

Homogenization

Why Homogenization?

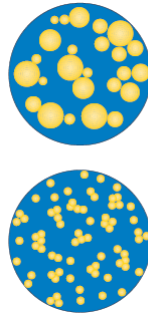
$$v_g = \frac{p^2 \times (\rho_{lp} - \rho_p)}{18 \times t} \times g$$

or $v_g = \text{constant} \times p^2$

v_g = velocity
 g = force of gravity
 p = particle diameter
 ρ_{lp} = density of the liquid
 ρ_p = density of the particle
 t = viscosity

Homogenization

- Homogenization was invented by a French named : Gaulin, in 1899 described it in French as “fixer la composition des liquides”.
- Homogenization primarily causes disruption of fat globules into much smaller ones
- The homogenisation reduces fat globule size from an average of 3.5 μm in diameter to below 1 μm , this is accompanied by a four- to six-fold increase in the fat/plasma interfacial surface area.



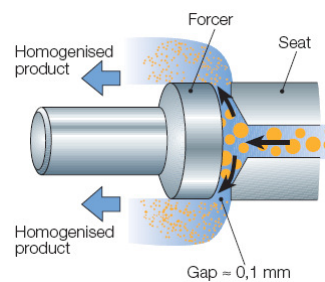
Homogenization

- The newly created fat globules are no longer completely covered with the original membrane material. Instead, they are surfaced with a mixture of proteins adsorbed from the plasma phase.
- Casein is the protein half of the complex and it is associated with the fat fraction through polar bonding forces.
- The casein micelle is activated at the moment it passed through the valve of the homogeniser, predisposing it to interaction with the lipid phase.

Process requirements

- The physical state and concentration of the fat phase contribute most
- Homogenisation below 40 °C results in incomplete dispersion of the fat phase.
- Products of high fat content are more difficult to homogenise & also more likely to show evidence of fat clumping.
- Increasing the homogenisation temperature decreases the viscosity of milk & improves the transport of membrane material to the fat globules.
- Homogenisation : Temp 55 – 80 °C & pressure is between 10 and 25 MPa (100 – 250 bar)

Flow characteristics



The Homogenization Valve

- When the liquid passes the narrow gap, the flow velocity increases. The speed will increase until the static pressure is so low that the liquid starts to boil.
- The maximum speed depends mainly on the inlet (homogenization) pressure.
- When the liquid leaves the gap, the speed decreases and the pressure increases again. The liquid stops boiling and the steam bubbles implode.

Homogenisation theories

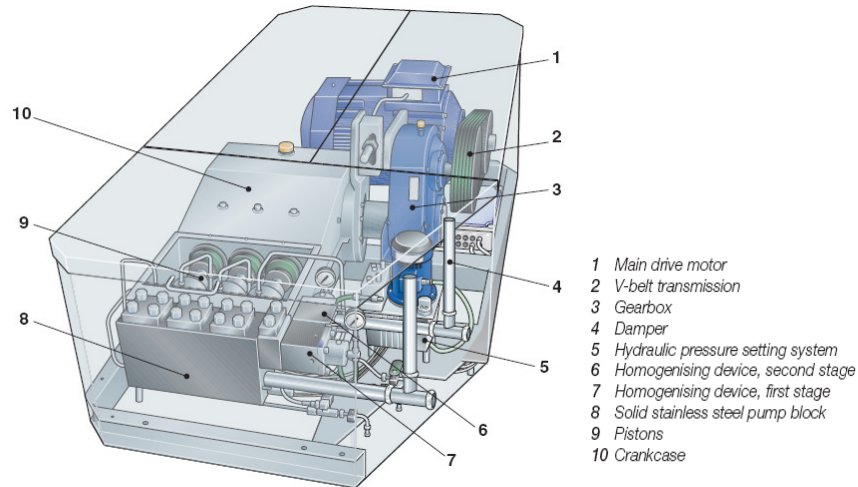
- The theory of globule disruption by *turbulent eddies* (“micro whirls”):
 - A lot of small eddies are created in a liquid travelling at a high velocity.
 - If an eddy hits an oil droplet of its own size, the droplet will break up.
 - Higher velocity gives smaller eddies.
 - This theory predicts how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

Homogenisation theories

- The *cavitation theory*
 - *Shock waves* are created when the steam bubbles implode disrupt the fat droplets.
 - Homogenisation takes place when the liquid is leaving the gap, so the back pressure which is important to control the cavitation is important to homogenisation. This has also been shown in practice.
 - However, it is possible to homogenise without cavitation, but it is less efficient.

