Thermal Processing of Foods
Professor R. Anandalakshmi
Chemical Engineering Department
Indian Institute of Technology, Guwahati
Lecture No. 4
Milk-Pasteurization

Good afternoon all, today we are going to see about milk pasteurization.

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So the outline goes like this, the regulations and definitions of milk pasteurization and milk processing that is nothing but a pasteurization and effects of pasteurization and packaging and shelf life.

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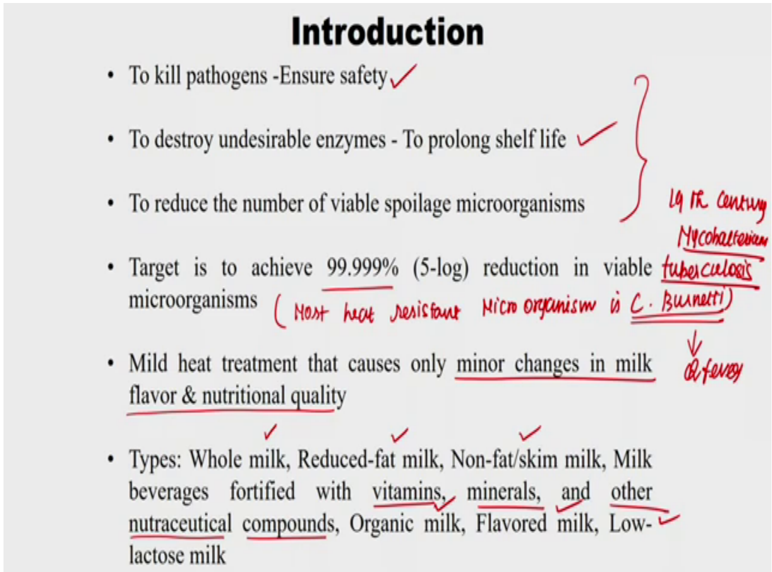

So the introduction about milk pasteurization is why we do milk pasteurization is, the first thing is to ensure the safety by killing pathogenic microorganisms and also to prolong the shelf life to destroy undesirable enzymes and to reduce the number of viable spoilage microorganisms. So these three are ends of milk pasteurization. And also our target is to achieve 99 point 99 percentage, that is nothing but a 5 log reduction in viable organisms.

So here the most heat resistant microorganism is Coxiella Burnetii. So we are going to do milk pasteurization for killing of this most heat resistant microorganism, which is present in the milk. Actually this pasteurization is nothing but a mild heat treatment this causes only minor changes in the milk flavor and nutritional quality. And also there are variety of milks, the milk means the whole milk, reduced fat milk, non-fat or skimmed milk which is free of cream and milk beverages fortified, nowadays there are supplements, vitamins, minerals and other nutraceutical components which are added into the milk to get a fortified milk.

So that is they also called as milk. And organic milk, flavored milk, low lactose milk., so all comes under milk category only. So actually if we see the history of milk pasteurization, so we all are know the word was coined after the name of Louis Pasteur. So who applied the heat treatment to increase the shelf life of the wine. So then he extended the same procedure to the milk to increase the shelf life. So initially when the pasteurization was done for the milk, so it was the heat resistant organism, which is nothing but mycobacterium tuberculosis so which causes tuberculosis. So in around 19th century, so that was around 19th century.

So that time this was the micro bacterium tuberculosis. So this was the most heat resistant bacterium at the time, so which causes the tuberculosis. To kill this pathogenic organism first first pasteurization was applied. So then after that they realized so this is the most heat resistant microorganism, which is nothing but a Coxiella Burnetii. So which causes a Q fever..

First country who made it mandatory for milk pasteurization was Chicago in U.S. and also after that the FDA which is nothing but a Food and Drug Administration, so they made it mandatory for sale of interstate. If we want to sell milk between the states then it is mandatory that milk should be pasteurized first, this was done in around 1987. So this is the past history then after that there were many regulations and rules there were ordinance they were followed to further milk pasteurization. So we are going to see one by one.

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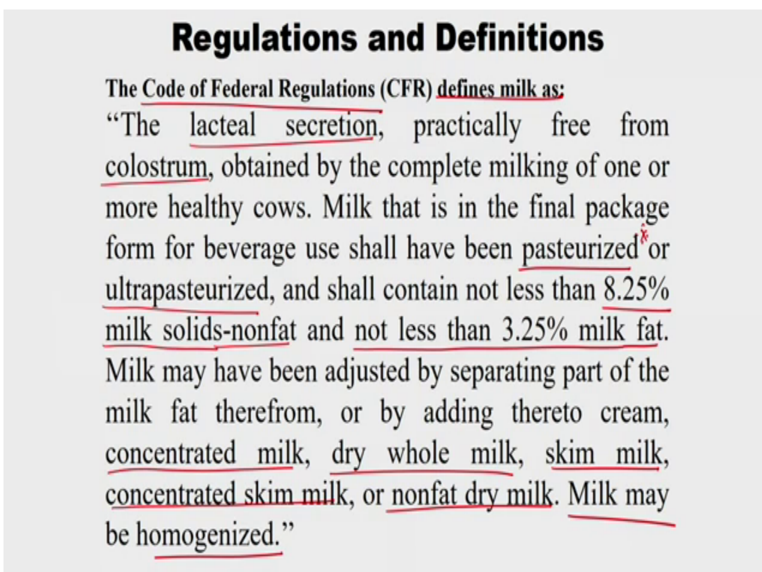

So the code of federal regulations that is CFR, so they defines the milk, what is called milk. So the lacteal secrecation practically free from colostrum, colostrum is nothing but a first milk of any mammals after the new born obtained by the complete milking of one or more healthy cows. Milk that is in the final package form for beverage use shall have been pasteurized. So that is button criteria or ultra-pasteurized.

So we will be seeing the conditions, so in subsequent slides, shall contain not less than 8 point 25 percentage of milk solids and non-fat and not less than 3 point 25 percentage of milk fat. Milk may have been adjusted by separating part of the milk fat therefrom or by adding that to cream. So you can remove or add, maybe some consumer wanted in that way, then the cream is added to the normal milk, or they may be separated from the milk as well and concentrated milk, dry whole milk, skim milk, concentrated skim milk, non-fat dry milk. So all comes under the definition of milk. And milk also may be homogenized. So this is the definition code of federal regulations gives for milk.

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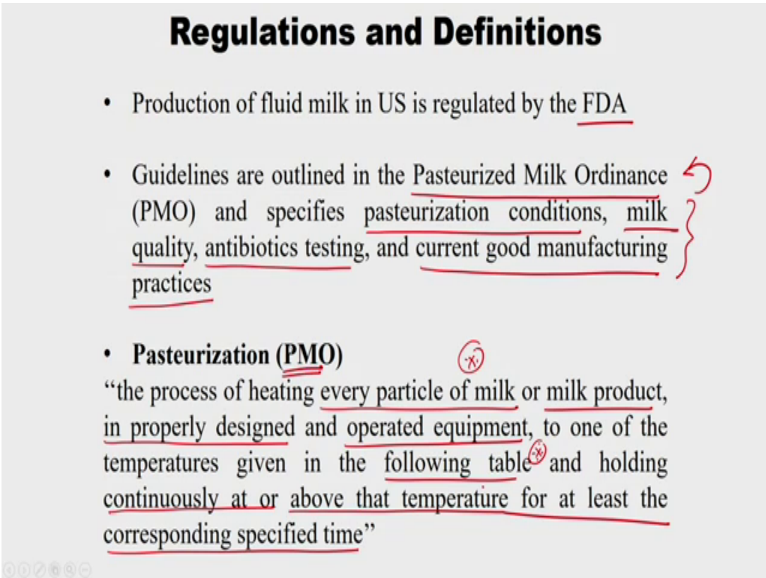

Then the production of fluid milk in U.S. is regulated by FDA that is nothing but Food and Drug Administration and also PMO that is there are guidelines which are outlined by FDA which is nothing but a pasteurized milk ordinance and which specifies the pasteurization conditions and milk quality, antibiotic testing and current good manufacturing practices. So for all categories, so they lay down some ordinance. So which is called PMO, pasteurized milk ordinance, which was proposed by FDA. So those were guidelines.

