

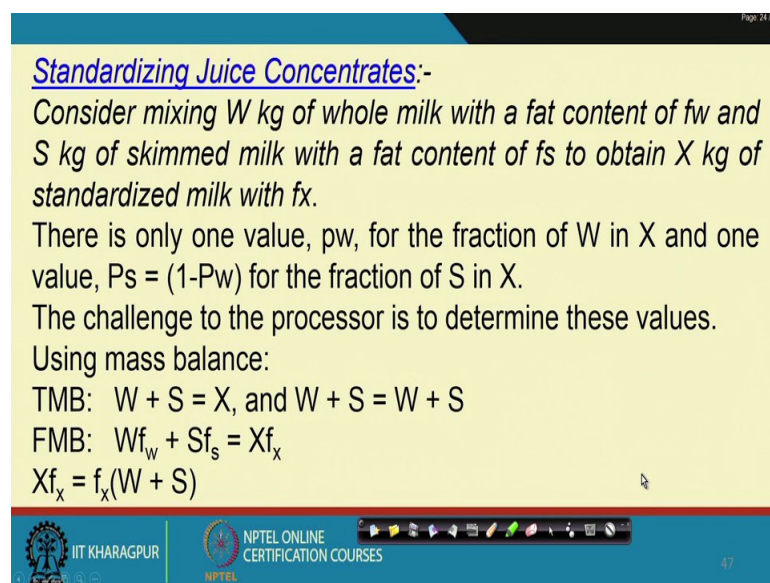
1
2
3
4
5
6
7
8

Dairy and Food Process & Products Technology
Prof. Tridib Kumar Goswami
Department of Agricultural and Food Engineering
Indian Institute of Technology, Kharagpur

Lecture - 46
Milk Homogenization

9So now, we are in the 46th class in Dairy and Food Process and Products Technology
10right, we had finished with standardization, but to have a little more.

11(Refer Slide Time: 00:33)



Standardizing Juice Concentrates:-
Consider mixing W kg of whole milk with a fat content of f_w and S kg of skimmed milk with a fat content of f_s to obtain X kg of standardized milk with f_x .
There is only one value, p_w , for the fraction of W in X and one value, $p_s = (1-p_w)$ for the fraction of S in X .
The challenge to the processor is to determine these values.
Using mass balance:
TMB: $W + S = X$, and $W + S = W + S$
FMB: $Wf_w + Sf_s = Xf_x$
 $Xf_x = f_x(W + S)$

Page 41/44

IIT KHARAGPUR | NPTEL ONLINE CERTIFICATION COURSES | 47

12

13So, I am just showing it, I am not going through it because now we will go to Milk
14Homogenization. So, before that just showing that standardizing juice concentrates, so
15this is one such way you can do the standardization.

1
2

1

1(Refer Slide Time: 00:49)

Expanding the equations

$$Wf_w + Sf_s = Wf_x + Sf_x$$

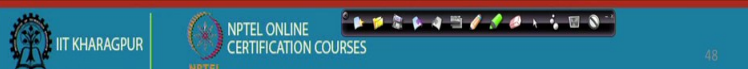
$$W(f_w - f_x) = S(f_x - f_s)$$

$$W/S = (f_x - f_s) / (f_w - f_x)$$

$$W / (W + S) = (f_x - f_s) / [(f_x - f_s) + (f_w + f_s)] = P_w = W / X$$

$$S / (W + S) = (f_w - f_x) / [(f_x - f_s) + (f_w - f_s)] = P_s = S / X$$

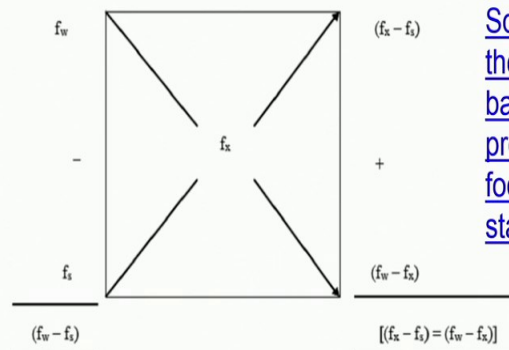
NB: $(f_x - f_s) + (f_w - f_x) = (f_w - f_s)$.



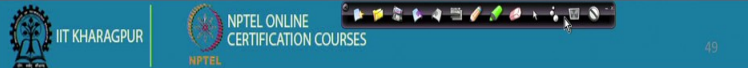
2

3And that is simply by mass balance, so by doing mass balance you can also do this.

4(Refer Slide Time: 00:58)



The Pearson Square simplifies the mass balancing process during food standardization.



5

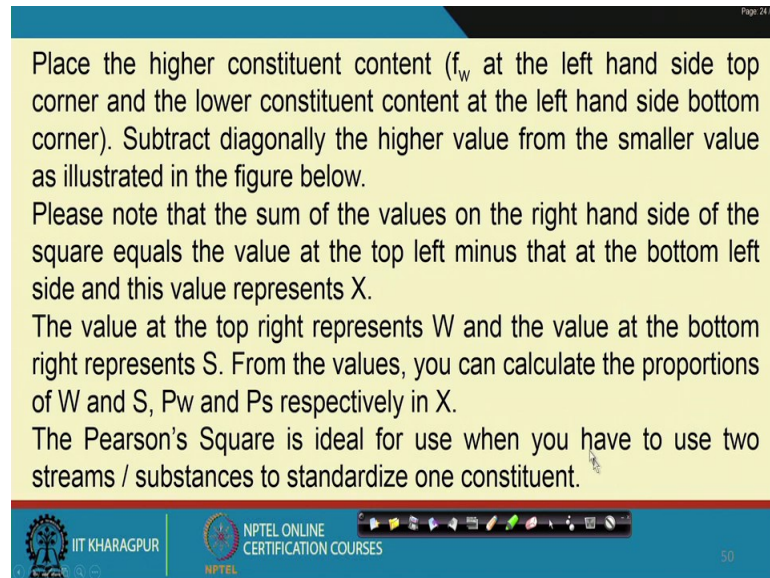
6And using the Pearson square which we have already said earlier this is a more
7elaborative example of doing that Pearson square.

