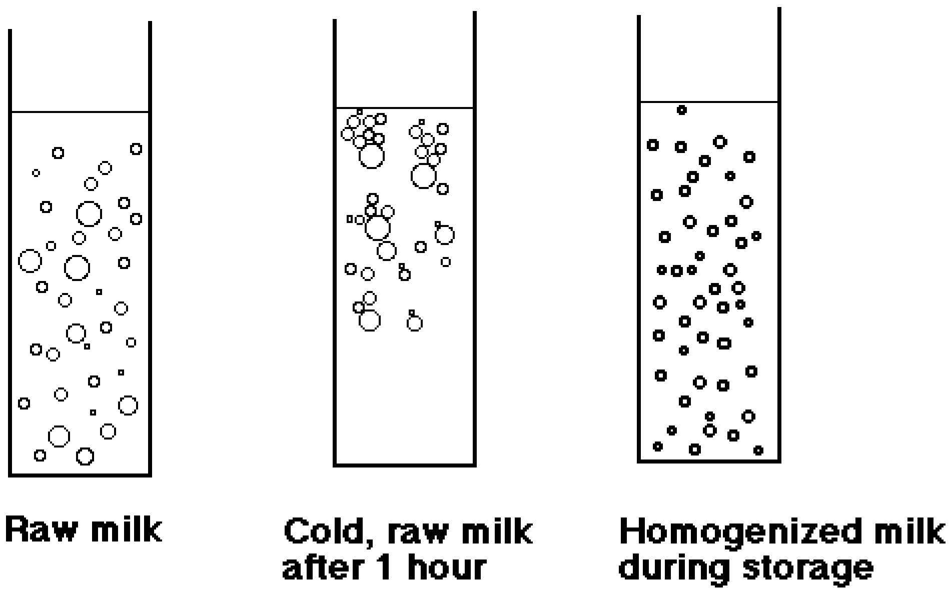
HOMOGENIZATION

- Milk is an oil-in-water ***emulsion***, with the fat globules dispersed in a continuous skim milk phase.
- If raw milk were left to stand, however, the fat would rise and form a cream layer. Homogenization is a mechanical treatment of the fat globules in milk brought about by passing milk under high pressure through a tiny orifice, which results in a decrease in the average diameter and an increase in number and surface area, of the fat globules.
- The net result, from a practical view, is a much reduced tendency for creaming of fat globules.
- Three factors contribute to this enhanced stability of homogenized milk:
  - ☞ a decrease in the mean diameter of the fat globules (a factor in Stokes Law),
  - ☞ a decrease in the size distribution of the fat globules (causing the speed of rise to be similar for the majority of globules such that they don't tend to cluster during creaming), and
  - ☞ an increase in density of the globules (bringing them closer to the continuous phase) oweing to the adsorption of a protein membrane.

In addition, heat pasteurization breaks down the cryo-globulin complex, which tends to cluster fat globules causing them to rise.

