amount of food in the glass tubes and perform the heat penetration test but when you scale up to commercial conditions how far your experimental results will be matching with the commercial conditions that is also important

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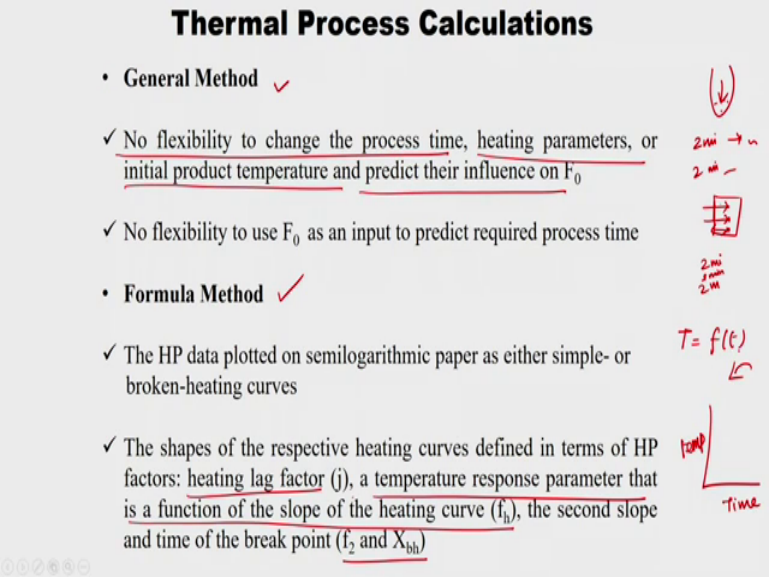

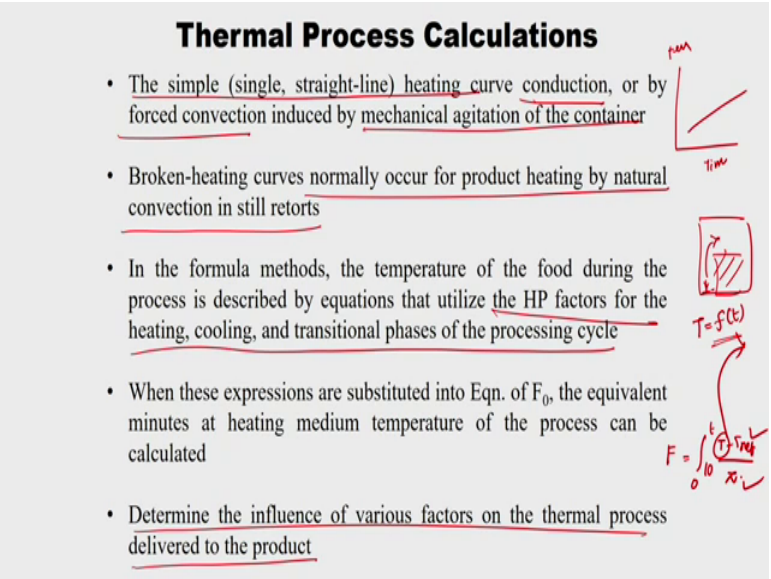

And thermal process calculation as we discussed already. General method, general method is nothing but a experimental method, so here there is no flexibility to change the process time and heating parameters. For example, if I am I am taking in the glass tube some of the food particles and initial known microbial counts then what I will be doing is for each two minute I will be taking out my sample each two minute and calculate my microorganisms level.

That is the way I I would be giving the microbial count and after that so I will take a food particle in the can then I will place my thermocouple and each two minute or three minute I will start measuring the temperature from the can wall to the slowest heating zone. So I do not have the flexibility, for example, if someone wants what happens at third minute I will not be able to tell, because I do not have the particular data.

So that is what there is no flexibility in change the process time or heating parameters or initial product temperature and predict their influence on F naught. And also the reverse is also not possible. But in formula method what I will be having is I will have T as a function of t. So here I need to substitute just t at any minute. For example, if I want to point 1th minute or point 2 minute, and I can just substitute my time and get all the values. And also, it is the shape of the curve, heating curve.

We already told the time versus temperature curve. So that depends upon the heating lag factor j and temperature response parameter that is a function of slope of the heating curve, fh, f2, Xbh. So these all terminologies we will see in the lecture of heating curve. So here we generally put it as a parameters. The shape of the respective heating curves are defined in terms of these parameters. There you get direct values. Here you, everything you get in terms of formula. And the simple heating curve conduction or by forced convection by mechanical.