1

2

2

1(Refer Slide Time: 01:09)



Place the higher constituent content (f_w at the left hand side top corner and the lower constituent content at the left hand side bottom corner). Subtract diagonally the higher value from the smaller value as illustrated in the figure below.

Please note that the sum of the values on the right hand side of the square equals the value at the top left minus that at the bottom left side and this value represents X.

The value at the top right represents W and the value at the bottom right represents S. From the values, you can calculate the proportions of W and S, P_w and P_s respectively in X.

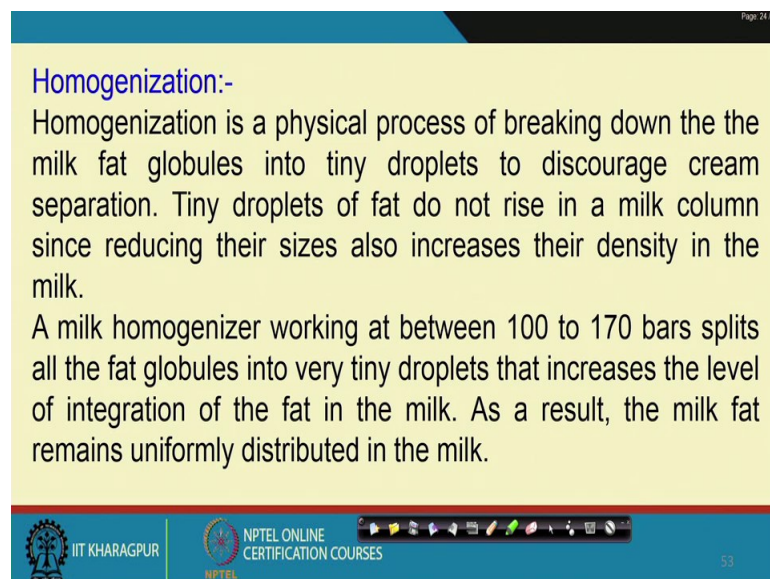
The Pearson's Square is ideal for use when you have to use two streams / substances to standardize one constituent.

IIT KHARAGPUR | NPTEL ONLINE CERTIFICATION COURSES | 50

2

3How the Pearson square is being used this is here been shown and some examples we
4have dealt with, and these examples you can also work out and do that right using the
5Pearson's square technique also.

6(Refer Slide Time: 01:30)



Homogenization:-

Homogenization is a physical process of breaking down the the milk fat globules into tiny droplets to discourage cream separation. Tiny droplets of fat do not rise in a milk column since reducing their sizes also increases their density in the milk.

A milk homogenizer working at between 100 to 170 bars splits all the fat globules into very tiny droplets that increases the level of integration of the fat in the milk. As a result, the milk fat remains uniformly distributed in the milk.

IIT KHARAGPUR | NPTEL ONLINE CERTIFICATION COURSES | 53

7

8Now, we come to homogenization, so this homogenization is very very important step in
9milk because as we have said earlier also that milk do contain fat in different sizes right.
10So, ranging from say decimal micron to around 25-30 μm this sizes are there and fat do
11have a common tendency to agglomerate. So, after agglomeration they became bigger

1

3

2

1 sizes and from that they do come out to the surface right this is by going we have said by
2 Stokes law you can find out at what rate this fat will get separated given a diameter right.

3 So, to avoid that for a longer period to keep the milk for a longer period at no separation
4 of fat. The next step required is pasteurization. In pasteurization, you have killed all the
5 pathogenic organisms. So, after that you need to homogenize, so homogenization is for
6 the for the settlement; for the fixation of the fat content right. So, that fat content will not
7 reduce because of separation to do that you need to do say homogenization.

8 Now, homogenization is a physical process of breaking down the fat right, milk fat
9 globules into tiny droplets small, small that will dictate at what may be 1 micron, may be
10 2 micron, may be 3 micron.

11 That size you will decide and to that all the bigger sizes will be brought down of course,
12 smaller sizes you cannot you cannot elevate, but the bigger ones will be brought down to
13 the smaller ones to discourage cream separation; tiny droplets of fat do not rise in a milk
14 column since reducing their sizes also increases their density in the milk. Because more
15 the size bigger the size was there less was the number now less is the size bigger will be
16 their numbers. So, more fat dense will be there in the particular or in a density in a
17 particular one or uniformly it will be.

18 A milk fat a milk homogenization is working at between 100 to 170 bars that splits all
19 the fat globules into very tiny droplets that increases the level of integration of the fat in
20 the milk. As a result the milk fat remains uniformly distributed in the milk right.

1(Refer Slide Time: 05:03)

Heating section
Utilizes heat from steam to raise the temperatures of the milk from about 60°C to the required 72°C that is effective to kill the *Clostridium botulinum* spores. The steam exchanges heat with the milk across the PHE plates in a counter current motion. At the end of this section, there is a temperature sensor, which controls the flow diversion valve. Any milk that does not attain the required temperature is diverted back to the heating section until it attains the required temperatures.