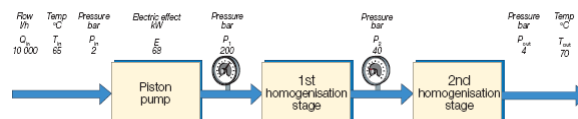
The homogeniser

- A high pressure homogeniser is basically a pump with homogenization device (valve)

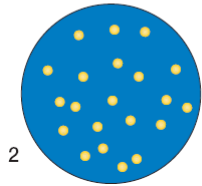
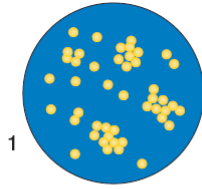


Single-stage and two-stage homogenisation

- Homogenisers may be equipped with one homogenising device or two connected in series
- In two-stage homogenisation the back pressure (P_2) is created by the second stage.
- Using modern devices, the best results are obtained when the relation P_2/P_1 is about 0.2
- The second stage also reduces noise and vibrations in the outlet pipe.



Single-stage and two-stage homogenisation



Disruption of fat globules
In first & second stages of
Homogenization

- Single-stage homogenisation may be used for homogenisation of products with high fat content demanding a high viscosity (certain cluster formation)
- Two-stage homogenisation is used primarily to reach optimal homogenisation results and to break up fat clusters in products with a high fat content.

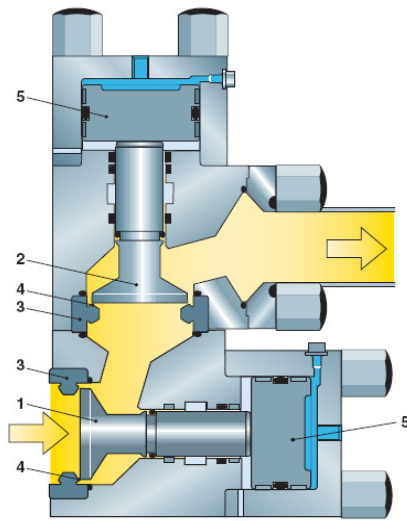
Effect of homogenisation

- Smaller fat globules leading to less cream-line formation
- Whiter and more appetizing colour
- Reduced sensitivity to fat oxidation
- More full-bodied flavour, and better mouthfeel
- Better stability of cultured milk products

Disadvantages

- Somewhat increased sensitivity to light – sunlight and fluorescent tubes – can result in “sunlight flavour”
- The milk might be less suitable for production of semi-hard or hard cheeses because the coagulum will be too soft and difficult to dewater

The homogenization valve

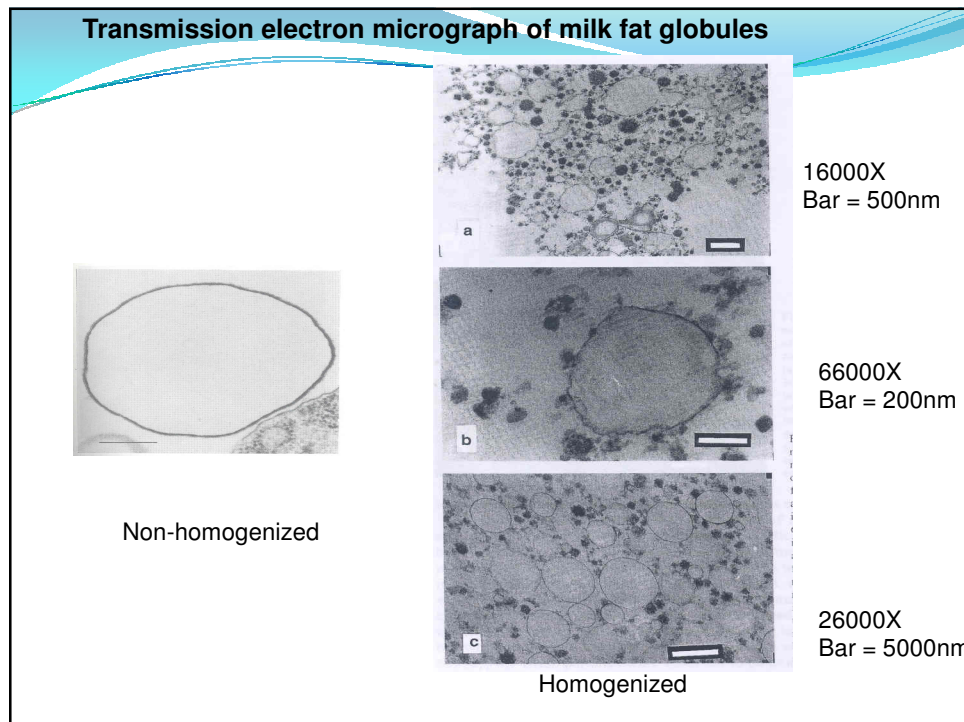


1 First stage forcer
2 Second stage forcer
3 Seat
4 Gap
5 Hydraulic actuator

- The distance between the seat and the forcer is approximately 0.1 mm or 100 times the size of the fat globules in homogenised milk.
- The velocity of the liquid is normally 100 – 400 m/s in the narrow annular gap.
- The higher the homogenisation pressure, the higher the speed.
- Homogenisation takes 10 – 15 microseconds.

