IIT KHARAGPUR

NPTEL ONLINE CERTIFICATION COURSES

NPTEL

Dairy and Food Process and Products Technology

PROF. TRIDIB KUMAR GOSWAMI
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IIT KHARAGPUR

Lecture No. 46: Milk Homogenization

2000 X 0.025 = 0.025 X C + 0.025 X M; C – cream & M - Milk

Solving the equations will give the values of C = 69.3 kg and the remaining milk M = 1930.7 kg.

Example 2

If 3000 kg of the same milk used in the previous example is separated into cream with 45% fat and skimmed milk with 0.05% fat, how much cream and skimmed milk are expected assuming no losses?

Solution

TMB: 3000 = C + M

FMB: 3000 X 0.038 = 0.45 X C + 0.0.0005 X S

Solving the equations will give C = 250.3 kg and S = 2749.7 kg

Standardizing Juice Concentrates:-

Consider mixing W kg of whole milk with a fat content of fw and S kg of skimmed milk with a fat content of fs to obtain X kg of standardized milk with fx.

There is only one value, pw, for the fraction of W in X and one value, Ps = (1-Pw) 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: $Wf_w + Sf_s = Xf_x$

$Xf_x = f_x(W + S)$

Expanding the equations

$Wf_w + Sf_s = Wf_x + Sf_x$

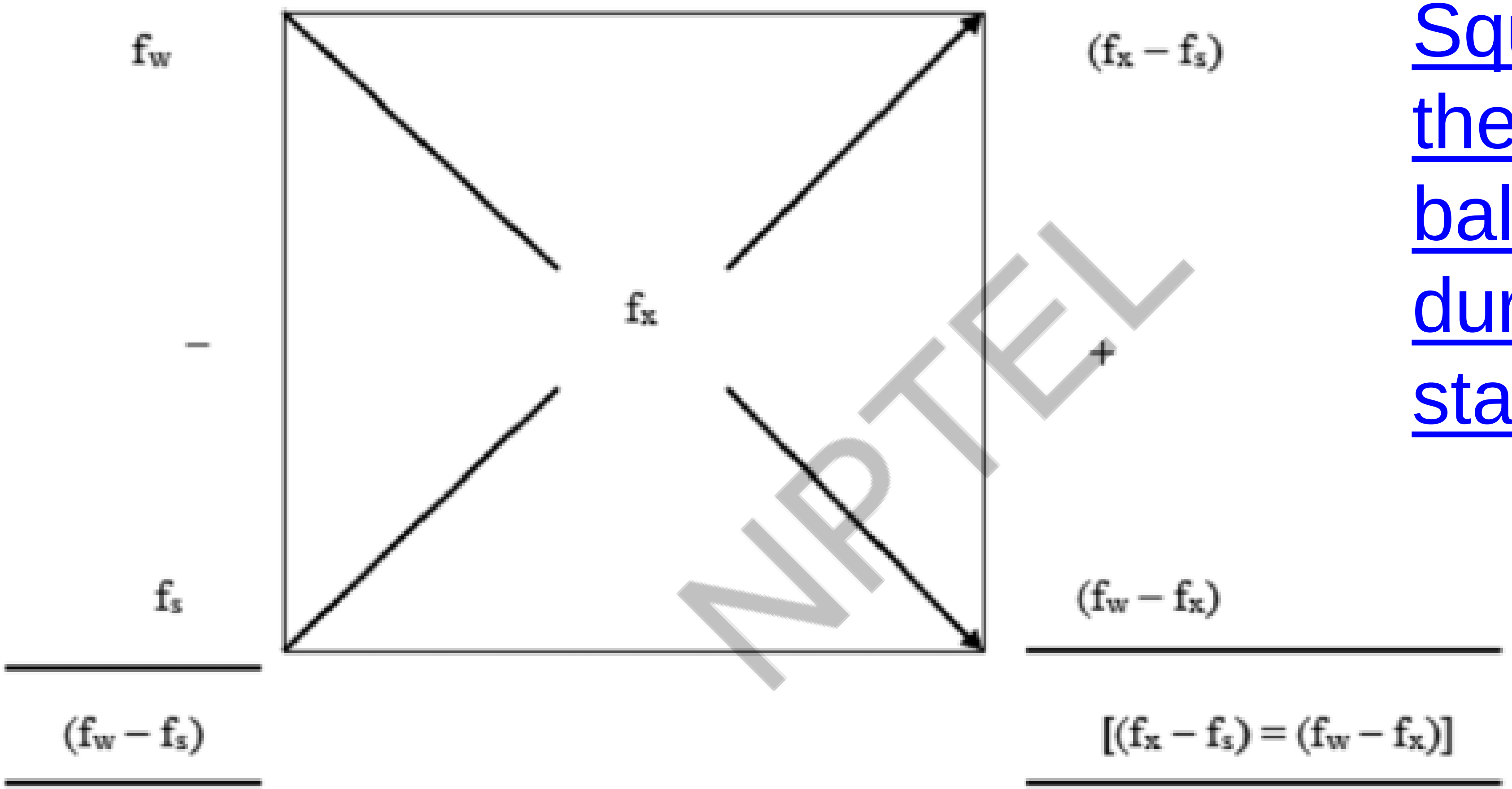
$W (f_w – f_x) = S(f_x – f_s)$

$W / S = (f_x – f_s) / (f_w – f_s)$

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

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

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



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

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, Pw and Ps respectively in X.

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

Example 3

How much whole milk with 3.9% fat and skimmed milk with 0.04% fat content will you need to produce 2000 kg of standardized milk with 2.5% fat?

Solution:

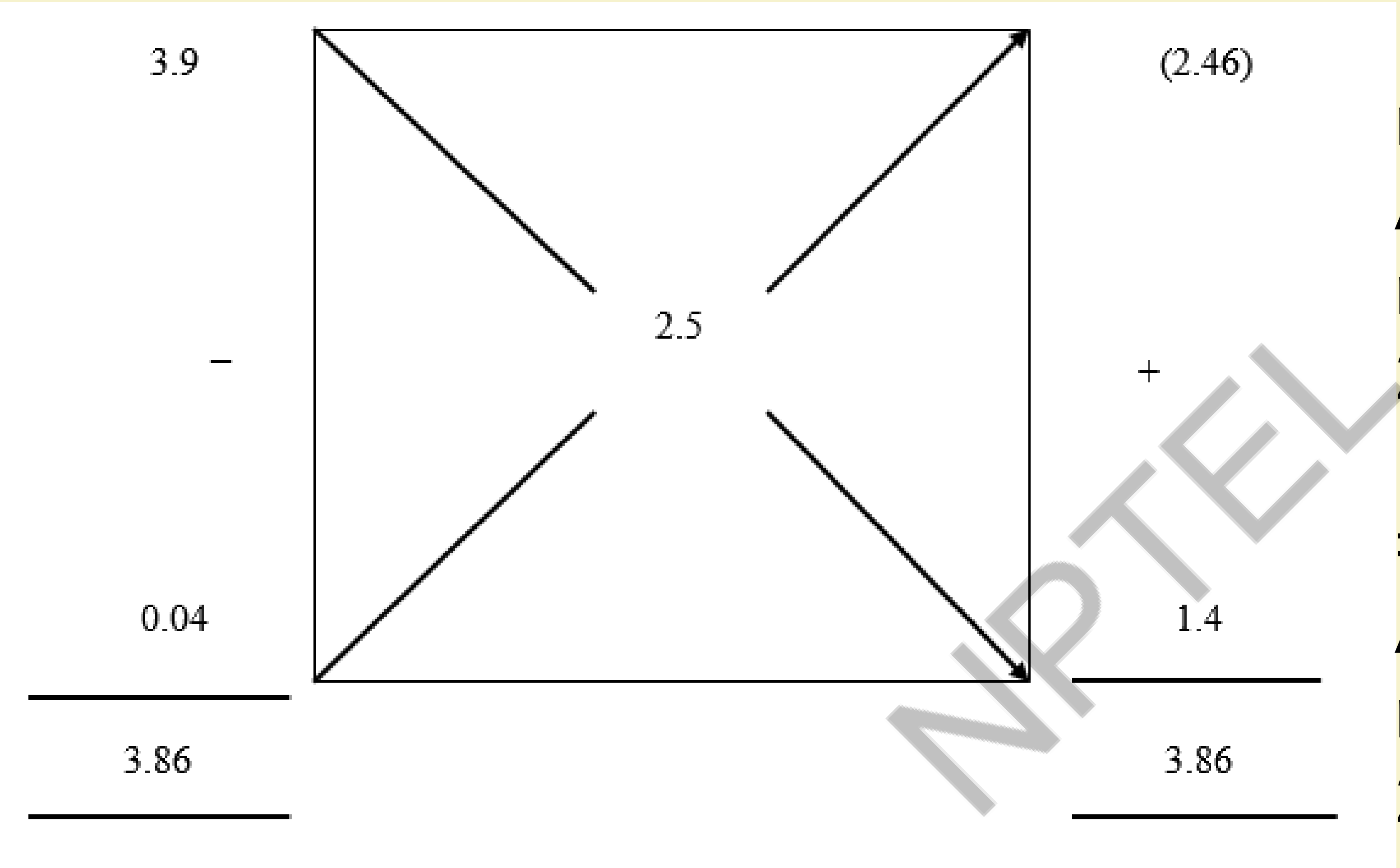
Using mass balance method:

TMB: $W + S = 2000$

MFB: $0.039 \times W + 0.0004 \times S = 0.025 \times 2000$

Solving for W = 1274.6 kg and S = 725.4 kg

Using Pearson's Square method:



Proportion of the whole milk = 2.46/3.86

Amount of whole milk required = (2.46 / 3.86) X 2000 = 1274.6 kg

Proportion of skimmed milk = 1.4 / 3.86

Amount of skimmed milk required = (1.4 / 3.86) X 2000 = 725.4 kg (or 2000 – 1274.6)

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.

Heading 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 if 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.

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.

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.

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.

Ohmic Heating.

Ohmic heating involves passing of electrical pulse through food via charged electrodes. The resistance to electrical flow produces heat which pasteurizes the food sample.

Heating is uniform and more efficient producing a greater quality product than other heating methods for pasteurization.

The process can be applied to liquid foods and foods with high moisture content like fruits.

High-Pressure Processing.

High hydrostatic pressure pasteurization is completely non-thermal process. It relies on high water pressure that is applied isostatically to the packaged food product.

The pressure disrupts the cell membranes of the target microorganisms leading to leakage of the protoplasm hence death of the microorganism.

This method promises the advantage of leaving the food structure intact and maintaining the nutritional and sensory quality of the food product.

It is also cheaper than heating since it uses tap water to apply the pressure to the food. Since pasteurization is done after packaging, there is no chance of food re-contamination after pasteurization.

Pulsed Electric Fields.

This method uses high voltages of electricity (>20 kV) that is applied to food in very short pulses lasting microseconds.

The electrical pulses interfere with the metabolic processes of the microorganisms and kills them rendering the food safe for human consumption.

Additionally, theism ethos leaves the food material unaffected structurally and in terms of the nutrient content.

Homogenization process: - Pasteurized milk $\rightarrow$ 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

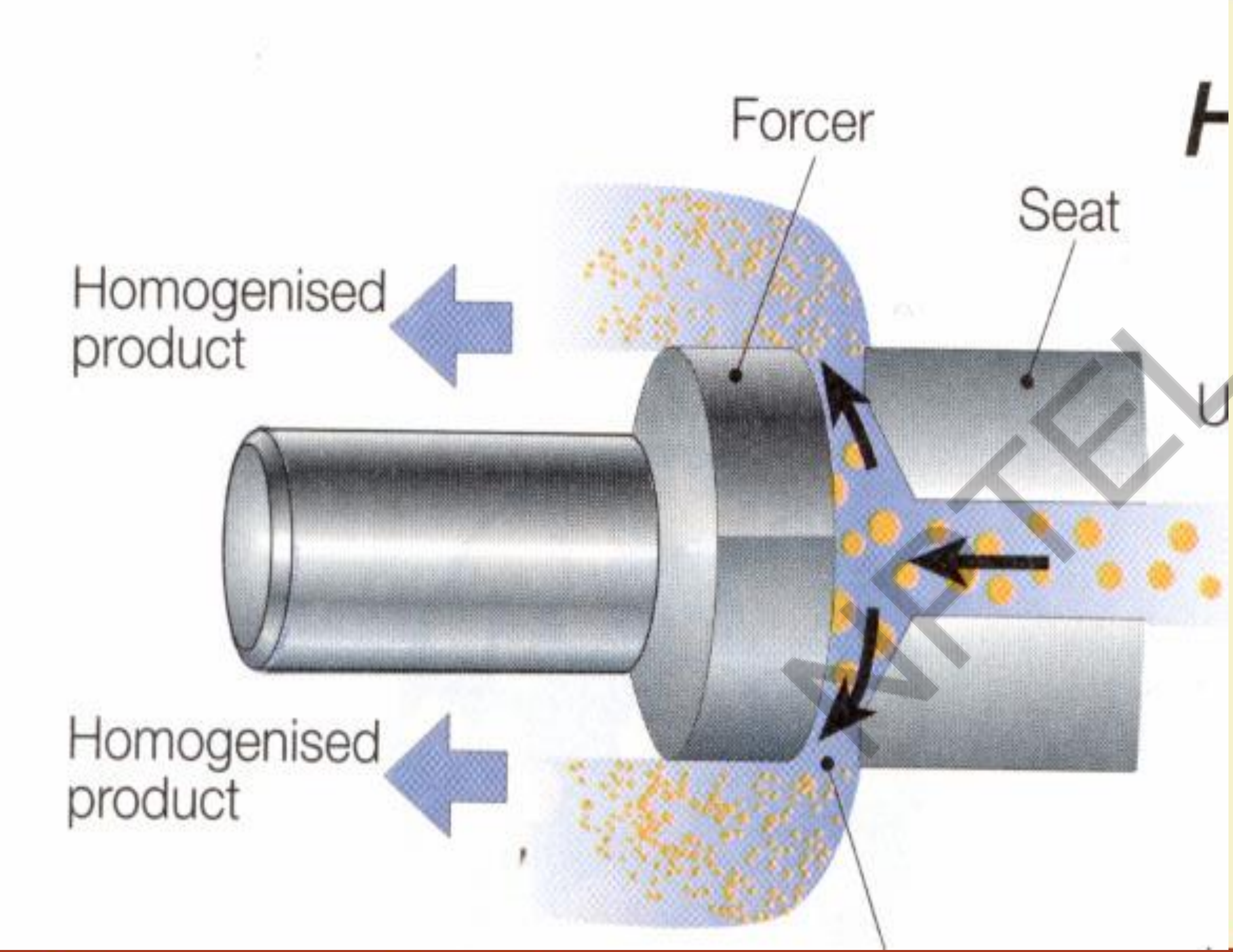


Fig. 1 Homogenization Valve

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 velocit 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.