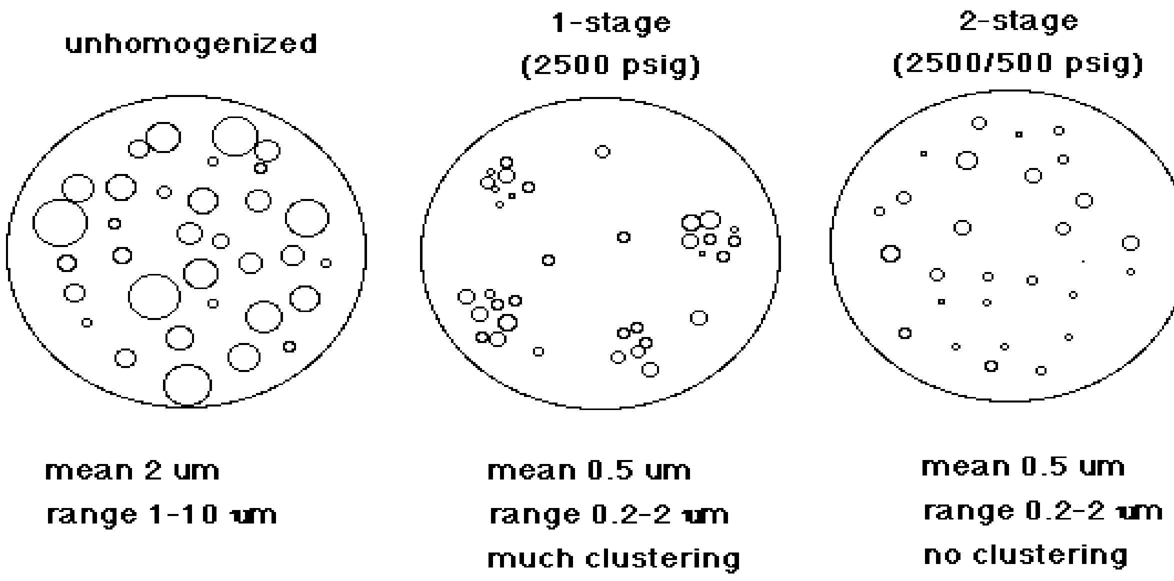


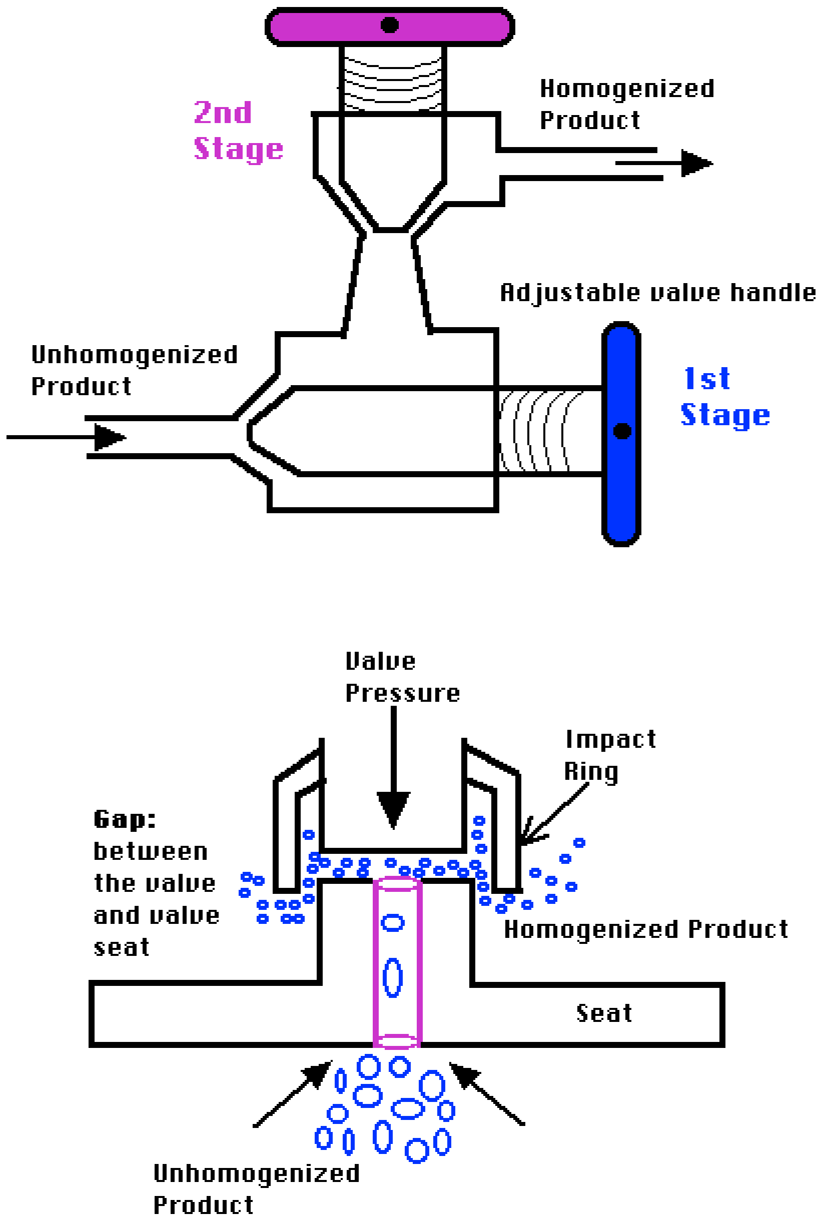
Mechanism of homogenization,

- consider a conventional homogenizing valve processing an emulsion such as milk at a flow rate of 20,000 l/hr. at 14 MPa (2100 psig).