Page 24/24

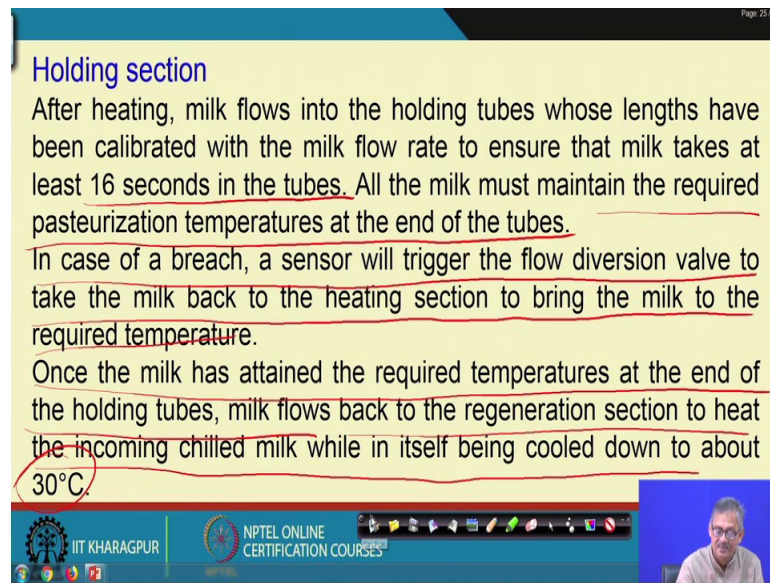
IIT KHARAGPUR NPTEL ONLINE CERTIFICATION COURSES

2

3Now, there is a heating section because milk homogenization subsequently is seen that
4homogenization is also a function of temperature, the higher the temperature better is the
5homogenization right. But there is also an optimum it is not that it will go on increasing
6like this steadily right, it will not go on increasing like this steadily that is also there that
7it will go like this it will be like this. So, there will be some optimum or maximum where
8the temperature is good.

9So, that is why it is that about 60 to 72°C is effective to kill the *Clostridium botulinum*
10spores. The steam exchanges the heat with the milk across the plate heat exchanger in a
11counter current motion at the same time at the end of this section. There is a temperature
12sensor which controls the flow diversion valve in a milk that does not attend the liquid
13temperature is diverted back to the heating section until it attains the required
14temperatures right.

1(Refer Slide Time: 06:32)



The slide is titled "Holding section" in blue text. The main text is black and describes the process of milk pasteurization in holding tubes. It states that after heating, milk flows into holding tubes calibrated for a 16-second residence time to maintain required pasteurization temperatures. A sensor can trigger a flow diversion valve to return milk to the heating section if a breach occurs. Finally, milk flows back to a regeneration section to heat incoming chilled milk while being cooled to about 30°C. The slide includes logos for IIT KHARAGPUR and NPTEL ONLINE CERTIFICATION COURSES. A small video inset in the bottom right shows a man speaking.

Holding section

After heating, milk flows into the holding tubes whose lengths have been calibrated with the milk flow rate to ensure that milk takes at least 16 seconds in the tubes. All the milk must maintain the required pasteurization temperatures at the end of the tubes.

In case of a breach, a sensor will trigger the flow diversion valve to take the milk back to the heating section to bring the milk to the required temperature.

Once the milk has attained the required temperatures at the end of the holding tubes, milk flows back to the regeneration section to heat the incoming chilled milk while in itself being cooled down to about 30°C.

2

3Once you got the temperature then holding section there is a after heating milk flows into
4the holding tubes, whose lengths have been have been calibrated with the milk flow rate
5to ensure that the milk takes at least 16 seconds in the tubes. All the milk must remain in
6the required pasteurization temperatures at the end of the tubes. In case of breach, a
7sensor will trigger the floor diversion valve to take back the milk to the heating section to
8bring the milk to the required temperature.

9Once the milk has attend the required temperature at the end of the holding tubes milk
10flows back to the regeneration section to heat the incoming chilled milk while in itself
11being cooled down to about 30°C. Now, after that that is again back to a pasteurization
12after that it goes to chilling or cooling which again is being done by a plate heat
13exchanger.

1

6

2

1(Refer Slide Time: 07:47)

Cooling / chilling section
After regenerative cooling of pasteurized milk, it moves to the cooling section of the PHE where chilled water / PHE coolant lowers the temperature of pasteurized milk to 4°C. The chilled milk is then pumped to the packaging machines for aseptic packaging and subsequent storage in the cold room.

If the milk is to be used for making yogurt, there is no need to chill it. It will only require regenerative cooling to about 45°C, which is the suitable temperature for yogurt bacteria.

IIT KHARAGPUR | NPTEL ONLINE CERTIFICATION COURSES

2

3So, that it is brought down to after pasteurization brought down to 4°C and the chilled
4milk is then pumped to the packaging machines for aseptic packaging ok, but before that
5this is homogenized which we have said that this is done right.

6(Refer Slide Time: 08:25)

Non-conventional Methods of Pasteurization:-
Conventionally, normal heating is used to pasteurize milk and other food products. However, there are other non-conventional methods of pasteurization. Some of these methods involve heating while others are completely devoid of heat.

Microwave Heating.
The method is currently still under development and has only been accepted for commercial sterilization of canned foods. Microwave heating is highly effective on low acid foods and can be used in a continuous and batched process.