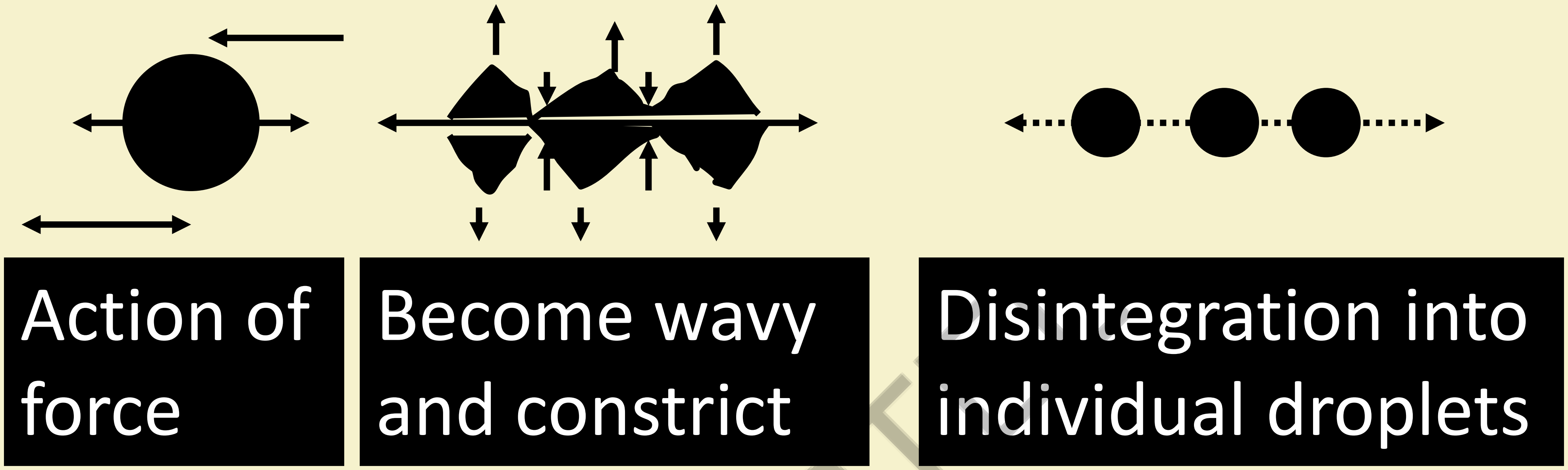


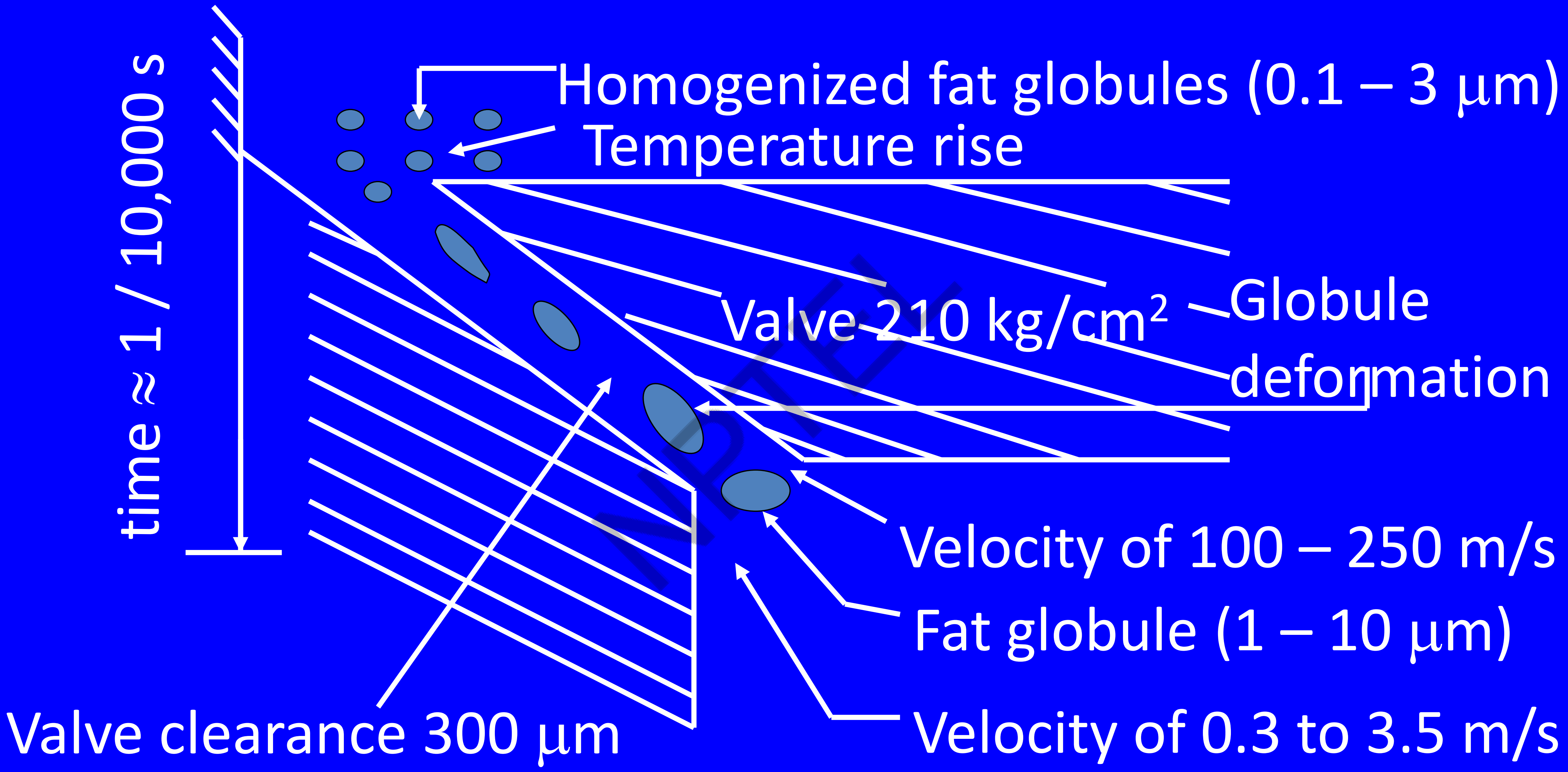
Fig. 2 Splitting of globules by homogenization

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 – 1/5th to 1/6th of the 1st stage.