So according to that guidelines what is pasteurization the which is lay down by PMO, which is nothing but a pasteurized milk ordinance. So the process of heating every particle of milk. This is very much important. So the moment I say okay, it should be 63 degree for 30 minute. So each and every particle of the milk should be heated to that particular temperature and hold on to the particular time of 30 minutes or milk product is properly designed and operated equipment. For example, pasteurization. So what we do at home, we heat the milk, is that part pasteurization?

So that is what so it should be properly designed and operated equipment to one of the temperatures given in the following table this we are going to see so what are all the time temperature regulations for pasteurization and holding continuously at or above that temperature for at least the corresponding specified time. So the particular temperature and particular minute, it should be heated to particular temperature and hold on for a specified time at that particular temperature. So this following table we are going to see. So this is the definition of pasteurization according to pasteurized milk ordinance.

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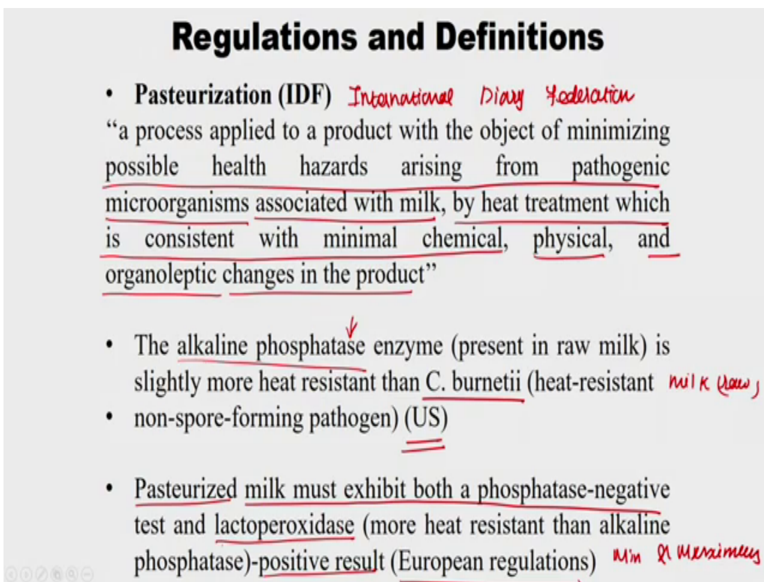

And there is a International Dairy Federation as well. This is IDF, International Dairy Federation. So how they define pasteurization is a process applied to your product with the object of minimizing possible health hazards arising from pathogenic microorganisms associated with milk by heat treatment, which is consistent with the minimal chemical physical and organoleptic changes in the product. So it is not only important to kill the pathogenic organisms, which is present in the milk. And also it should not give any damage to the chemical or physical or organoleptic changes in the product. That is also important.

So one such example is the alkaline phosphatase enzyme which is present in the raw milk is slightly more his heat resistant than the Coxiella burnetii, which is the heat resistant non spore-forming pathogen. So which is present in the raw milk. So the heat treatment is applied to kill these pathogenic organisms and also we need to take care of this alkaline phosphate. Sometimes the test is to conduct the phosphatase enzyme activity, whether if the activity is present, so that means the pasteurization is not enough. So we also have to reduce or inactivate alkaline phosphatase enzyme activity, but this regulation is given by U.S.

So your pasteurization should be good enough to inactivate this alkaline phosphatase enzyme activity as well. But in European regulation says not only reduce the phosphatase activity and also we need to take care of lactoperoxidase activity because it should not inactivate this lactoperoxidase activity which is present in the milk. So they give minimum, maximum ranges of pasteurization temperature. So what they say is pasteurized milk must exhibit both the phosphatase negative test as I said, so this is also harmful.

So we need to inactivate along with pathogenic organism and lactoperoxidase positive test because that is the enzyme which is present in the milk., okay. So they give you minimum and maximum activity minimum and maximum. So it should show negative test for phosphatase activity and positive results for lactoperoxidase activity accordingly, the temperature is chosen. So in the subsequent chapters, we will also see how to choose a particular time temperature combination which kills the organisms as well as which does not give any denaturation of enzymes, that we will see in the subsequent lectures, okay.

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Temperature	Time	Pasteurization type
63°C (145°F)	30 min	Vat pasteurization. Low-temperature, long-time pasteurization (LTLT) Batch process
72°C (161°F)	15 s	High-temperature, short-time pasteurization (HTST) continuous process
89°C (191°F)	1 s	Higher-heat, shorter-time pasteurization (HHST)
90°C (194°F)	0.5 s	HHST
94°C (201°F)	0.1 s	HHST
96°C (204°F)	0.05 s	HHST
100°C (212°F)	0.01 s	HHST
137.8°C (280 °F)	2.0 s	Ultrapasteurized (UP)

Plate type Heat Exchanger

3 months @ Refrigerated storage.

So this is the following table what I was talking about here given by PMO. So if it is a vat pasteurization, vast pasteurization is nothing but a batch process, okay. So vat pasteurization is done for 63 degree centigrade for 30 minute. So this process is called low temperature and low time pasteurization which is nothing but a LTLT. So here how it is being done is, first we need to heat it at 63 degrees centigrade and hold it for 30 minute and cool it to the ambient temperature then remove it from the batch by batch.

So this is the energy consuming process because what you do is you heat it to 63 and hold it and we again to heat it you need to use heating medium and to cool it to again to the temperature and you need to use cooling medium. And also you are taking long time but process wise it is simple because what you require is just one jacketed vessel to heat and hold and cool, but though I am saying one jacketed vessel is enough, but it is always a good practice, Wwe already told it as a proper equipment proper typical licensed vat pasteurizer you should do it. So then after that the continuous that that is nothing but high temperature short time pasteurization. So this is nothing but a continuous process.

So this was introduced to reduce the energy consumption, which is a disadvantage in the batch process. So here the temperature is 72 degrees centigrade the hold on time is 15 second. So here one advantage is what happens is the pasteurized milk which comes out of the plate type heat exchanger here, we use plate type heat exchanger. So the pasteurized milk which comes out of the holding tube is used to heat the raw milk, so that the pasteurized milk gets cooled and your raw milk is getting heated to some medium temperature.

So that way you conserve some of the energy so this is a good practice compared to the batch sterilization process. So the time consumption also very less compared to the batch process. It is 15 second. And also there are certain HHST process, which is nothing but higher heat so here high temperature short time, but here higher heat shorter time pasteurization. So this is done at 89 degrees and one second and 90-degree point 5 second and 94-degree if point 1 second and 96 degree point 05 second and hundred degree point 01 second. So these are all are HHST processes.

And if you heat it to 137 point 8 degree for 2 seconds, so that is called ultra-pasteurized milk. So in U.S. most of the people prefer the ultra-pasteurized milk compared to normal pasteurized milk because this can stay up to 3 months, 3 months of refrigerate stor storage. So the temperature is a bit high, but sometimes the flavor you get cooked flavor because of this high temperature. So this is the time temperature relation given for various process by PMO.