IIT KHARAGPUR | NPTEL ONLINE CERTIFICATION COURSES

7

8So while homogenization we do.

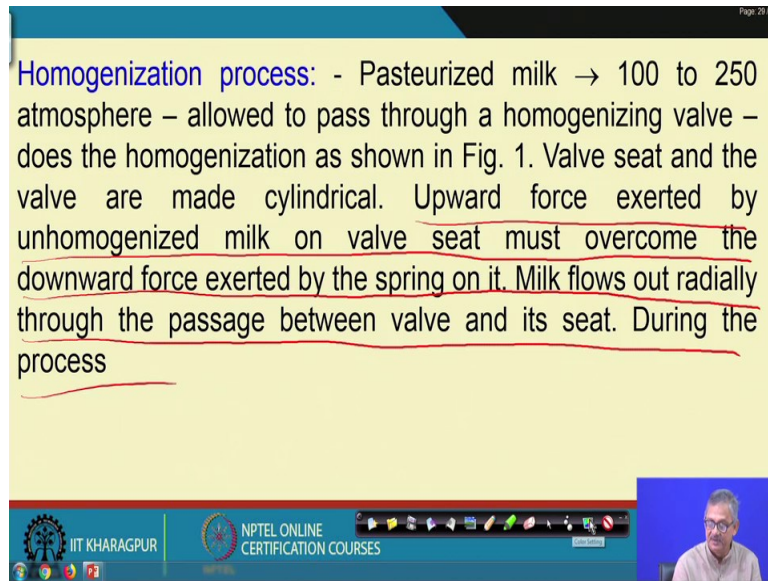
1

7

2

1(Refer Slide Time: 08:42)

Homogenization process: - Pasteurized milk → 100 to 250 atmosphere – allowed to pass through a homogenizing valve – does the homogenization as shown in Fig. 1. Valve seat and the valve are made cylindrical. Upward force exerted by unhomogenized milk on valve seat must overcome the downward force exerted by the spring on it. Milk flows out radially through the passage between valve and its seat. During the process



2

3That homogenization what it does pasteurize milk around 100 to 125 atm is allowed to
4pass through a homogenizing valve right. This homogenizing valve it does the
5homogenization right, as given in the next figure will show the figure is like this let us go
6back to that figure which will be easier to understand.

7(Refer Slide Time: 09:13)

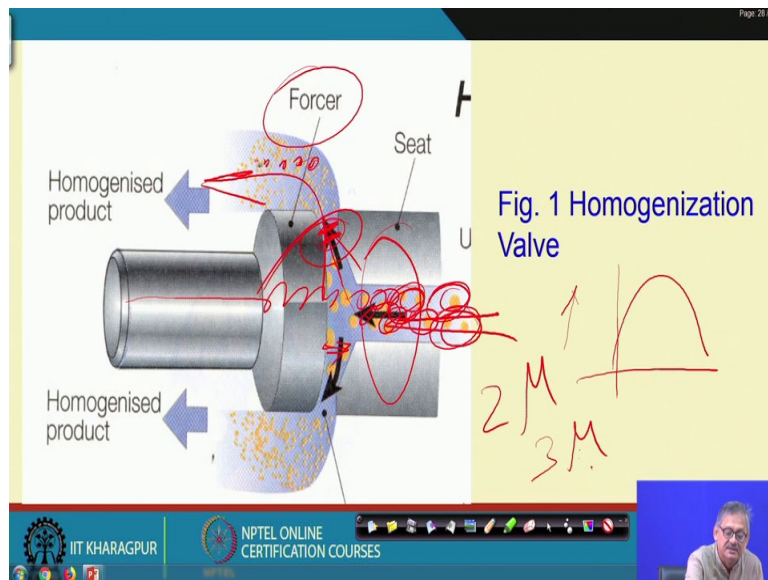


Fig. 1 Homogenization Valve

8

9So, this is that homogenization is being done here, so milk is flowing like this right. So,
10these are the fat bigger fat globules they are moving right through this slit; this is the slit
11gap right this is slit gap.

1

8

2

1So, through this slit it is going; I hope if you have gone through our earlier class that was
2on that the naming of the class was not on milk that was general class on the fluid flow
3right. The fluid flow if you had gone through there you might have seen that the velocity
4profile and all others we have done when it is flowing through a slit like this right that
5we have done. So, there we have not taken like this the fat globules we have taken a
6general fluid, but and there we have shown the velocity profile how the velocity profile
7is coming like this right ok.

8But when this fat globules are going through this slit whose size is according to your
9desirable size, what do you want 2 μm then this size will be 2 μm , if you want 3 μm then
10this size will be 3 μm . Therefore, according to your requirement this is right and this is a
11seat this is the forcer which you are adjusting what the distance will be or how the how
12the pressure will be. So, this is going that homogenized fat globules which are of smaller
13size like this right these are the smaller sizes homogenized product is going right.

14So, this is the homogenization valve, so if we go back to that if we go back to that then
15we say that the valve seat and the valve are made cylindrical, made of cylindrical
16structure upward force exerted by the homogenized milk on valve seat must overcome
17the downward ex exerted downward force exerted by spring on it milk flows out radially
18through the passage between the valve and the seat during the process what happens
19during this process we have show already shown the valve.

20(Refer Slide Time: 12:24)

Fat globules are sheared. If the rate of shear is large, globules are elongated, ripples are formed on their surface and finally break into smaller sizes as shown in Fig. 2.