The homogenization valve

- The piston pump boosts the pressure of the milk from about 300 kPa (3 bar) at the inlet to a homogenization pressure of 10 – 25 MPa (100 – 250 bar)
- The oil pressure on the hydraulic piston and the homogenisation pressure on the forcer balance each other.
- The hydraulic unit can supply both first and second stage with an individually set pressure. The homogenization pressure is set by adjusting the oil pressure
- Homogenization always takes place in the first stage. Second stage basically serves two purposes:
 - Supplying a constant and controlled back-pressure to the first stage, giving best possible conditions for homogenization
 - Breaking up clusters formed directly after homogenization as shown in



Product specific purposes of Homogenization

- Market milk - creaming of fat is avoided & taste improvement is achieved
- Coffee cream, evaporated milk - avoids creaming & improved the whitening power in coffee
- Cheese milk - enhances the biochemical fat degradation especially in mould ripened cheeses
- Acidified dairy products - improvement in consistency & taste, more stable acid gel and reduced whey syneresis
- Milk mix beverages - improving body, good distribution of stabilizer & additives
- Ice cream mix - reduced buttering of fat during freezing process

Homogenizer in the processing line

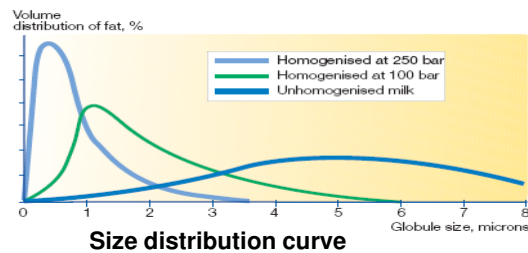
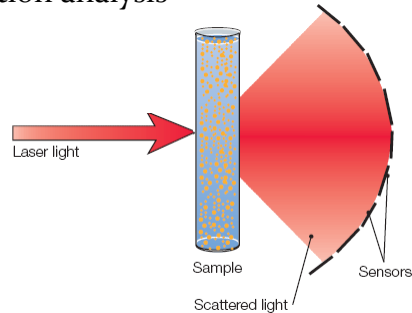
- In general, the homogenizer is placed upstream, *i.e. before the final heating* section in a heat exchanger. In most pasteurization plants for market milk production, the homogenizer is usually placed after the second regenerative section
- In production of UHT milk, the homogenizer is generally placed upstream in indirect systems but always downstream in direct systems, *i.e. on the aseptic side* after UHT treatment. In the latter case, the homogenizer is of aseptic design

Factors affecting the fat globule size

- Homogenization pressure
- Stages of homogenization
- Fat content & ratio of amount of surfactant (usually protein) to amount of fat
- Temperature
- Proper operation of the homogenizer

Homogenisation efficiency

1. Size distribution analysis



Homogenisation efficiency

2. Studies of the creaming rate

- a. 1 000 ml is stored for 48 hours, after which the fat content of the top 100 ml is determined, as well as the fat content of the rest. Homogenization is reckoned to be sufficient if 0.9 times the top fat content is less than the bottom fat content
- b. Creaming index by centrifugal method: 50 ml of milk is centrifuged at 1000 rpm/5 min in 3 sets. Top 5 ml milk is separated and fat content determined for both the fractions :

Creaming index = $(A-B)/B \times 100$, A = fat% of top, B = fat% of bottom

Quality of homogenization: Excellent up to 10, Good 11-20, Fair 21-30 & Bad over 30

Homogenisation efficiency

3. Farrall index: efficiency in excellent when upon microscopic examination 90% of the fat globules has average diameter $\leq 2\mu$

Overall effect of Homogenization

- Reduction of size of the fat globules accompanied by four- to six-fold increase in the fat/plasma interfacial surface area
- Creation of new MFGMs and adsorption of disrupted casein micelles on the new MFGMs
- Slight increase in viscosity
- Increased foaming properties
- Increased digestibility
- Whiter and more appetizing colour
- More full-bodied flavour, and better mouthfeel
- Reduction in heat stability
- Increased in foaming properties
- Somewhat increased sensitivity to light – sunlight and fluorescent tubes – can result in “sunlight flavour”