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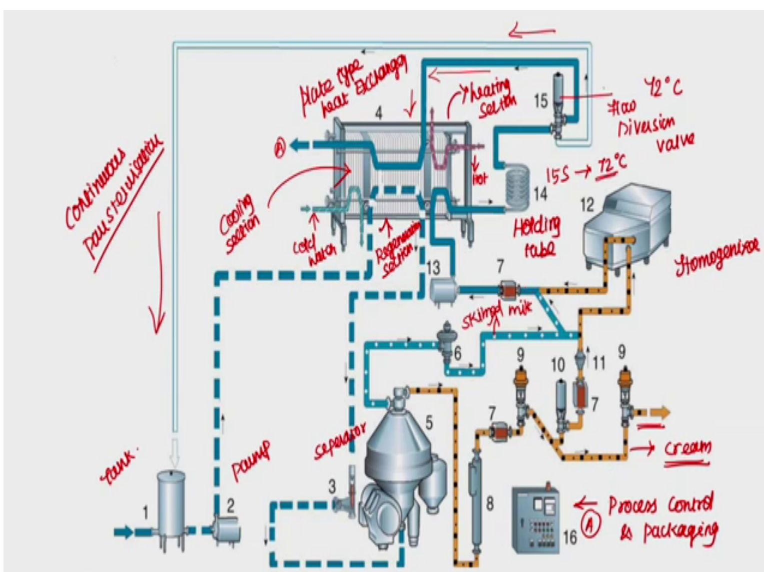

So this is the typical continuous pasteurization. Now, but there may be changes because sometimes we already discuss the milk means maybe whole milk, may be organic milk, may be skimmed milk. So based on the product there may be changes in this diagram. So it is like a generic diagram, how the sterilization happens. So the major equipment is this is a tank, and this is nothing but a pump. So this is separator and this is a homogenizer and this is plate type heat exchanger.

So this is holding tube. So where it is holding to that particular temperature or higher that is all measures. This is after packaging., this is process controlled and packaging section. So in the plate type heat exchanger, so this is the regeneration section. So this is cooling section. This is heating section. So this is hot water. This is cold water. So this is creamy milk, cream part. So this is skimmed milk part.

So what happens is from the balance tank, the raw milk is pumped and sent to the regenerator section. So where from here you are pasteurized milk is coming. So this is your pasteurized milk. So it exchanges heat then after that the raw milk is passed through the separated section via flow controller. So this is nothing but one flow controller. So these are all safety measures these flow controllers and valves certain valves are there and certain pumps also there, so those were to check in between the conditions. So then it goes to the separator where cream and skimmed milk part is separated. So then this is the density transmitter, this is again flow transmitter, 7 is a flow transmitter.

So then 9 is a another regulating valve. So this 10 is nothing but a shut up valve so which if any problem then then it will stop the input. So then 7 is nothing but again flow transmitter. So 11 is nothing but a check valve. So it allows only this direction of the flow and if you want cream, then it will be taken from here or otherwise it will go to the homogenizer, homogenizer in the sense the large fat chunks will be homogenized, homogenized into small particle size.

Then if you want then it can be again added back to the skimmed milk, then 7 is nothing but a flow transmitter, then it is pumped to the heating section of the plate type heat exchanger where more hot water is used to exchange the heat then it is heated to the particular temperature. For example, we said it is 72 degrees centigrade at 15 seconds. So in the hold on tube, so it will be almost it the milk spends 15 seconds so which is now heated at 72 degree centigrade at the heating section of the plate type heat exchanger. Then after that it goes to this is CFDV flow diversion valve.

So what happens here is it ensures the 70-degree after it comes out of the holding tube it is heated to 72 degree because it is it is held at 72 degree 15-second. So if the temperature is not enough or it is not pasteurized to that temperature, then it it sends back, it sends back to the balance tank again, or if it meets the temperature regulation, then it has to go through the regenerator section.

Then it goes to cooling section where cold water is used to cool and it comes then after that from here, it goes to this section so further packaging. So this is a generalized overview of pasteurization in the continuous process. So there may be changes. I already told here we if we want to cream milk some consumer wanted the creamy layer above the milk if the consumer wanted that product or if the company manufactures that product so then there is no need of separation or if they wanted to go for production of skimmed milk, then it is cream is separated then only skimmed milk is going.

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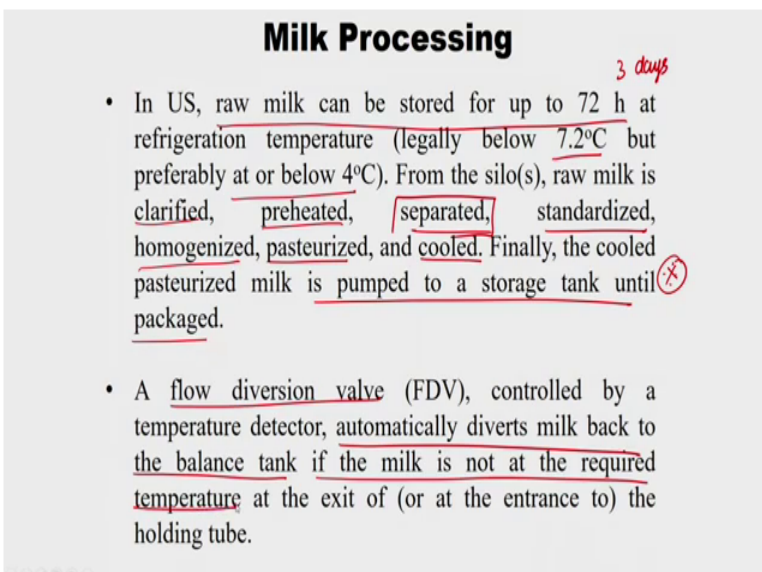

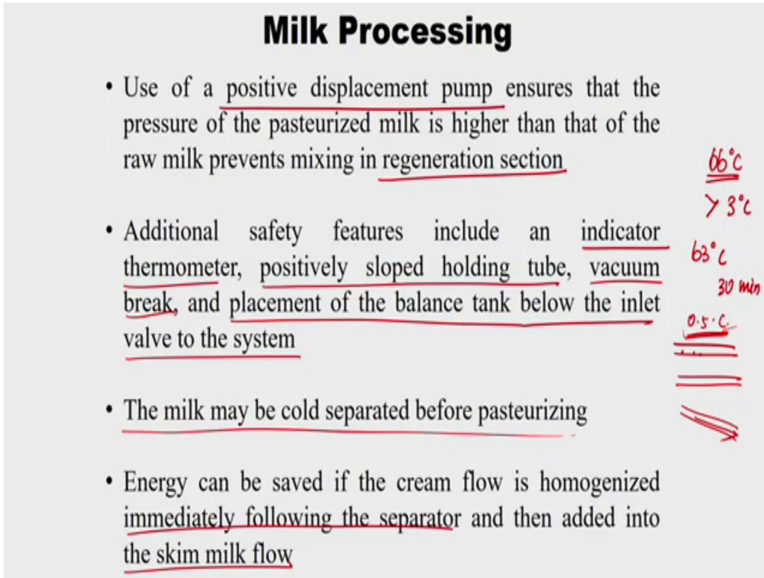

So this is the milk processing. In U.S. raw milk., so which is what we are having it in the balance tank that is stored up to 72 hours almost 3 days at a refrigeration temperature legally below 7 point 2 degree centigrade, but preferably at or below 4 degrees centigrade. So in the balance tank, you are allowed to keep it for 3 days but if you are maintaining at refrigeration temperature, so from the silos raw milk is clarified, preheated, separated, standardized, homogenized, pasteurized and cooled. So what we have seen is heating, pasteurized and cool and in between then some separation we have seen, the creamy layer from the skimmed milk.

So other than that, this also can be done, so based on the industry needs, what for they have employed the pasteurization unit. And finally the cooled pasteurized milk is pumped into the storage tank until package. So here also the we should ensure there is no recontamination issue. So there are certain safety measures also taken while processing the milk by a pasteurization. So one is the flow diversion valve as I said, already, so it automatically diverts milk back to the balance tank if the milk is not at the required temperature.

So if it is not at 72-degree, it will send back to the balance tank and use of positive displacement pump which ensures so we use pumps to ensures that the pressure of the pasteurized milk has higher than that of the raw milk. So that there will not be any mixing at the regeneration section. Additional safety measures include an indicator thermometer, I already told while explaining the process itself and positively sloped holding tube. So for example, if I put holding tube this way right and there may be a chance of some milk packet stays here. So when we put slope, then it flows without any resistance.

So that way they ensured positive slope holding tube and vacuum break sometime and placement of the balance tank below the inlet valve of the system. So these are all ensures there should not be any recontamination. For example, if some milk packet stays in the holding tube and also when the next batch of pasteurized milk comes then there may be a temperature difference with this milk chunk and what what comes freshly and also the milk maybe cooled separated before pasteurizing.