As milk flows out radially along b-b face of valve, the velocity reduces due to the increase in CSA of flow. Velocity is highest at point 'a' depending on milk velocity at the point. This will result in cavitation. Pressure of milk will increase as it moves radially outward from the center of valve, i.e., from pt 'a' to pt 'b'.

Homogenization of milk is due to the effect of shear on fat globules and not on cavitation.

IIT KHARAGPUR | NPTEL ONLINE CERTIFICATION COURSES

21

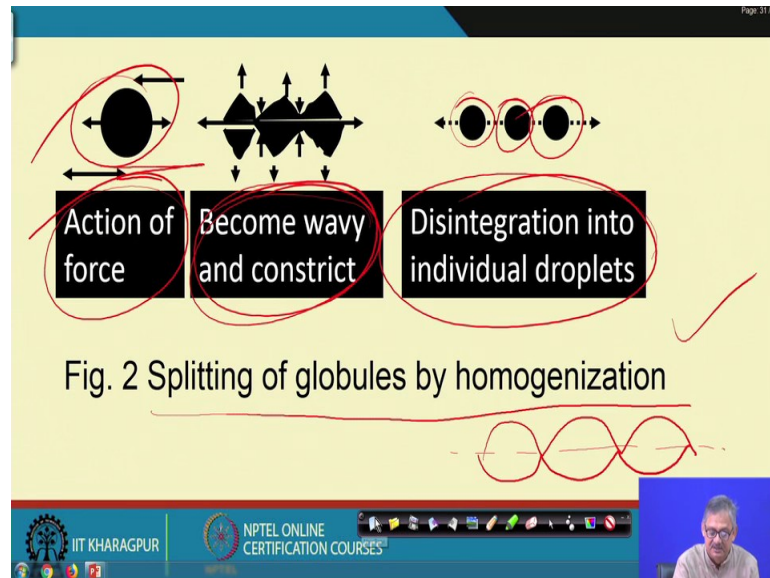
1

9

2

1So, during this process the fat globules are sheared right this is the fat globule. So, a
 2force is acting like this, so by that they are there is shear action on the fat globule and
 3this fat globules then if you look at the other figure it will be like this right.

4(Refer Slide Time: 12:52)



5

6So, this is the fat globule, so there is a shear action that is happening like this and
 7because of that the fat globule is getting say it is enlarged view like this they are getting
 8segmented right and ultimately this is becoming the intermediate become wavy and
 9constrict right. So, this is the action of the force this becomes wavy and constrict and this
 10disintegrate into the individual droplets from this bigger droplet to the smaller ones they
 11are getting by the shear action. So, this is splitting of globules by homogenization this
 12mechanism follows right.

13So, now we go back to that, so that is what is happening in the in the homogenization
 14valve that if the rate of shear is large globules are elongated, ripples are formed on their
 15surface and finally, break into smaller sizes as we have shown in the next figure right, as
 16milk flows out radially along the face say bb that is not we have not shown here right.
 17So, on the face of the valve the velocity reduces due to the increase in the cross sectional
 18area right.

19Velocity is highest at point say 'a' depending on the milk velocity at that point this will
 20result in cavitation and pressure of milk will increase as it moves radially outward from
 21the centre of the valve that is from the point 'a' to the point 'b'. So, that if we can we can

1

2

1 see this show radially here radially so; that means, it is going like this right. So, if this is
2 point 'a' and if this is point 'b' according to that what we are referring to right. So, that is
3 how it is, so from point 'a' to point 'b'.

4 Homogenization of milk is due to homogenization of milk is due to the effect of shear on
5 the fat globules and not on the cavitation though there will be cavitation, but the fat
6 globules are fat globules are disintegrated into smaller ones by the shear action right this
7 shear action takes place and that is what.

8 Now, in that cavitation one thing which will may not be able to explain in more in detail
9 that you know that if there is pressure in a bubble, and then it gets exploded right that is
10 called explosion. The inside pressure is more than the outside pressure, but if it is the
11 other way if the outside pressure is more than the inside then that is called earlier it was
12 explosion. Now, this one will become implosion right in cavitation that implosion takes
13 place and by which. So, in the fat globules also get disintegrated right this also you keep
14 in mind.

15 (Refer Slide Time: 17:13)

Page 35/35

After the fat globules are broken down into smaller size and came out of homogenizing valve (Fig.2) they are found to remain sticking to each other forming a cluster. In order to break the cluster and disperse fat globules, milk is passed through another homogenizing valve (Fig.3) – second stage homogenization – pressure supplied to the compression spring – $1/5^{\text{th}}$ to $1/6^{\text{th}}$ of the 1^{st} stage.

Effect:- Homogenization increases its (i) whiteness – larger no. of fat globules scatter light, (ii) viscosity – increase of shear force created by the presence of large no. of fat globules, (iii) temperature – friction on the homogenization valve as milk flows through it at high velocity,

IIT KHARAGPUR NPTEL ONLINE CERTIFICATION COURSES

16

17 Then this we have already said, so after the fat globules are broken down into smaller
18 size and shear and came out of homogenizing valve they are found to remain sticking to
19 each other form a cluster and in forming a cluster, in order to bring the cluster and
20 dispersed fat globules milk is passed through another homogenizing valve, that is that is

1

11

2

1the second homogenizing valve and this second homogenizing valve takes place, second
2homogenization and the pressure is around one-fifth to one-sixth of the first right.

3(Refer Slide Time: 18:05)

and (iv) gel strength – during milk curdling through microbial fermentation – acids join the milk protein present on fat globules membrane.