Actually the simple heating curve in the sense straight, the straight line heating curve. When you plot time versus temperature, this you get when there is a conduction or forced convection or induced by mechanical agitation of the container. But broken heating curves normally occur when the product heating happens by natural convection in still retorts, we already told. So I have a retort where my cans are stacked. So here there will be a steam sprays through which my steam is sprayed inside the retort.

So it will take some time to reach to that steam temperature. Then after that the product starts getting heated. So the broken heating curves normally happens when still retorts. In the formula method, the temperature of the food during the process is described by equations that utilize HP factors. So we already told heating, cooling and transitional phases of the processing cycle. These expressions are substituted in equation of F naught. So if you remember your F equation. So this is nothing but 0 to t, T minus T reference upon z, so 10 to the power of. So this T is nothing but this value, T as a function of f of t. So this is reference temperature this is z. So this equation whatever we get, in the previous slide, so we told formula method everything we will we will get in function of temperature.

So that will be substituted here to calculate F. So determine the influence of various factors on the thermal process delivered to the product. So the one advantage is, we have told that were four important parameters: type of packaging, type of retort and initial product temperature so everything matters when you get F. So but here you have the flexibility to change any number of

parameters because it is in terms of equations, I need not change initial product temperature then once more perform the experiments. So this gets the flexibility.

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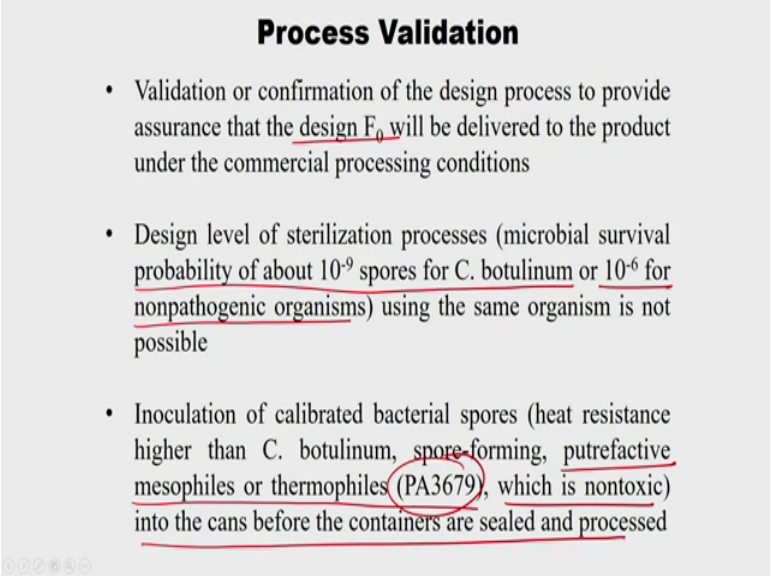