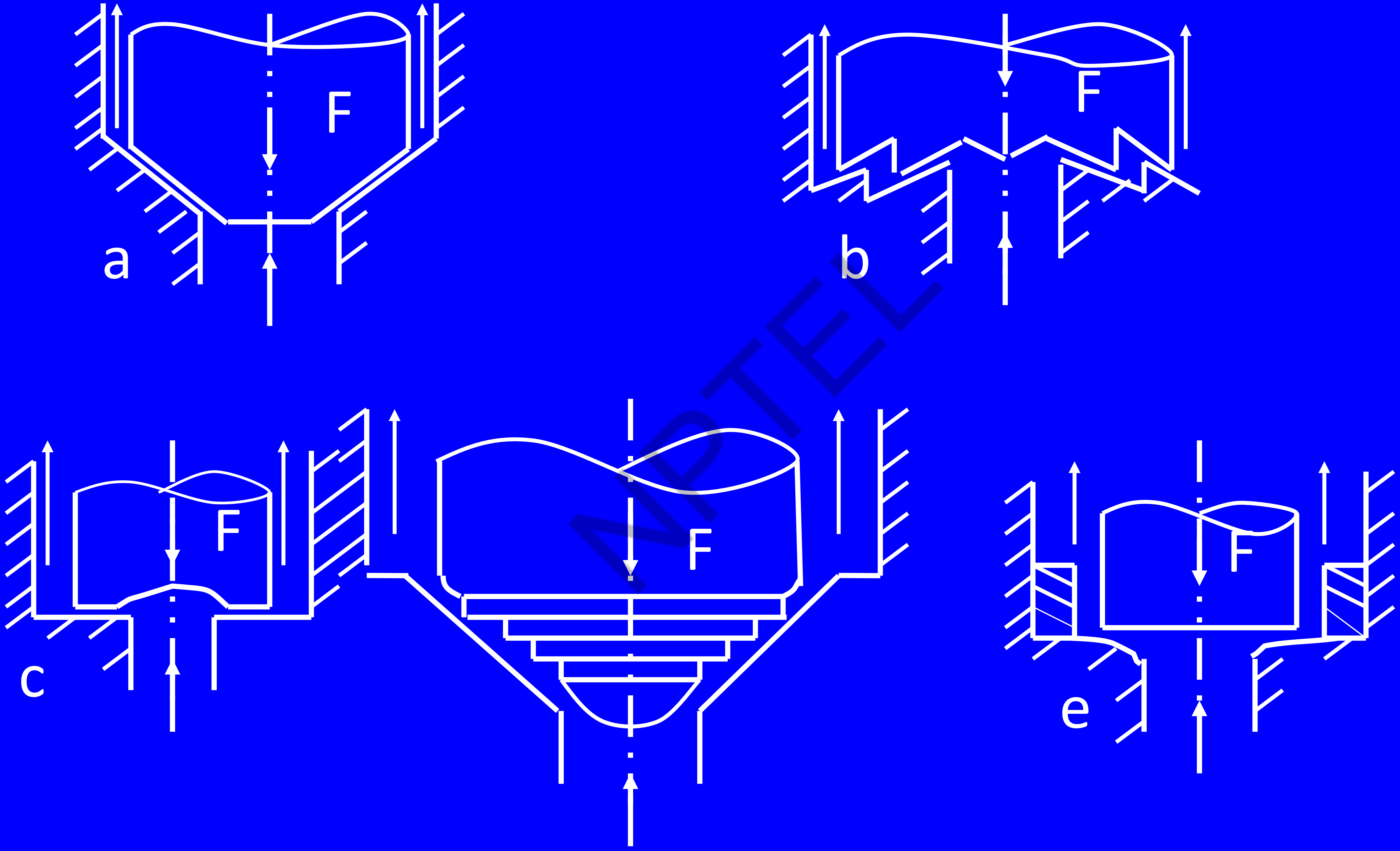
Effect:- Homogenization increases its (i) whiteness – larger no. of fat globules scatter light, (ii) viscosity – increase of shear force created by the presence of large no. of fat globules, (iii) temperature – friction on the homogenization valve as milk flows through it at high velocity, and (iv) gel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

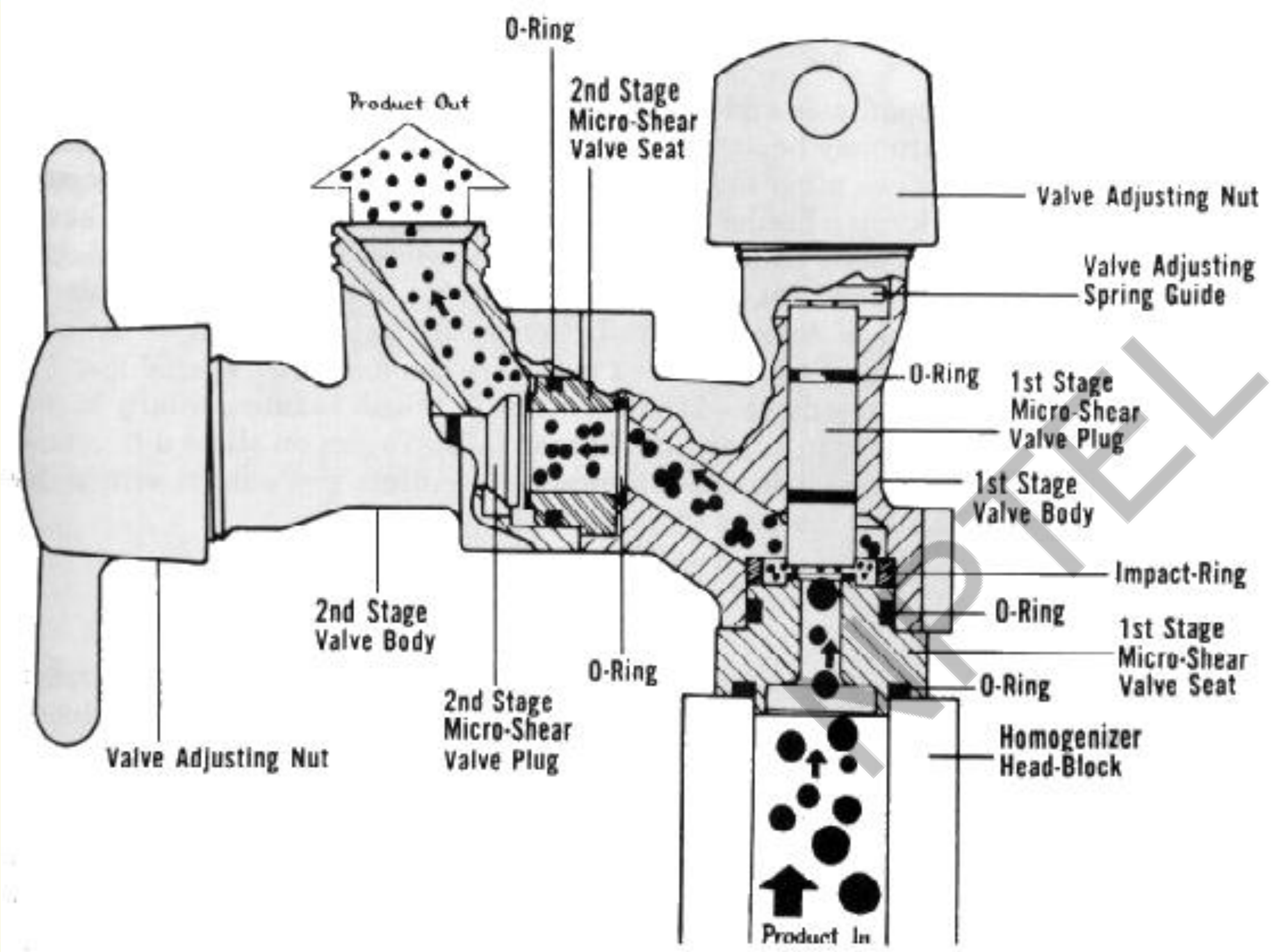
During homogenization – likelihood of lipase enzyme – in contact with milk fat increases. To inactivate – heated to 65 ^oC or more before homogenization. $>$ 80 ^oC – coagulation of whey protein.