Fresh milk contains lipase enzyme – resides outside the fat globule membrane – hydrolyses and transforms into free fatty acids when comes in contact with milk fat – not desirable – unsuitable for human consumption beyond a certain amount.

During homogenization – likelihood of lipase enzyme – in contact with milk fat increases. To inactivate – heated to 65 °C or more before homogenization > 80 °C – coagulation of whey protein.

IIT KHARAGPUR NPTEL ONLINE CERTIFICATION COURSES

4

5 (Refer Slide Time: 18:21)

Fig. 1 Homogenization Valve

1st 2500 psig
2nd 500 psig

IIT KHARAGPUR NPTEL ONLINE CERTIFICATION COURSES

6

7However, this second homogenization valve so that is like this one from here which goes
8to another valve this one it goes to another valve right, along with this say this is one
9valve and say this is acting around say 2500 psig right, if this is acting at that another
10valve similar to this that was around one of this that is 500 psig right. So, that is called

1

12

2

1this is called first stage this is called second stage homogenization that is two stage
2homogenization right.

3So, if we take that then we can say that in the second homogenization it is taking place at
4around one fifth of the first that is that is if the original was 2500, now it is 500 psig, why
5it is required because why it is required because when the first stage homogenization
6from the bigger to the smaller ones it happen these smaller ones start to agglomerate
7again and again become bigger one right.

8So, this, so that in future in further this should not happen that second stage is there and
9which works at much lower pressure then the former one around one fifth of the former
10one say if the former one is 2500, now it is 500 only psig that is why I am saying because
11in bar it will be much low less in number.

12So, it is and you can convert in atmosphere and in Pascal. So, those are convertable, but
13since the number is unique to 2500 psig and this is 500 psig that is why I am giving the
14difference with respect to psig. So, that the numbers you can remember 2500 and 500.
15So, these are the two stages and these in the second stage this agglomeration gets further
16ruptured, and then permanently it is form into the smaller size as you have decided 2 μm ,
173 μm whatever right.

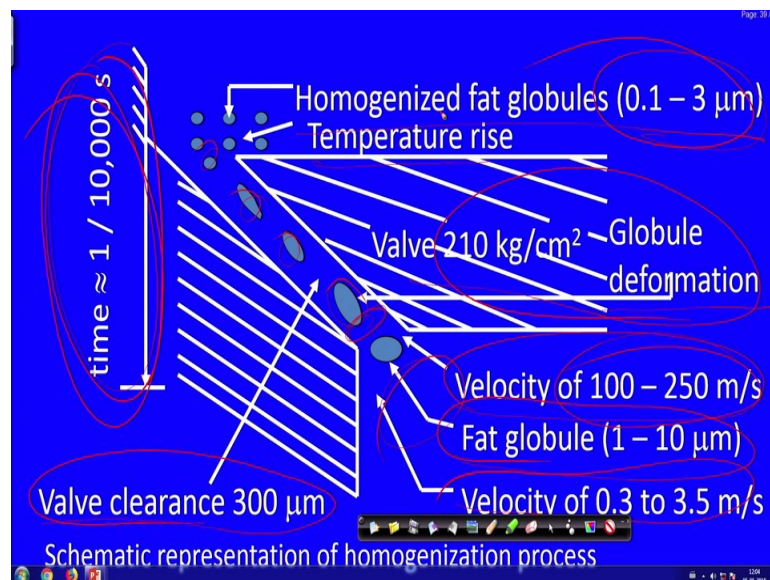
18The what are the effects of homogenization, effect of homogenizations are like that that
19the homogenization increases its whiteness larger number of fat globules are produced
20that is why light is scattered then viscosity increases, viscosity increases and this is
21increases the shear force created by the presence of large numbers of fat globules. Then
22temperature is also increases because of the friction on the homogenization valve as milk
23flows through it, high at high velocity temperature is also increases the hand and fourth
24one is that gel strength, gel strength during milk curdling through microbial fermentation
25acids joins the milk protein present on the globule membrane.

26So, gel strength increases, fresh milk contains lipase enzymes; resides outside the fat
27globule membrane hard and hydrolyzes that and transforms into free fatty acids, when
28comes in contact with the fat this is not desirable and undesirable for human
29consumption be under certain level. So, lipase enzyme has to be inactivated and this is
30done during both pasteurization and homogenization both are at high temperature right.

1 Now, during homogenization there is a likelihood of lipase enzymes to be active in
 2 contact with milk fat increases to inactivate this is heated up to 65°C before
 3 homogenization or 80°C is coagulation of whey protein if it is beyond 80°C this is done
 4 at 65°C.

5 If it is beyond 80 degree centigrade then coagulation of whey protein occurs because we
 6 said whey protein is a soluble protein, but it is soluble till the temperature is low
 7 solubility goes down if the temperature goes beyond 80 degree centigrade. So, that is
 8 why you cannot heat beyond 80 degree centigrade otherwise that that this soluble whey
 9 protein will come out or separate out from the milk right.