So what we have done we have separated the skimmed milk with the creamy milk before pasteurizing itself to save the energy and also energy can be saved if the cream flow is homogenized immediately following the separator and then added into the skim milk flow because the skim milk need not homogenized because what we wanted is the fat part of the milk should be homogenized in that way also we save some of the energy

Before that as I told and the safety measures and also there is important thing when we talk about the batch process the atmosphere above the milk, which is nothing but a the head space. So the head space should have at least greater than 3-degree temperature which is maintained in the milk. For example, batch process ensures 63-degree temperature at almost 30 minute. So your head space should be maintained at least 66-degree centigrade to avoid any temperature difference and also because it loses the heat, because the top layer is set to 63 if your air layer is at normal temperature, there may be a del T.

And also we need to ensure all the valves and inlet tube, outlet tube everywhere, there should not be any delT, delT in the sense if it has to be maintained at 63, so all the equipment should also be at the same temperature and if at all there is a del T, it should be less than point 5 degree Centigrade. So literally there should not be any temperature difference. So if at all then only allowed is point 5-degree Centigrade only. So these are all safety measures we need to ensure it will greatly reduce your post contamination process. It is not only pasteurization. So it is there maybe post contamination as well.

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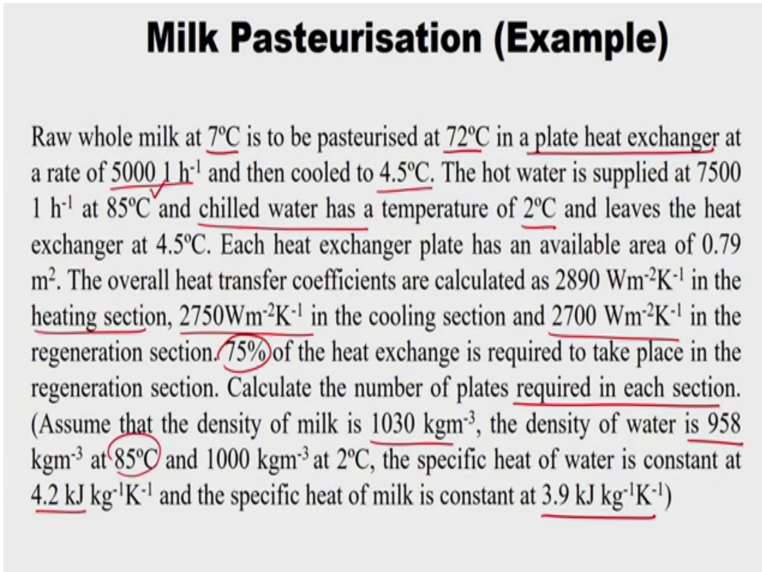

So then we are going to see one of the example for milk pasteurization. So the problem is defined here, raw whole milk at 7 degree is to be pasteurized at 72 degree centigrade in a plate heat exchanger at a rate of 5000 liter per hour then cool to 4 point 5 degree centigrade. So the milk is pasteurized from 7 degree to 72 degree centigrade in a plate type heat exchanger. So the volumetric flow rate is given here 5000 liter per hour then it is cool to 4 point 5 degree centigrade. The hot water is supplied at 7500 liter per hour at 85 degrees centigrade and chilled water has a temperature of 2 degree and leaves the heat exchanger at 4 point 5 degree centigrade.

Chilled water in the cooling section temperature and leaving temperature is given each heat exchanger plate has an available area of point 79 meter square, the overall heat transfer coefficients are calculated as 2890 Watt per meter squared Kelvin in the heating section, the same overall heat transfer coefficient is given for cooling section as well, which is 2750 Watt per meter squared Kelvin and 2700 Watt per meter squared Kelvin in the regeneration section. So this is important thing 75 percentage of the heat exchange required to take place in the regeneration section.

Calculate the number of plates required in each section and properties are given which is nothing but density of the milk is given, density of the water is given, which is set hot water because 85 degrees centigrade. So here it is and the 1000 kg per meter cube at 2 degree, so which is nothing but chilled water. So though the temperature differences there in the heat exchanger, these properties are assumed to be constant throughout the range of temperature. The specific heat of water is given that is 4 point 2 kilo Joules per kg Kelvin and specific heat of the milk is also given. So our aim is to find out how many number of plates in the each section.

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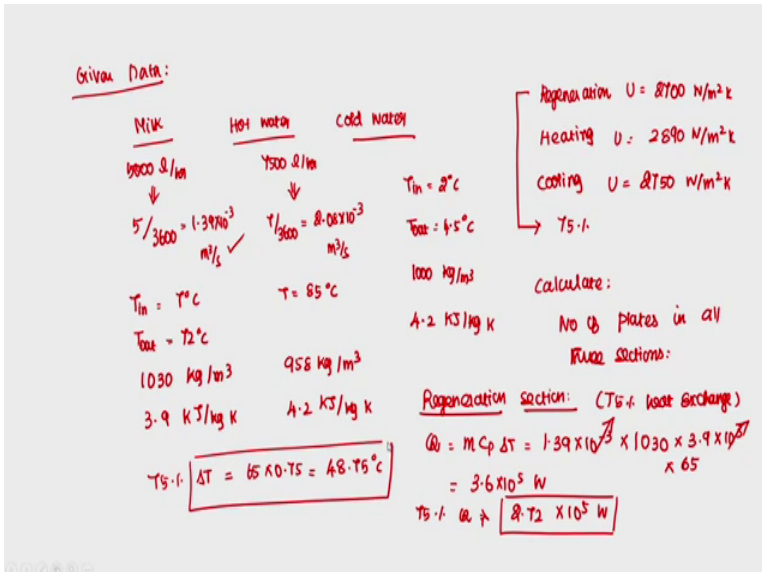