Schematic representation of homogenization process


F
a
F
b
F
c
F
F
e

The milk travels through a homogenizer machine where the fat (cream) is broken uniformly in the milk.



- Forces milk through small orifices or turbulent flow paths
- Subdivides fat globules & clumps into small particles to prevent floating
- Gives milk a whiter color

Homogenization theories:- Many theories of the mechanism of high pressure homogenization have been presented over the years. For an oil-in-water dispersion like milk, where most of the droplets are less than 1 μm in diameter, two theories have survived. Together, they give a good explanation of the influence of different parameters on the homogenizing effect.

The theory of globule disruption by turbulent eddies (“micro whirls”) is based on the fact that a lot of small eddies are created in a liquid travelling at a high velocity. Higher velocity gives smaller eddies. **If an eddy hits an oil droplet of its own size, the droplet will break up. This theory predicts how the homogenising effect varies with the homogenising pressure. This relation has been shown in many investigations.**

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.**

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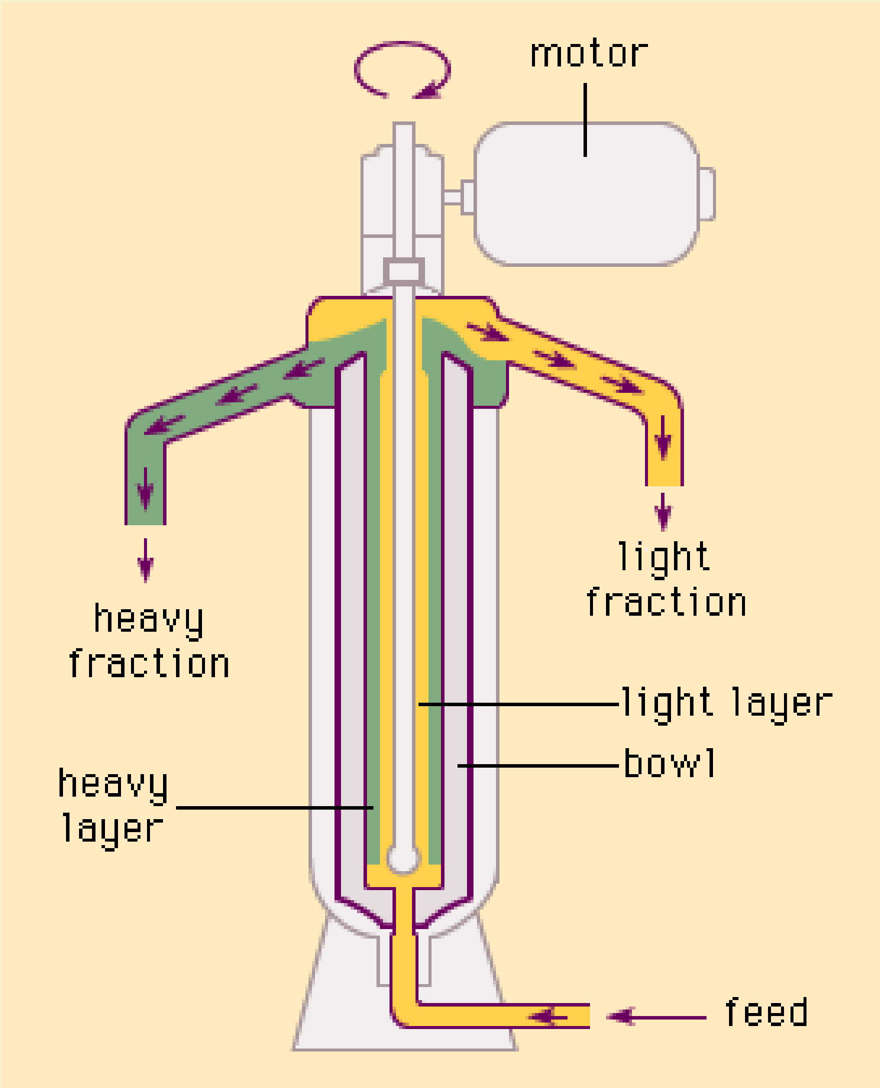
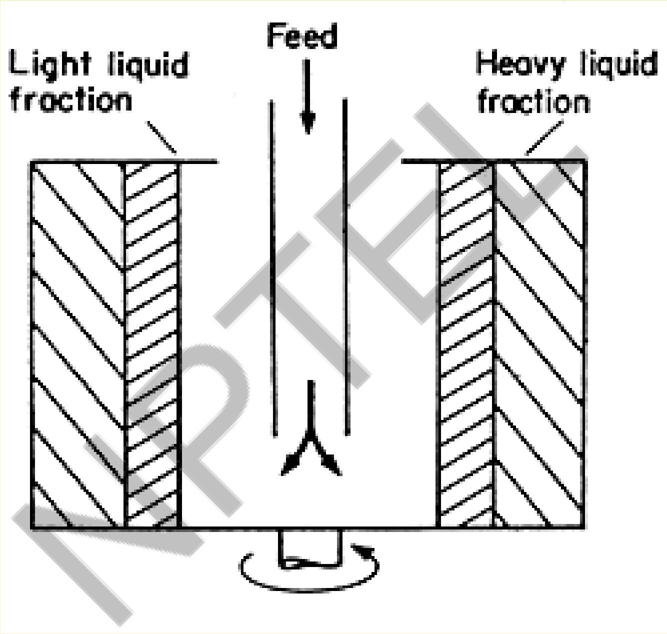
Lecture No. 47: Milk Centrifugation