10 (Refer Slide Time: 23:46)



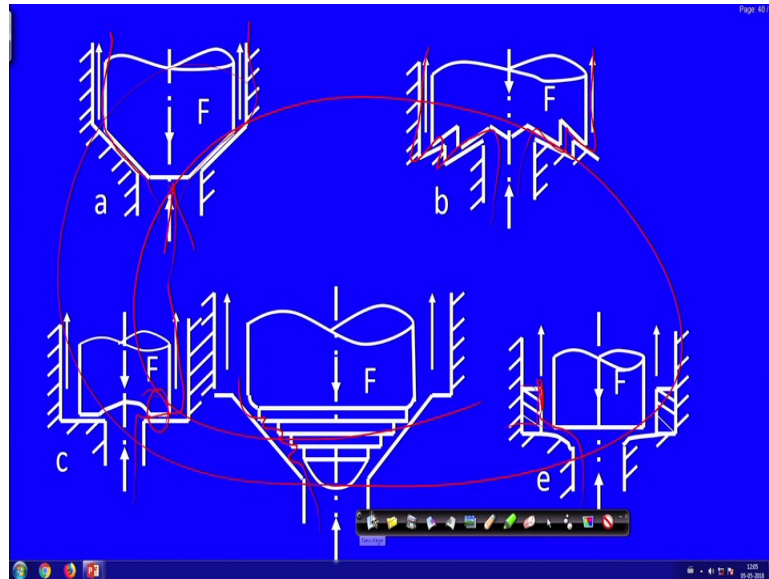
11

12 (Refer Time: 23:45) if you look at this is a true picture of the valve where it is going
 13 through, the fat globules are like that right it is getting shattered and then becoming
 14 smaller you see the time scale given is around 1/10000 second that time it is happening.

15 And velocity or valve clearance is around 300 micrometers, this is the schematic presentation of
 16 the homogenization process velocity of point 3 to 3.5 m/s is a fluid that is milk velocity
 17 that is occurring, fat global size is between 1 to 10 micrometers say velocity of around 100 to 200
 18 m/s is at the at the inlet and because outside it was low. So, the moment is going into the
 19 smaller diameter you need a smaller size velocity is increasing drastically.

1 Valve is around 200 kg/ cm² that is the pressure is being applied and their global
 2 deformation take place, like this was the one from where this is gradually deforming and
 3 then coming to that. So, homogenized fat globules between point 1 to 3 μm as you are
 4 deciding that is being produced right. So, this is the flow diagram or the pictorial
 5 diagram of the fat globules.

6 (Refer Slide Time: 25:44)

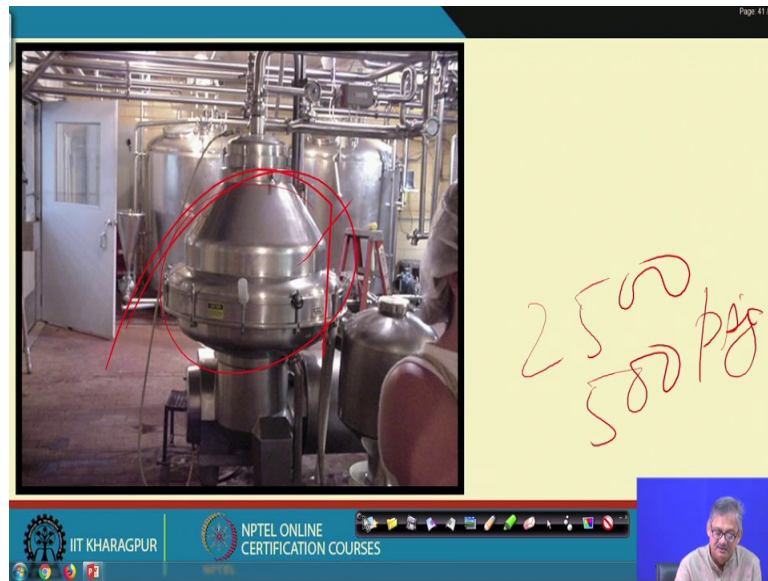


7

8 And the valves are like that there are different types of homogenization valves different
 9 ways different types right and you see depending on this is a flow diagram. So, They are
 10 going through this one is such and there is that this is good going a zigzag path like this
 11 right then another one where the slit is here.

12 So, going like this the another one is tapered like this going like this is tapered right.
 13 And the fifth one could be there is a baffle in between and that is going through that
 14 should bending on that different size different type different different geometry. They
 15 will be different configuration there will be different type of pressure generation, and
 16 different fragmentation also will happen right.

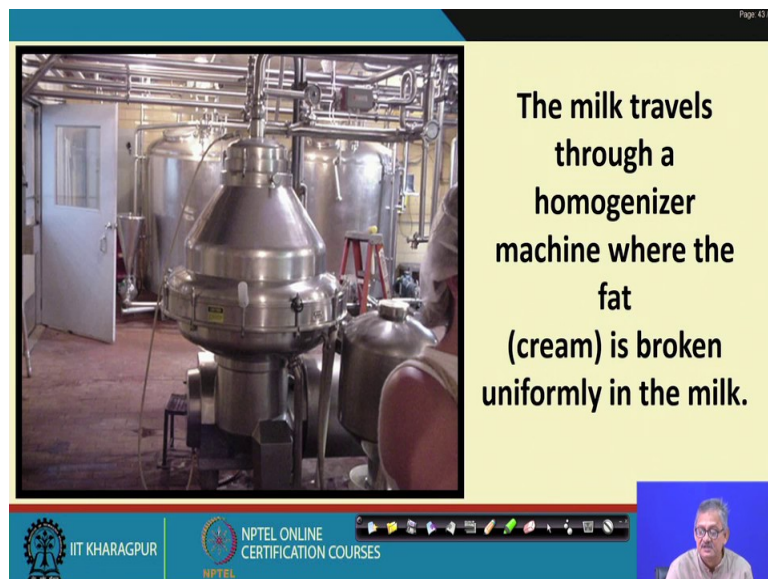
1(Refer Slide Time: 27:00)



2

3So, this is a generalized homogenizer that homogenizer looks like that the pictorial view
4homogenizer looks like that, hopefully in any dairy industry or institute this type of
5homogenizer is there, and that will dictate a pressure, there are two stage one pressure is
6generally 2500 psig and another pressure is 500 psig right, this is the pictorial view of the
7valve right.