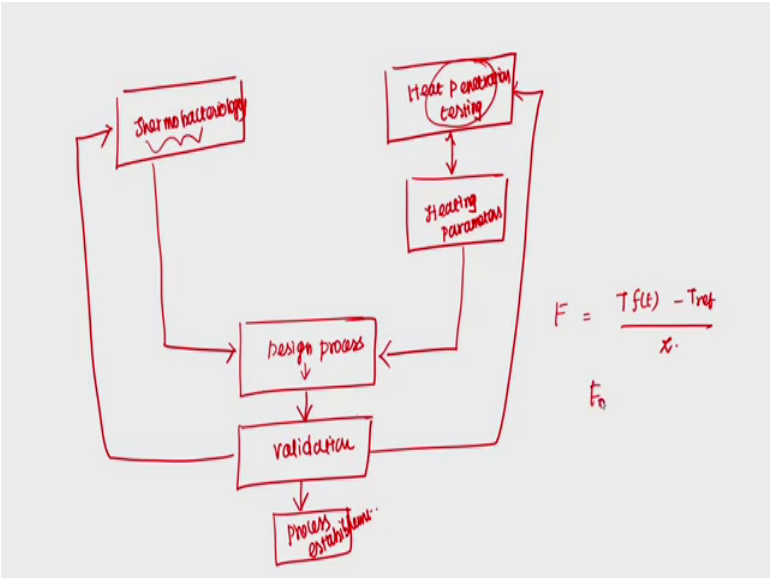

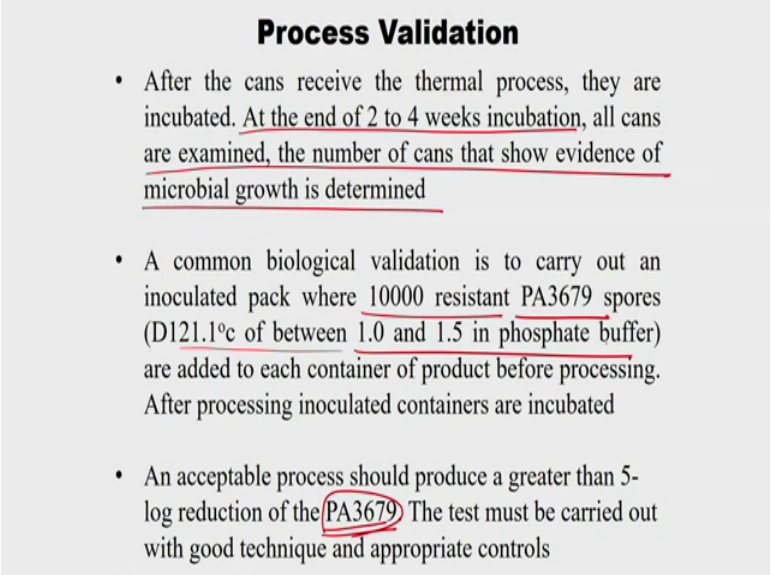

And the process validation is done in confirmation of the design process to provide assurance that the design F naught. Design F naught in the sense, so if you remember our earlier slides, so we discussed about thermobacteriology, we discussed about heat penetration testing, so the now we are in the design process. So after combining these two in terms of F, So F talks about the T which is the function of time and T reference and z value for that microorganism. So we combined both and designed F not we come up with.

Alright and now here we are going to do the process validation. So design level of sterilization process microbial survival probability of about 10 to the power of minus 9 spores. This will not harm and 10 to the power of minus 6 for nonpathogenic organism. Using the same organism is not possible. So what happens is when I am testing so even if I am microbiologist, I will not choose this C.bot.. So and even if you are in the if the testing is done in the commercial plants, so it is not good to have such kind of pathogenic organisms in the plant itself. So normally we use the surrogate organisms so which is nothing but putrefactive Mesophiles or thermophiles so PA3679, which is nontoxic, not like C.bot and I into the cans before the containers are sealed and processed

So the testing is done using PA3679. This is also heat resistant higher than C.bot and spore forming organisms. So one thing is this is nontoxic and very safe to handle. So the process validation is done using this particular organism. So normally what we do is; after the cans are received thermal process, they are incubated. So first what we do is, we inoculate the calibrated bacterial spores. So that means my initial concentration is known. Known initial concentration is inoculated. Then after the can received the thermal process, so at the end of 2 to 4 weeks of incubation, all the cans are examined. The number of can that show the evidence of bacterial

growth is determined.

So the common biological validation to carry out an inoculated pack where this is 10 to the power 5 resistant PA3679 spores. So this is conducted in between 1 to 1.5 in phosphate buffer are added to each container of product before processing. After processing inoculated contains are incubated. So the initial concentration, they have taken as 10 to the power of 5 and the this is the maintained condition is phosphate buffer, 1 to 1.5. This is much low to maintain the pH and acceptable process should produce greater than 5 log reduction of the PA3679. So if that is the case, then it passed the validation. Otherwise, the alteration should be carried out. So that means we have not understood any either, either our thermal process correctly or sometimes there may be a problem in the thermobacteriology as well.

So the process validation, so to cut short. The process validation is done using some other organism, which is nothing but a PA3679. So the conditions are 10 to the power of 5 initially taken and check the condition for 5 log reduction. So if it pass the test, then the conditions whatever we have designed, that is nothing but F naught value is applicable to the commercial sterilization. Otherwise we need to back retreat. We need to change either the thermobacteriology studies, or we need to conduct heat penetration testing, then come up with a new F naught, then again validate. So if it is acceptable then go for process establishment.

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Canning operations are very much wide varieties, so I request you to refer some of the additional resources for this particular lecture. So these are all some of the references and additional resources. Thank you.