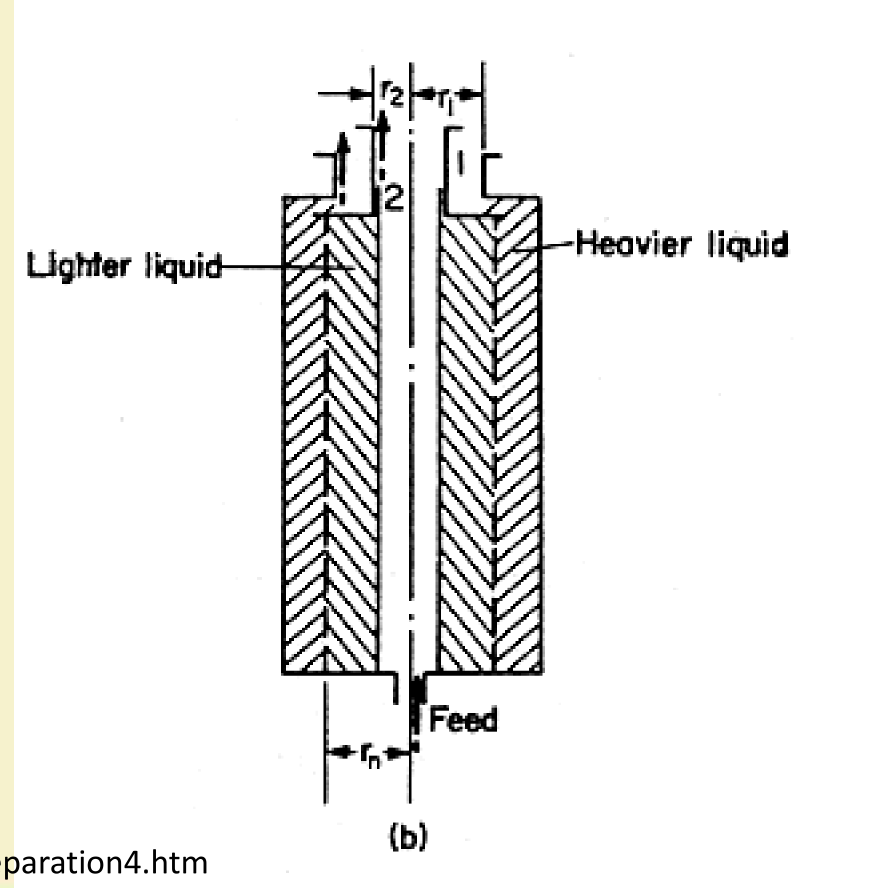
Centrifugal separation of fat in milk:-

- **Feed added to spinning bowl**
- **Sedimentation of particles occurs in centrifugal field**
- Flow is upwards at a particular rate which determines residence time in device
- **Separation happens if sedimentation velocity is high enough for particle to reach side of bowl within residence time**
- **Large particles have higher settling velocities than small particles**
- **Both large and small are still particles, have small Reynolds no.s (<1) and obey Stokes' Law**

Separation of milk into skimmed milk and cream is done with a centrifuge







http://www.nzifst.org.nz/unitoperations/mechseparation4.htm

Centrifugal Motion

- Centrifugal acceleration = $r\omega^2$
- **ω is the angular velocity in rad/s**
- **r is the radius of rotation**
- **Centrifugal force = $mr\omega^2$**
- m is the mass of the particle

Comparison with gravity separation:-

- mg
- **Acceleration constant**
- In direction of earth
- Equilibrium velocity reached
- **Terminal velocity given by:**

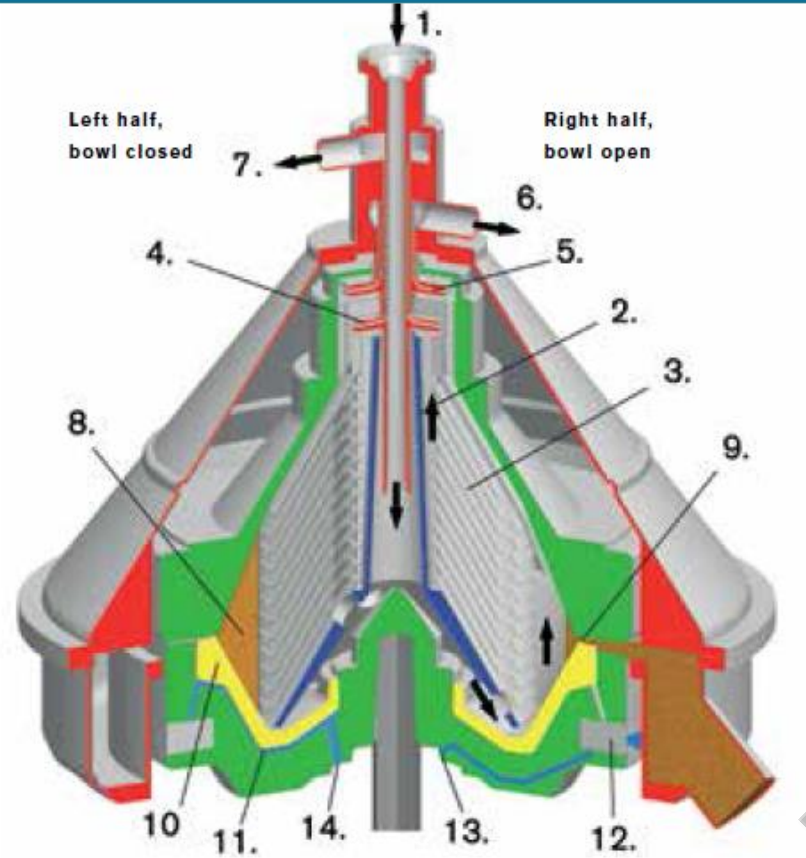
$$v_T = \frac{d^2\left(\rho_p - \rho_f\right) g}{18\mu}$$

where,
d is particle diameter (m)
ρ_p is the particle density (kg/m^3)
ρ_f is the fluid density (kg/m^3)
g is acceleration due to gravity (m/s^2)
μ is the fluid viscosity (Pa.s)

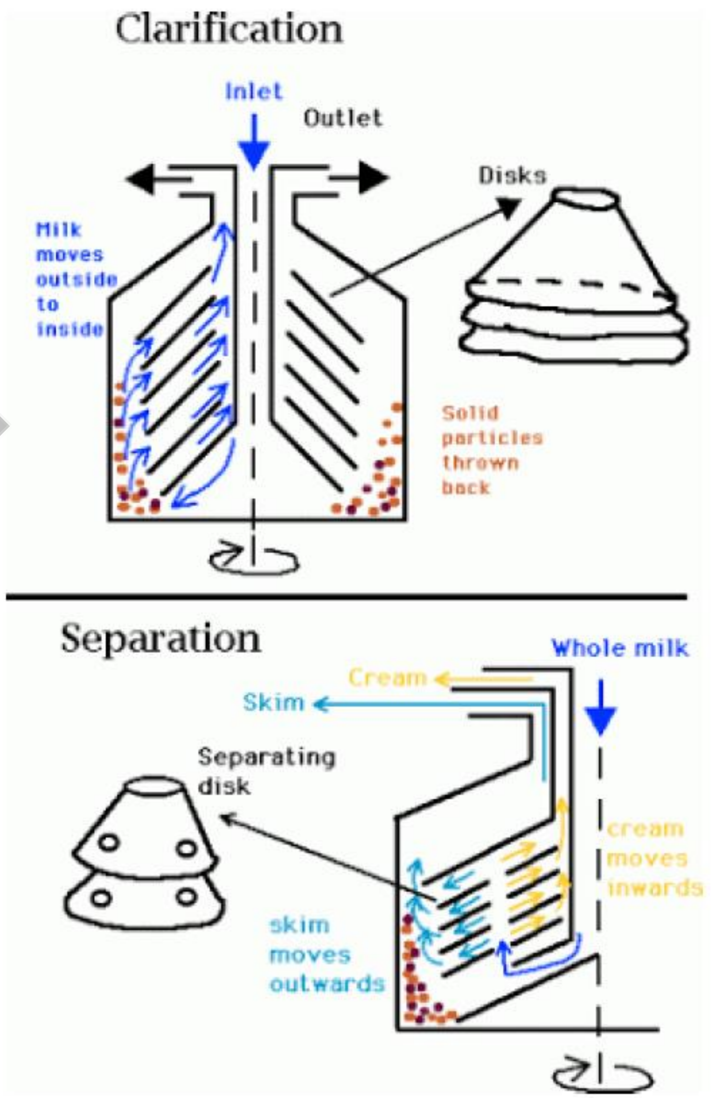
- mrω^2
- **Acceleration increases with r**
- **Acceleration increases with ω**
- Away from axis of rotation
- Equilibrium velocity never reached
- **Instantaneous velocity:**