8(Refer Slide Time: 27:37)



9

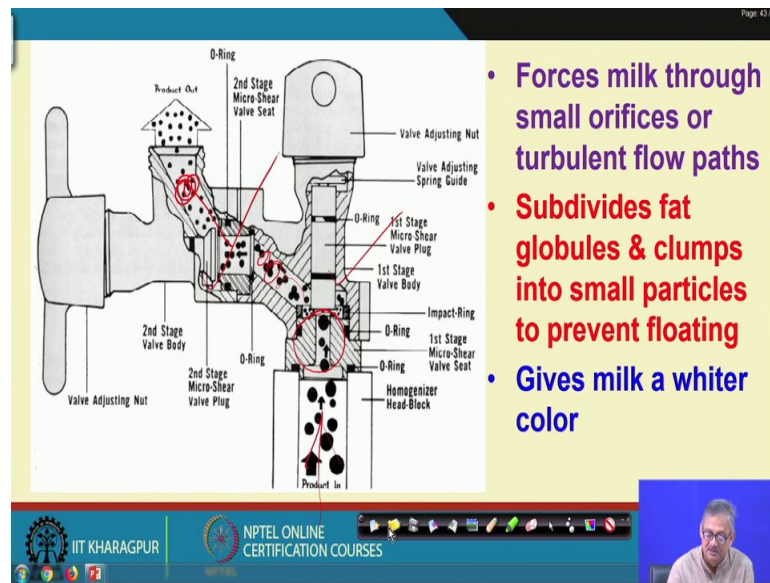
10And milk travels to the homogenizer machine where the fat that is cream is broken in
11uniformly right.

1

16

2

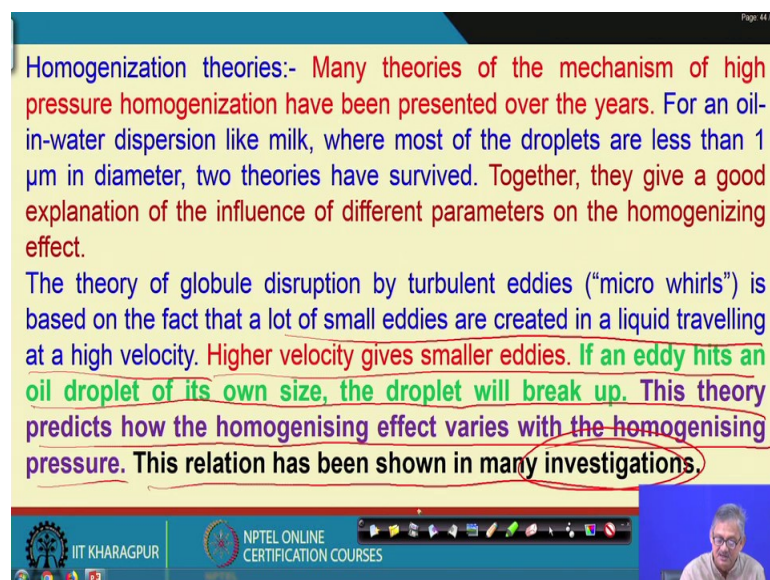
1(Refer Slide Time: 27:47)



2

3So, this which you I was looking for that that two stage this is that typical two stage
4valve or picture as you had given figure 2. This is like that this is the first stage, this is
5the second stage the milk is flowing through the first stage again getting agglomerated
6and through the second stage it is coming to the smallest size as you have given right this
7is the two stage homogenizer valve right.

8(Refer Slide Time: 28:24)



9

10The theory is like this; let us go quickly many theories of the homogenization of high
11pressure homogenization have been presented over the years for and oil in water

1

17

2

1 dispersion like milk where most of the droplets are less than 1 μm in diameter, two
2 theories have survived. Together they give a good explanation of the influence of
3 different parameters on the homogenizing effect.

4 The theory of globule disruption by turbulent eddies that is micro whirls is based on the
5 fact that a lot of small eddies, are created in a liquid travelling at a high velocity higher
6 velocity give the smaller radius. If any eddy hits an oil droplet of its own size the droplet
7 will break up this theory predicts how the homogenizing effect varies with the
8 homogenizing pressure this relation has been shown in many investigation, the other one
9 is like this that the cavitation theory.

10 (Refer Slide Time: 29:41)

The cavitation theory, on the other hand, claims that the shock waves created when the steam bubbles implode disrupt the fat droplets. According to this theory, homogenization takes place when the liquid is leaving the gap, so the back pressure which is important to control the cavitation is important to homogenization. This has also been shown in practice. However, it is possible to homogenize without cavitation, but it is less efficient.

11

12 The cavitation theory says that on the other hand claims this cavitation theory claims that
13 the shock waves created, when the steam bubbles implode disturb the fat droplets
14 according to this theory homogenization takes place when the liquid is leaving the gap.

15 So, the back pressure which is important to control the cavitation is important to
16 homogenization this has also been shown in practice. However, it is possible to
17 homogenize without cavitation, but it is less efficient right, so we have ended up to this
18 class.

19 Thank you.