- As it first enters the valve, liquid velocity is about 4 to 6 m/s.
- It then moves into the gap between the valve and the valve seat and its velocity is increased to 120 meter/sec in about 0.2 millisec.
- The liquid then moves across the face of the valve seat (the land) and exits in about 50 microsec.
- The homogenization phenomena is completed before the fluid leaves the area between the valve and the seat, and therefore emulsification is initiated and completed in less than 50 microsec.
- The whole process occurs between 2 pieces of steel in a steel valve assembly.
- The product may then pass through a second stage valve similar to the first stage.
- While most of the fat globule reduction takes place in the first stage, there is a tendency for clumping or clustering of the reduced fat globules.
- The second stage valve permits the separation of those clusters into individual fat globules.
- It is most likely that a combination of two theories, turbulence and cavitation, explains the reduction in size of the fat globules during the homogenization process.

The Effects of 2-stage Homogenization on Fat Globule Size Distribution as Seen Under the Light Microscope





Homogenizer and Valve

In summary, the **homogenization variables** are:

- type of valve
- pressure
- single or two-stage
- fat content
- surfactant type and content
- viscosity
- temperature

General effect of Homogenization:

1. In normal milk fat globules are in size from 1 to 15 microns. After homogenization, all the fat globules are under 2 microns in size. .
2. Fat globules will not rise to the top to form a cream layer, as in normal milk.
3. Increase in the viscosity of the milk.
4. Single stage homogenization increases viscosity considerably because it produces clusters in which the membranes of the individual fat globules join each other, although the fat itself is not in contact.
5. In two stage homogenization, the fat globule clusters which under normal circumstances are not easily broken up; are torn apart during the second stage. This results in a reduction of viscosity.
6. A high fat content, a high homogenizing pressure and a low product temperature can increase the degree of clustering and thus a viscosity.
7. Homogenizing increases the whitening power of milk because of the greater surface area of the fat.

Homogenizing valve:

- The heart of the homogenizer is the homogenizer valve.
- There are several types of valve.
- Puppet valve is used as a breaker ring which surrounds the main homogenizing valve so that the fluid strikes the inner surface of the breaker ring at right angles as it leaves the orifice formed by the conical shaped valve and seat.
- In operation, the valve is held down by a heavy spring having adjustable tension; as the fluid pressure comes against it the valve rises a few thousandths of an inch to form a very narrow annular orifice.
- Since the opening of the valve is only a few thousandths of an inch, it is apparent that slight grooving of a valve of this type due to wear is bound to destroy its efficiency.

Theory of Homogenization:

- The principal theory is disrupting action takes place as the result of a shearing action between the globules as they flow through a passage at high velocity, much as rocks are sheared and worned by the action of a fast-moving river.
- The solid particles nearest the edge of the stream are retarded somewhat by friction of the fluid on the banks of the stream, and the center or fast-moving part of the stream therefore carries the particles in the center at a more rapid pace than those nearer the edge.

- This difference in speed causes the solid particles to grind against each other with a shearing effect, resulting in the reduction in size of the particles.
- The faster the flow and the narrower the stream, the greater is the shearing action.
- The principal action in the homogenizer is of the same in nature; because of the extremely high velocity and the minute orifice the shearing action is very great.
- In addition to the above, there is also a certain disrupting action due to impact which takes place when the high-velocity streams strikes a solid surface as the breaker ring, for example, in some types of valves.
- Then there is some disruptive effect due to the sudden drop in pressure or explosive effect as the fluid leaves the valve.
- Forces caused by collapse of bubbles due to cavitation may also be an important factor in homogenization.
- In most valves employ a combination of the three principles.
- The size of the orifices and the shape are determined by the volume to be handled in a given time and also b the viscosity of the product.
- Steady pressure of the forced fluid gives best result of homogenizer valve.
- This is because the shearing effect of the valve changes with the velocity of the fluid passing through it.
- The fluctuating pressure, will fluctuate velocity, thus causing irregular results.

Types of Homogenizer

There are four type of homogenizer,

1. High speed mixers
2. Pressure homogeizers
3. Colloid mills, and
4. Ultrasonic homogenizer

High speed mixer:

☞ Turbine or propeller type high speed mixers are used to pre-mix emulsions of low-viscosity liquids.