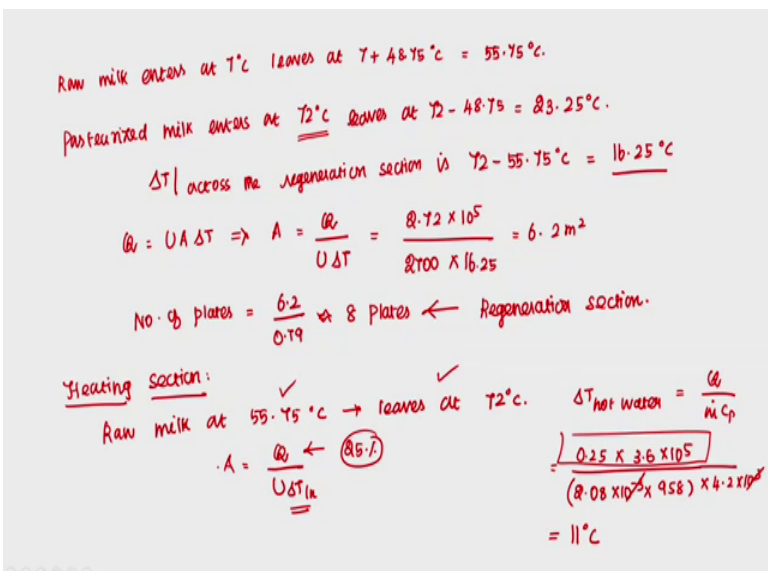

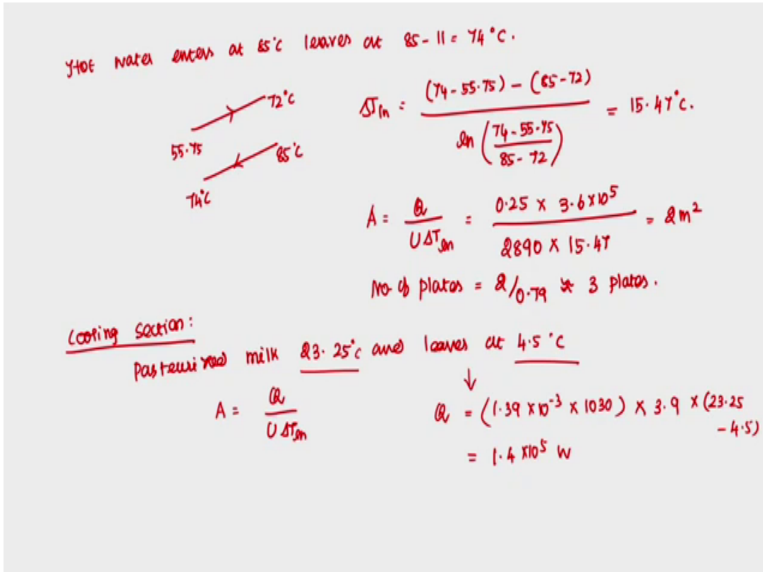

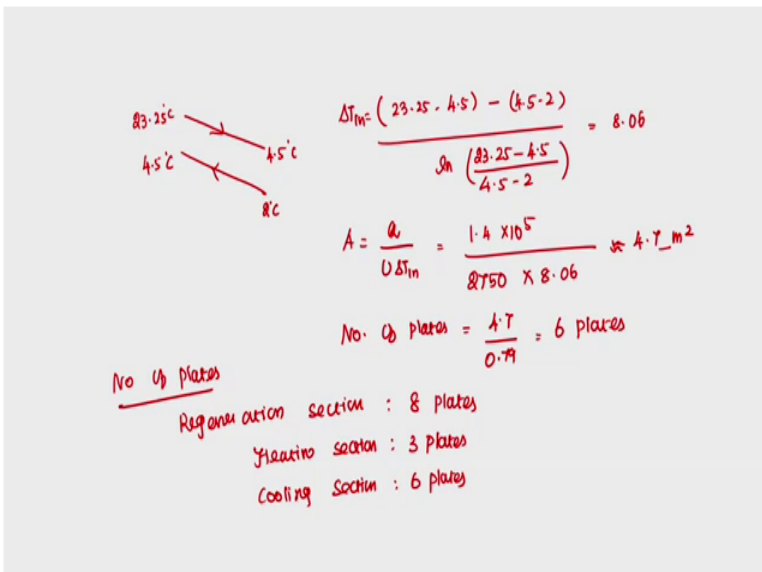

So we will write given data. One is milk side; another is hot water side. another is cold water side. So milk volumetric flow rate is given which is nothing but 5000 liter per hour. So we would be using in terms of Watts, so we can better convert this into kg per second. So for that you need to multiply with the density, now here we convert in terms of seconds then later we will see, meter cube per second we will convert and later we will see so 5 because 1 liter is 10 to the power of minus 3 meter cube. So 5 and the 3600 seconds so which is coming around 1 point 39 into 10 to the power of minus 3 and water side, it is given as 7500 liter per hour.

Same conversion goes here. So 7 upon 3600 so which is nothing but 2 point 08 into 10 to the power of minus 3, so this is a in meter cube per second. Later we will convert to kg per second.

So the cold water side nothing is given so then milk Tin is given which is nothing but 7 degree centigrade and Tout is given which is nothing but 72 degrees centigrade and in the hot water side temperature is given 85 degree centigrade and density of the milk is given so which is nothing but 1030 kg per meter cube and same way Cp is given which is nothing but 3 point 9 kilo Joules per kg Kelvin and this side again density is given which is 958 kg per meter cube.

And Cp is given which is 4 point 2 kilo Joules per kg Kelvin. In the cold water side, so Tin is given which is nothing but 2 degree centigrade and Tout is given which is nothing but 4 point 5 degree centigrade and density is given which is nothing but 1000 kg per meter cube and Cp is given which is 4 point 2 kilo Joules per kg Kelvin. So this is all the properties we have written and if we remember we just have seen there are three major sections, one is heating regeneration and cooling. The regeneration section, the pasteurized milk which comes out of the holding tube is used to preheat the raw milk. So that is nothing but a regeneration section.

So what are all the information given for all three sections we will just see this is heating section, another is cooling section. So if we see so all the section they have given U. so in regeneration section U is 2700 Watt per meter squared Kelvin and heating section U is 2890 Watt per meter square Kelvin and then the cooling section U is 2750 Watt per meter squared Kelvin and the important thing is in the regeneration section almost 75 percentage of the total Q is exchanged between the raw milk and the pasteurized milk. So we are ready to calculate what we supposed to calculate is, number of plates in each section, plates in all three sections. So we will start with our regeneration section.

So regeneration section, it is told that 75 percentage of the heat exchange is done. So for that, I need to know first what is Q. so Q I I will be calculating using MCp delta T for the pasteurized milk. The mass is given, mass flow rate is not directly given, it is a volumetric flow rate is given. So 1 point 39 into 10 to the power of minus 3 into density is nothing but 1030 and the Cp is given 3 point 9 into 10 to the power of 3 because it is given in kilo Joules and the total temperature gradient is 72 minus 7, so which is nothing but 65, so this goes, so the total Q what you would be getting is 3 point 6 into 10 to the power of 5 Watt, so in that 75 percentage of this Q is nothing but 2 point 72 into 10 to the power of 5 Watt, so this much heat is being exchanged in the regeneration section.

So another one is the 75 percentage of the temperature difference as well. Because if you see Q was nothing but UA deltaT, so U is constant throughout and area is also so then whatever the 75 percentage of the heat exchange. We can also calculate the 75 percentage of the deltaT across the regeneration section, so which is nothing but the total delT is 65. 65 into point 75 so which is nothing but 48 point 75 degree centigrade. So this is delT which happens in the regeneration section. Now, we will be able to tell, my raw milk enters at 7 degree and leaves at 7 plus we have calculated the delT is 48 point 75 degree centigrade.

So totally it is 55 point 75 degree centigrade and the second one is pasteurized milk which comes out of the holding tube, which enters at 72 degrees centigrade and leaves at again 72 minus 48 point 75 so which is nothing but 23 point 25 degree centigrade. So we know what is the delT across the exchanger now, so delT across the regeneration section is, so this is 72, this is 55, so 72 minus 55 point 75 degree centigrade. So which is equivalent to 16 point 25 degree centigrade 16 point 25. So delT across the exchanger is 16 point 25 degree centigrade. So we already know the formula which is nothing but UA delT.

So what I supposed to calculate from here is A which is nothing but Q upon U delT. So we know what is the heat exchange which is nothing but 75 percentage of the total heat so which we calculated in the previous slide is 2 point 72 into 10 to the power of 5 upon U is given, U is given in the regeneration section. So it is 2700 into delT we just calculated 16 point 25. So which comes around 6 point 2 meter square. So each plate area, this is the total area, so number of plates is nothing but 6 point 2 and each plate area is given I guess here somewhere.

Yeah point 79. So point 79 so which comes around approximately 8 plates. So in the regeneration section the number of plates required would be 8 plates. So now we slowly move on to next one is heating section. In the heating section what happens the raw milk, which heated from 7 to 55 point 75 will be introduced into heating section and it will be heated to final pasteurizer temperature of 72 degree centigrade. So the raw milk which comes out of the regeneration section at 55 point 75 degree centigrade is getting heated in the heating section and leaves it 72 degree centigrade.

Here if I want to calculate the area, so what formula I would be using is Q upon U delTm delT it is a logarithmic mean temperature. It is lon of delT. What is a clue about Q, Q we have already told 75 percentage of the heat exchanges happening in the regeneration section. So remaining 25 percentage heat exchange happens in the heating section. So I have a clue so I can calculate how much is 25 percentage and U is given but I supposed to calculate delTn, which is nothing but a logarithmic delT. But I know in the heating section raw milk enters at 55 point 75 and leaves at 72, but if you see the problem, in the hot water side, you are given only the entering temperature but I do not know what is a leaving temperature of the hot water in the heating section.