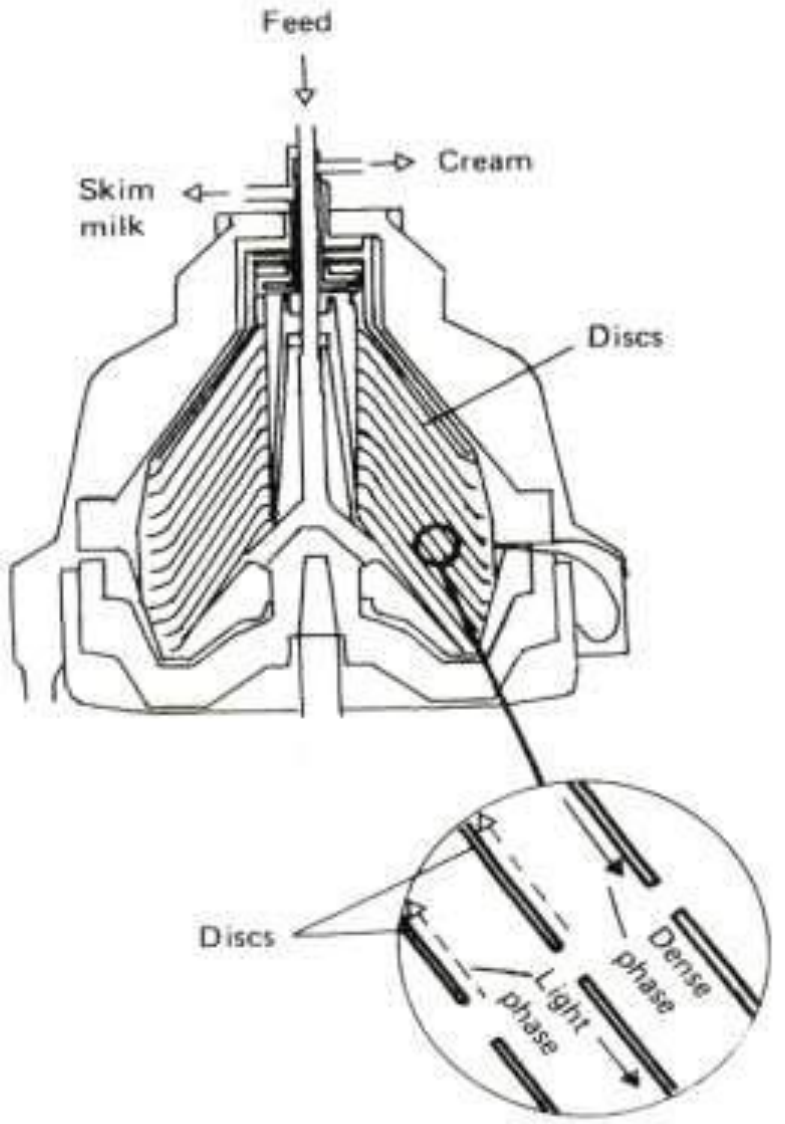
$$v = v_T \frac{r\omega^2}{g}$$

where,
v_T is the terminal velocity of the particle
r is the distance from axis of rotation
ω is the angular velocity



1. Product inlet
2. Distributor
3. Disk stack
4. Light phase centripetal pump
5. Heavy phase centripetal pump
6. Heavy phase outlet
7. Light phase outlet
8. Solids/impurities
9. Discharge holes
10. Moving ram
11. Water closing chamber
12. Bowl valve
13. Operating water inlet for bowl opening
14. Operating water inlet for bowl closing





Working principle of a disc bowl centrifuge: -

Disc bowl and tubular centrifuges can have capacities even up to 150000 l/h.

Better separation is obtained by the disc bowl centrifuge due to the formation of thinner layers of liquid.

Periodic cleaning of deposited solids is required.

The disc bowl centrifuge, in addition to being widely used for separation of cream from whole milk, is also used for clarification of oils, coffee extracts and juices, and separation of starch-gluten.

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Lecture No. 48: Types of available Milk

Different forms of Milk:-

A. Raw milk - fresh, unpasteurized milk straight from the cow.

B. Whole milk - contains no less than 3.25% milk-fat.

- It must contain not less than 8.25% solids-not-fat.
- **Almost all whole milk marketed is also fortified with vitamin**

C. **Low-fat milk - has had sufficient milk-fat removed to bring the levels between 0.5 and 2%.**

- It also contains at least **8.25%** solids-not-fat. It must contain **2000 IU** of vitamin A per kg. Vitamin A is added to offset its loss caused by removal of some of the milk-fat. You can find milk in this category labeled:

- 1. low-fat
- 2. 2% milk
- 3. 1% milk

D. **Skim milk** - also called nonfat milk, has had sufficient milk-fat removed to bring the level to less than 0.5%. It must contain not less than 8.25% solids-not-fat and must be fortified with vitamin A.

E. **Chocolate milk** - is made by adding chocolate or cocoa and sweetener to 2% milk. It must be fortified with Vitamin A and addition of vitamin D is optional.

F. **Eggnog** - is a mixture of milk, eggs, sugar and cream. It may also contain added flavorings such as **rum** extract, **nutmeg** or **vanilla**. It's a seasonal product most readily available during the holidays.

G. Nonfat dry milk - is the product obtained by removal of water only from pasteurized skim milk.

H. **Buttermilk** - is made by adding a special bacterial culture to milk to produce the **desirable** acidity, body, flavor and aroma characteristic of this product.

This concentrate is then homogenized, fortified with vitamin D, packed in cans, sealed and sterilized by heat.

J. **Sweetened condensed milk** - is a canned whole milk concentrate, prepared by **evaporating enough water**, under vacuum, from fresh whole milk to reduce the volume by half.

- It is pasteurized and sugar added to prevent spoilage.

K. Whipping cream - is the fat of whole milk. • Heavy cream contains a minimum of 36 percent fat, while light whipping cream contains 30 to 36 percent fat.

L. Half-and-half - a blend of milk and cream has **10 to 12 percent fat**.

M. **Sour cream** - with **18 percent fat**, is cream that has been soured **by lactic-acid bacteria**.

N. Yogurt - is a milk product with a custard-like consistency. It is made by fermenting partially skimmed milk with special acid-forming bacteria.

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Lecture No. 49: Types of Available Milk in the Market

Evaporated milk is concentrated sterilized milk.

It has roughly 50% of its liquid evaporated away.

It is then homogenized, canned, sterilized and cooled.

Condensed milk is evaporated milk with added sugar.

Sugar makes up 50% of the content.

It doesn't need to be sterilized because the sugar helps to preserve it.

Both of these milks can be made with whole, semi skimmed or skimmed milk.

Process technology for manufacturing dried milk:

Raw milk on arrival at the factory is rapid tested for temperature, hygiene, antibiotics, water addition and adulteration.

On acceptance the milk is pumped into a silo storage tank at the processing plant and held at temperatures below 7 ^{o}C and usually below 5 ^{o}C.

Milk is standardized for a definite milk fat to milk solid not fat (MSNF) ratio.