☞ Operate by a shearing action on the food at the edges and tips of the blades.

☞ They are used to mix, agitate or dissolve the solids within liquids.

Pressure Homogenizer:

☞ Used for liquids having a viscosity less than 2 kg s/cm^2.

☞ It has two main parts; high pressure pump and the homogenizer valve.

- ☞ The emulsion is fed at 1-2 kg/cm^2 into a reciprocating pump, consisting of three or more plungers.
- ☞ Increase in number of plungers gives better constant feeding and reduce the machine vibration.
- ☞ Liquid flows through the suction valves of the pump cylinders, during the withdrawal of the plungers.
- ☞ The suction valve close, while each plunger moves forward again, compressing the contents of the corresponding cylinder through the discharge valves, to the homogenization valve.
- ☞ The pressure applied depends on the product and the final size of particles required.
- ☞ In milk, the efficiency of homogenization decrease, if the fat content increases, since fat increase the viscosity of the product.
- ☞ The pressure in such homogenizer may be 102-714 kg/cm^2.

Colloid Mill:

- ☞ It provide superior shearing and grinding.
- ☞ There are three shear points that gives higher degree of grinding.
- ☞ Undispersed material is forced into a cavity formed by a spinning rotor and fixed stator.
- ☞ Centrifugal force propels the material to the outside of the rotor, causing intense hydraulic shear that breaks agglomerates and homogenizes the solid and liquids.
- ☞ This can be used for the viscosity of the product in relatively high (>1 kg s/cm^2).
- ☞ In colloid mill the disk rotates 3000-15000 rpm.
- ☞ High viscous products require slower the rotation of the disks.
- ☞ The gap between the disks may be adjusted between 0.1 and 10 mm.
- ☞ The pressure during homogenization lies between 1.53 to 3 kg/cm^2.
- ☞ At 2 to > 30 m^3/h the required energy may lie between 5 and 100 kW.

Ultrasonic Homogenizer:

- ☞ It works at high-frequency sound waves (18.30 kHz).
- ☞ It causes alternate cycles of compression and tension in low viscosity liquids and cavitations of air bubbles.
- ☞ It forms an emulsion with droplet sizes of 1-2 mm.
- ☞ Feed is provided at a pressure 3.50 to 14.25 kg/cm^2.
- ☞ Sound waves are created electrically or mechanically.

Temperature rise :

In homogenization mechanical energy is converted into heat. Hence, temperature of fluid will rise.

The temperature rise is given by

$\theta = p/40$

where θ = rise in temperature ^oC.

p = homogenizing pressure, kg/cm^2.

Example :

Calculate the temperature rise if the pressure is 250 kg/cm^2.

$\theta = 250/40 = 6.25\ ^oC$

Exercise : Compute the rise in milk temperature if homogenized at 150, 200 and 225 kg/cm^2 pressure.

Homogenizer efficiency:

The effect of homogenization is frequently expressed in terms of the mean droplet diameter of the disintegrated fat globules. However, a diameter related to the total number of fat droplets would be unrealistic as almost 80% of all the fat globules have a diameter of less than 1 µm and represent only a small fraction of the total volume of fat.

Mean droplet diameter is given by

$$d_m = (\Sigma N_i d_i^3)/ (\Sigma N_i d_i^2)$$

where d_m = mean droplet diameter

N_i = number of droplets with diameter d_i for the range i

Example : The energy requirement of a homogenizer is given by

$E = p . Q$

Where E = power requirement, kgm/h

p = homogenizing pressure, kg/m^2

Q = volume of flow, m^3/h

Example:

If Q = 1000 l/h, p = 250 kg/cm^2, calculate the horsepower required for homogenization.

Q = 1000 l/h = 1 m^3/h

p = 250 kg/cm^2 = 25 x 10^5 kg/ m^2

E = 1 x 25 x 10^5= 25 x 10^5kg m/h = (25 x 10^5)/ (3600 x 75) = 9.26 hp (1 hp = 75 kg m/s)

Example:

Compute the horse power requirement for homogenization if discharge is 2000 l/h at pressure of 225 and 200 kg/cm^2.