So I would be calculating here the delT of hot water. So we know Q is equal to MCp delT. So delT of the hot water is nothing but Q upon mass flow rate into Cp so Q I know so point 25 of my total Q is nothing but 3 point 6 into 10 to the power of 5 so divided by hot water mass flow rate is given so which is nothing but we calculated 0 2 point 08 into 10 to the power of minus 3. So this is nothing but a volumetric flow rate that has to be multiplied with the density which is nothing but 958 into Cp, Cp is nothing but 4 point 2 into 10 to the power of 3 because it is given in the kilo Joules.

This will get cancelled. So we are getting the delT of about 11 degree centigrade. So I know delT of milk the temperature difference which is happening in the heating section and the temperature difference which is happening in the hot water side. So then we will be able to calculate logarithmic delT and Q already we have seen so this is nothing but 25 percentage of the total Q. So from there I will be able to calculate what is a area. So hot water entering temperature is hot water enters at 85 and leaves at 85 minus 11 because delT is 11. So that is nothing but 74 degree centigrade. So the delT for hot water side as well as the raw milk side.

So the raw milk enters at 55 point 75 and it is heated to 72 degrees centigrade and we already told it is a counter flow plate heat exchanger. So hot water enters at 85 and leaves at 74 degrees centigrade. So if we calculate delT logarithmic so which is nothing but 74 minus 55 point 75 minus 85 minus 72 divided by lon of 74 minus 55 point 75 upon 85 minus 72 so which is coming around 15 point 47 degree centigrade. So we already know what is that A, A is nothing but Q upon U delT lon so U already we told point 25 into 3 point 6 into 10 to the power of 5, 25 percentage of the total heat requirement. So U is given for hot water 2890 Watt per meter squared Kelvin and the logarithmic mean temperature difference is 15 point 47.

So your area coming around 2 meter square. So number of plates is nothing but 2 upon point 79 so which is coming around approximately three plates. Then there comes a cooling section, so cooling section the information given is pasteurized milk. So pasteurized to milk when it leaves the regeneration section. So if you see it is set 23 point 25 centigrade. So it is cool to 4 point 5 degree centigrade. So from pasteurized milk, enters at 23 point 25 and leaves at 4 point 5 degree centigrade So the temperature difference we suppose to find out by logarithmic mean and before that we also have to see because the A is nothing but Q upon U delT lon, so in the cooling section we found out what is the entering and leaving temperature of pasteurized milk, but the entering and leaving temperature of the cold water is also given here.

So delTm we know, we can calculate and we can calculate U but I do not know how to calculate Q so that we supposed to calculate now, for example, if we see if we take the pasteurized milk, which is nothing but Q, Q is the milk is 1 point 39 into 10 to the power of minus 3 volumetric flow rate into density that is 1030 into the Cp is 3 point 9 so the temperature difference is nothing but 23 point 25 minus 4 point 5. So which comes around 1 point 4 into 10 to the power of 5 Watts. So we know Q then we suppose to calculate the logarithmic mean temperature difference.

So if we see in the cooling section, so one is the pasteurized milk enters at 23 point 25, which is cool to 4 point 5. So the same way my cooling water enters at 2 degree centigrade and leaves at 4 point 5 degree centigrade. So delT lon so 23 point 25 minus 4 point 5 minus 4 point 5 minus 2 lon of 23 point 25 minus 4 point 5 divided by 4 point 5 minus 2. So the logarithmic mean temperature is coming around 8 point 06 degrees centigrade. So area is nothing but Q upon U delT lon, so just to we calculated Q, Q as 1 point 4 into 10 to the power of 5 divided by the U is given 2750 and the logarithmic mean temperature gradient is 8 point 06.

So if you substitute you will get around 4 point 7 meter square, so number of plates required is 4 point 7 upon point 79 which is around 6 plates. So number of plates you need to section regenerations section around 8 plates. Then heating around 3 plates then cooling section around 6 plates. So this is the way heat exchanger plate type heat exchanger is designed for pasteurization of milk in continuous process. And also here these values are approximate approximately 4 point 7. So for example, if you are taking more digits here, then you would be ending up with 7 or 8 plates. I might have done some numerical mistakes also. So here the way how do you design is important. So if there are any error, please, excuse me, while writing the numerical values.

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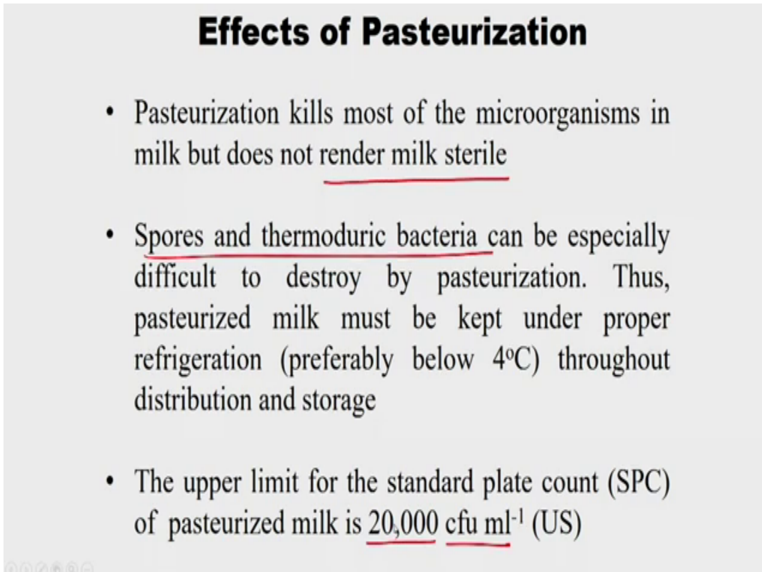

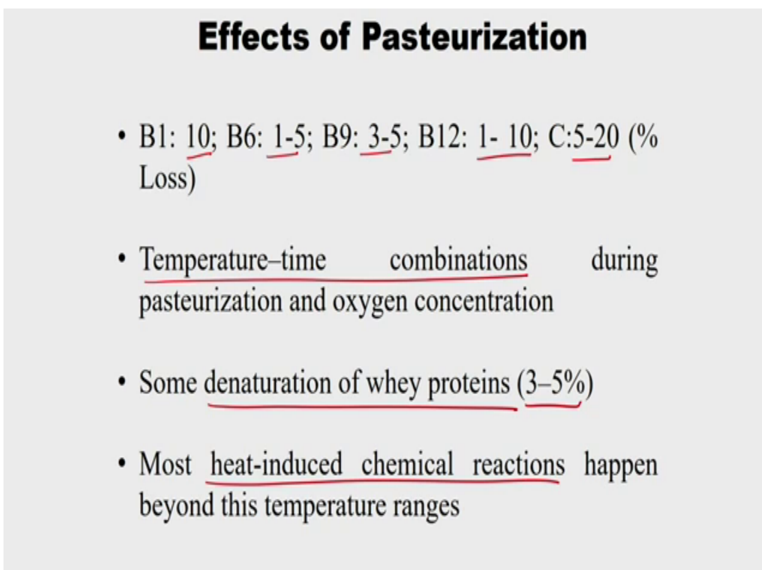

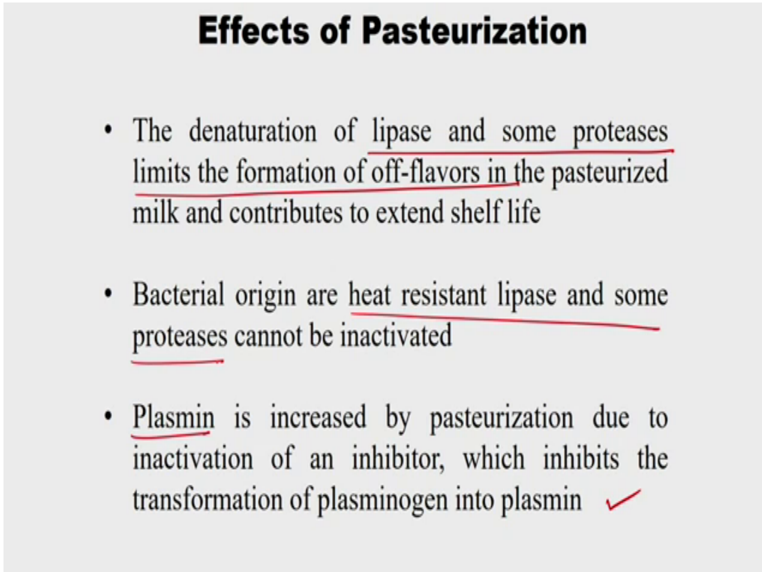

So then next we will see the effect of pasteurization actually pasteurization kills most of the microorganisms in milk, but does not render milk sterile. So it should always be stored in the refrigerator condition because the spores and thermoduric bacteria may be especially difficult to destroy by that pasteurization temperature can be survived. So the pasteurized milk must be kept under proper refrigeration temperature preferably below 4 degree throughout the distribution and storage. And also this can be checked using standard plate count.