The microbial quality of milk powders is very important and it is possible at this early stage of processing to take out 99.9% of the spore-forming bacteria by either bacto-fugation or microfiltration prior to heat treatment. This is a the ideal next stage but many processors primarily **due to cost involvement do not include this stage.**

The milk is high temperature short-time pasteurized (HTST) by heating to at least 72 ^{o}C, and holding at or above this temperature for at least 15 seconds, (An equivalent temperature / time combination can be used). Most high volume liquid milk plants now operate on a higher holding time of 25 to 35 S as a precaution over the possible survival of MAP which can cause Crohn's disease in humans. (Mycobacterium avium subspecies paratuberculosis may be capable of surviving pasteurization.)

In skimmed milk powder, the extent of heat treatment (and holding time) can be measured by the whey protein nitrogen index (WPNI), which measures the amount of un-denatured whey protein.

Homogenization is not a mandatory step in whole milk or buttermilk processing, but is usually applied in order to decrease the free fat content.

The milk is concentrated in a series of calandrias in an evaporator to around 40-60% total solids, prior to Spray Drying. Most milk evaporators are today of the falling film type where a fine film of milk / concentrate is passed down the tubes wetting the surface whilst steam is on the other side of the tube and the vapours extracted from the centre by vacuum.

Vapours are normally recompressed in a vapour recompressor making evaporators very efficient.

Water from evaporators can be recovered and re used.

Evaporation of the milk prior to drying is done for reasons of energy efficiency as it is far cheaper to evaporate the water than to spray dry it. The energy used in multi pass evaporators with steam vapour recompression is about 10 times less than spray drying.

Spray drying milk powder involves atomizing concentrated milk (or other liquids) into a hot air stream (180 – 220 ^{o}C). The atomizer may be either a pressure nozzle or a centrifugal disc. By controlling the size of the droplets, the air temperature, and the airflow, it is possible to evaporate almost all the moisture while exposing the solids to relatively low temperatures. Spray drying yields milk powders with excellent solubility, flavour and colour. This is the most common procedure for manufacturing milk powders.

The spray drying process is typically a two-stage process that involves the spray dryer at the first stage with a static fluid bed integrated in the base of the drying chamber. The second stage is an external vibrating fluid bed. Product is moved through the two stage process quickly to prevent overheating of the powder. Powder leaves the dryer and enters a system of cyclones that **simultaneously cools it**.

NEW TECHNOLOGIES IN DAIRY INDUSTRY

- **Membrane Processing**:- ability of semi-permeable membranes of appropriate physical and chemical nature to discriminate between molecule – primarily on the basis of size and to a lesser extent on shape and chemical composition.
- **Ultrafiltration**:- Ultrafiltration membranes allows separation of smaller molecular weight substances ranging from 10,000 – 75,000 daltons with operating pressure ranging between 10 – 200 psig.
- **Reverse Osmosis**:- The reverse osmosis membranes are characterized by a molecular weight cut off of nearly 100 daltons and pressure involved are 5 – 10 times greater than those used in ultrafiltration.

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Lecture No. 50: New Technologies in Dairy Industries

NEW TECHNOLOGIES IN DAIRY INDUSTRY

- **Membrane Processing**:- ability of semi-permeable membranes of appropriate physical and chemical nature to discriminate between molecule – primarily on the basis of size and to a lesser extent on shape and chemical composition.
- **Ultrafiltration**:- Ultrafiltration membranes allows separation of smaller molecular weight substances ranging from 10,000 – 75,000 daltons with operating pressure ranging between 10 – 200 psig.
- **Reverse Osmosis**:- The reverse osmosis membranes are characterized by a molecular weight cut off of nearly 100 daltons and pressure involved are 5 – 10 times greater than those used in ultrafiltration.

Nanofiltration:- Nanofiltration is a demineralization process. Acid whey can be partially demineralized (about 40%), particularly with respect to the monovalent ions, and concentrated simultaneously to approximately 25% total solids using nanofiltration process. It separates particles with molecular weights in the range of 300 – 1000 daltons. Operating pressures required are nearly 300 psig.

Microfiltration: Microfiltration is essentially used as a clarifying process to remove macromaterials and suspended solids, milk fat globules, bacteria and colloidal particles. In microfiltration, membranes with pore size ranging from 0.1 – 10 micron and the operating pressure in the range of 1 – 25 psig are used. The most significant application of microfiltration is for selective separation of bacteria from milk.

Ohmic Heating Ohmic heating, also called electric resistance heating, is a direct heating method that uses the food itself as a conductor of electricity that is taken from mains. The most important benefit of ohmic heating is that heating is very rapid and uniform. The process is ideal for shearsensitive products.

Microwave Heating:- Microwaves are a form of electromagnetic radiation, characterized by wavelength and frequency. Microwaves used in the food industry for heating are of ISM (industrial, scientific and medical) frequencies (2450 or 900 MHz, corresponding to 12 or 34 cm in wavelength). In this frequency range the dielectric heating mechanism dominates up to moderated temperatures. Polar molecules, the dominant water, try to align themselves with the rapidly changing direction of the electric field. The energy to achieve this alignment is taken from the electric field. When the field changes direction, the molecule “relaxes” and the energy previously absorbed is dissipated into the surroundings, that is, directly inside the food. This means that the water content of the food is an important factor in the microwave heating performance of foods.

High Hydrostatic Pressure Processing:- The application of hydrostatic pressure to food results in instantaneous and uniform transmission of the pressure throughout the product independent of the product volume. The hydrostatic treatment is unique in that the effects do not follow a concentration gradient nor do they change as a function of time. Other advantages include the absence of chemical additives and operation at low or ambient temperatures so that the food is essentially raw. Liquid foods can be pumped to treatment pressures, held, and then decompressed aseptically for filling as with other aseptic processes. Pressures of 650 MPa can reduce the viable numbers of microbes.

Pulsed Electric Field:- High-intensity pulsed electric field processing involves the application of pulses of high voltage (typically from 20 to 80 kV/cm) to foods placed between two electrodes. Pulsed electric field treatment is conducted at ambient, sub-ambient, or slightly above ambient temperatures for less than 1 sec, as a result of which the energy loss due to heating of foods is minimized. Pulsed electric field technology is considered superior to traditional heat treatment of foods because it maintains food quality by avoiding or greatly reducing detrimental changes to the sensory and physical properties of foods.

Osmotic Dehydration The concentration of food products by means of product immersion in a hypertonic solution is known as osmotic dehydration. Osmotic dehydration consume less energy compared to air drying and freeze drying because water removal occurs without a phase change. Heat damage to the food product is minimum in case of osmotic dehydration as the product is not subjected to high temperature for extended periods. Successful attempts have been made to dehydrate traditional Indian dairy products such as ras malai, rasogolla and paneer using osmotic dehydration technology.

Hurdle Technology:- Hurdle technology is a concept in which three or more preservation parameters (hurdles) are employed in suitable combination and every hurdle is used at optimum level so that damage to the overall quality of food is kept to minimum. Hurdle technology has been tried for preservation of several Indian dairy products such as milk cake, paneer and paneer curry.

Biopreservation:- Biopreservation refers to the extended storage life and ehhanced safety of foods using their natural or controlled microflora and/or their antimicrobial products. The diverse group of lactic acid bacteria synthesize a variety of inhibitory substances such as organic acids, carbon dioxide, H_2O_2, diacetyl, bacteriocin, etc. which prevent the development of undesirable bacteria.

Thank You!!