So the U.S. regulation says the upper limit for the standard plate count after the pasteurization is the 20000 CFU, colonies per ml. So anyway, the fresh pasteurized milk will have less than that only. And also when you pass trays so what are all happens to the so this is based on microbial. So we told that thermoduric bacteria may be still there in the pasteurized milk. So it has to be stored under refrigeration. The count is 20000 CFU per ml. If you do it in the standard plate count and there are certain enzymes which are not affected that is A and D but B1 B6 B9 B12 and C all are having 10 percentage 1 to 5 percentage 3 to 5 percentage and 1 to 10 percentage and 5 to 20 percentage loss would be there.

And also these time temperature combinations during pasteurization. So we have told 63 degree if it is a batch batch process 63 degree and 30 minute and if it is a continuous process it is nothing but 72 degree and 15 seconds. So these time temperature combinations, it is no hard and fast rule that these time temperature combinations would leave this percentage loss. So there is a quality consideration and optimization module of this course, so that talks about how to optimize minimum destruction to the vitamins and maximum kill to the microorganisms.

There we derive the best time temperature combinations to reduce this percentage loss and there are some denaturation of whey proteins also happens during pasteurization that is 3 to 5 percentage and most heat-induced chemical reactions happens beyond 140 degree. So we did not worry about much and in enzymatic ways and there are a denaturation of lipase and some proteases which limits the formation of off flavors in the pasteurized milk which contributes to extend shelf life and bacterial origin heat-resistant lipase and some proteases cannot be inactivated at this pasteurization temperature.

And also sometimes what happens there is some enzymes called plasmin which is the plasmin is increased by pasteurization because the enzyme which transforms plasminogen to plasmin so that incubator, so that incubator get inactivated during pasteurization. So because of which then there is a transformation of plasminogen into plasmin, so this also happens sometime and you cannot do anything about certain heat resistant lipase and some proteases. So these are all effects of pasteurization on enzymes.

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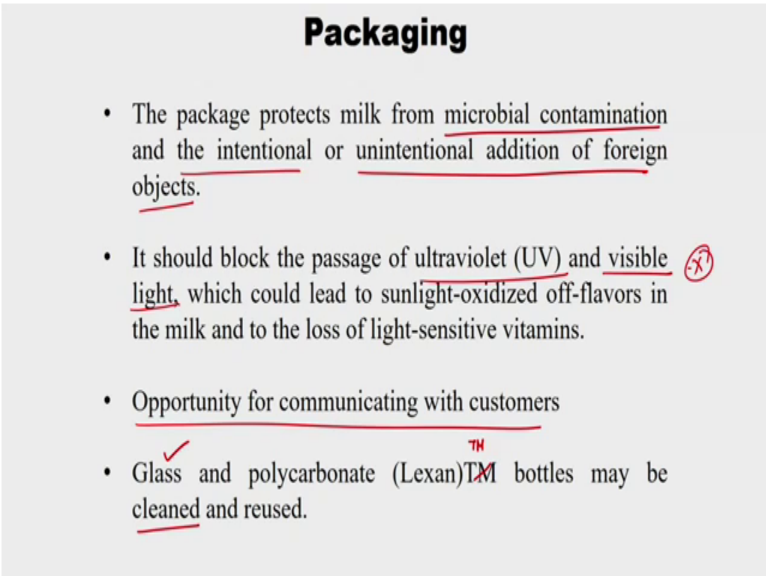

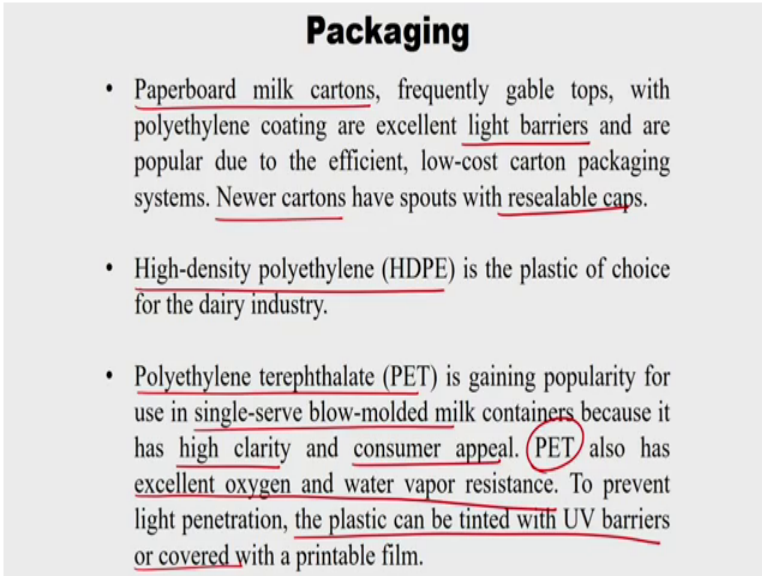

And packaging wise actually packaging should protects milk from microbial contamination and the intentional or unintentional addition of foreign objects. There should not be any further contamination after pasteurization. So that is the basic characteristics of the packaging and also you should block the passage of UV lights or any visible light, so which can lead to oxidized off flavors and also some loss of heat light sensitive vitamins.

So your packaging should be high enough to block the passage of UV lights and also it should be opportunity for communicating with the consumer. So the package should be attractive and all nutrition values should be printed on the packaging so it should be printable, so that way also. So usually glass and polycarbonate bottles are preferred, preferred in the sense that is like they can be cleaned and reused but the problem is while cleaning if we should make sure that there is no recontamination and also the glass bottles are very much unsafe to handle, we should take extra care to handle.

So in that way this receives less attention when compared to plastic PET jars. So and there are some paperboard carton, milk cartons but the problem is the opening, the opening and closing and re-sealing. So usually they are excellent light barriers. So which also satisfy our one of the three criteria, this criteria, but the problem is re-sealable caps. So once you are opening then you may be suffering, I mean to reclose that opened package. So in that way, but nowadays new cartons are also coming up with re-sealable caps.

So that problem is well taken care. And the most prominent one is the HDPE. So this is the choice of every dairy industry and they also have separate molding section to produce HDPE based packaging and also PET jars is gaining popularity because of single serve blow molded milk containers because it is high clarity and consumer appeal and also it has excellent oxygen and water vapor resistance. So this has oxygen and water vapor permeability is very much low. So that is because of that PET is the most wanted one. So to prevent light penetration the plastic can be tinted with UV barriers. So there are some UV barriers are covers which is in film form. So that will be wrapped through the plastic cans, so that also can be tried.

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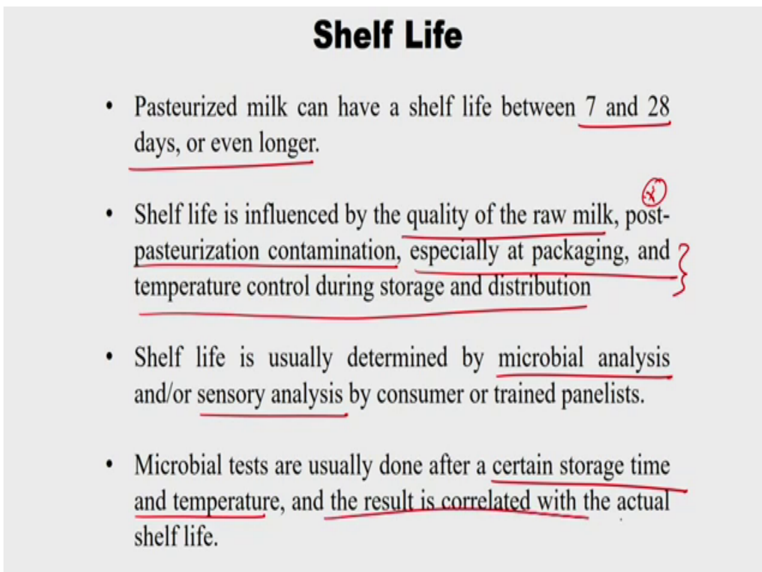

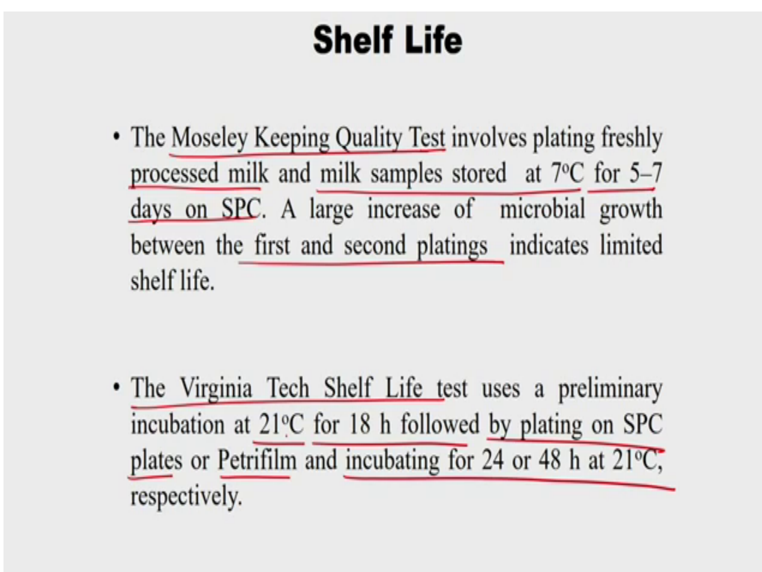

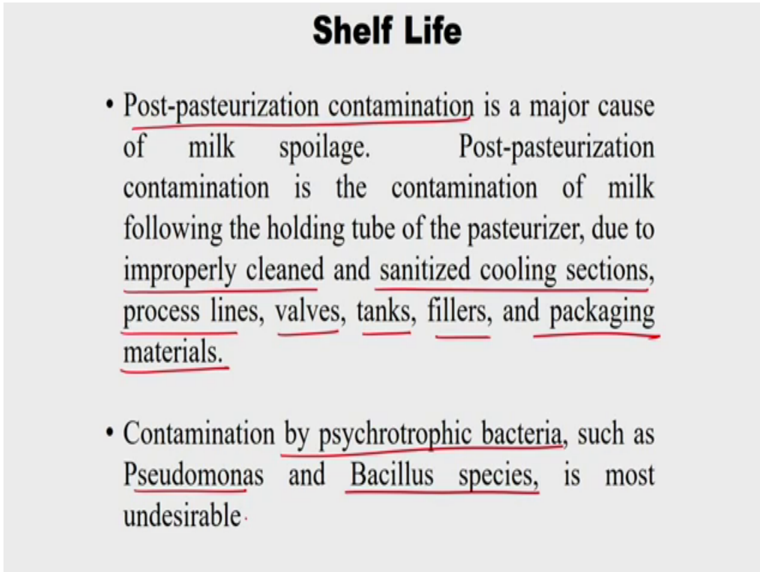

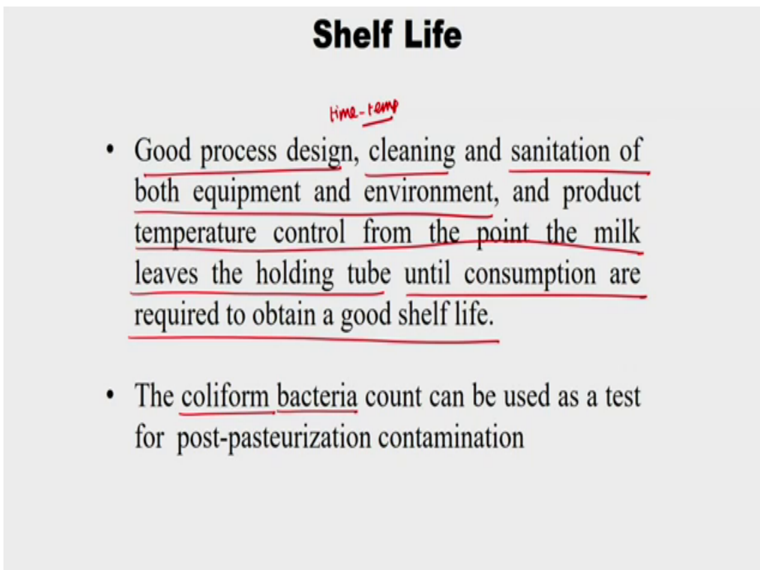

And the shelf life wise pasteurized milk can have a shelf life between 7 and 20 or even longer. So this mainly influenced by the quality of the raw milk and post pasteurization contamination, so we already talked about this is very much important and especially at packaging and temperature control during storage and distribution. So these two places where post pasteurization contamination is very much happening. So we need to take care that as well. Their shelf life is usually determined by microbial analysis or sensory analysis. So these two ways we do the post pasteurization contamination test.

Usually the microbial test are usually done after a certain storage time and temperature and the result is correlated with the actual shelf life. So after that they do validation with the actual shelf life. There are two main techniques one is the Moseley Keeping Quality Test which involves plating freshly processed milk and milk samples stored at freshly processed milk and milk sample stored at 7 degree for 5 to 7 days on a standard plate count. So a large increase of microbial growth between first and second platings indicates limited shelf life.

For example, I am taking processed milk and I am also taking milk which is stored at 7 degrees for 5 to 7 days. So then compare both and if there is some microbial growth, then there must be some post contamination and the Virginia Tech Shelf Life test uses a preliminary incubation of 21 degrees centigrade for 18-hour and followed by plating on standard plates or petri film and incubating for 24 to 48 hours at 21 degree respectively. So then they compare both and validate how much is the contamination and the main cause for the milk spoilage is this post pasteurization contamination. Because we told that there is a FDV valve which ensures the pasteurization temperature at the holding tube.

So only milk spoilage happens based on the post pasteurization only so that may be happening during storage or packaging or transportation and post pasteurization contamination is the contamination of milk following the holding tube of the pasteurizer due to improperly cleaned and sanitized cooling sections, process lines, valves, tanks, fillers and packaging materials. We already told that care must be taken in the plant itself to ensure there should not be any temperature difference. But sometimes there may be improperly cleaned vessels or equipment and valves, fillers so that also the cause for those pasteurization beyond your storage or distribution or transportation or packaging.

Actually this contamination happens by psychrotrophic bacteria, which are either Pseudomonas or Bacillus species is the most undesirable, this happens due to these two bacteria, but this is mostly undesirable. Actually good process design and cleaning, good process design in the sense, we ensure time temperature relation to get time temperature relation as we discussed yesterday, so all the factors to be taken into account and cleaning and sanitation of both equipment and environment and product temperature control from the point of the milk leaves the holding tube until consumption or also required to obtain a good shelf life.

So this is very much important and also the coliform bacteria count. So this will be done immediately it leaves the holding tube because these coliform bacteria cannot survive in the pasteurization temperature. So when the pasteurized milk out of the holding tube, so if we can do coliform bacteria count test then that also ensures any post pasteurization contamination is happening or not.

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References and Additional Resources

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So these are all some references and additional resources. So you may would like to check for further milk pasteurization details. Thank you all will meet for next lecture.