# HOMOGENIZATION

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Milk is an oil-in-water type emulsion in which the butter fat is dispersed as fat globules in the skim milk portion. The greater part of the fat volume consists of globules with a diameter ranging from 2 to 6 µm. A few fat globules may exist which have a diameter of 10 µm. Milk fat contains also a large number of small fat globules with diameters down to 0.1 µm, but this do not greatly increase the total volume of the fat (Ahmad, 2012).

Homogenization refers to the process of forcing the milk through a homogenizer with the object of sub-dividing the fat globules (De, 2001). Homogenization has become a standard industrial process, universally practised as a means of stabilising the fat emulsion against gravity separation (Bylund, 2003). Gaulin, who invented the process in 1899, described it in French as “fixer la composition des liquides” which means it makes liquid composition stable.

The purpose of homogenization is to disintegrate or finely distribute the fat globules in the milk, in order to reduce creaming. Homogenization primarily causes disruption of fat globules into much smaller ones. Consequently, it diminishes creaming and mayalso diminish the tendency of globules to clump or coalesce. Essentially, all homogenised milk is produced by mechanical means.

## Homogenized milk

According to the United States Public Health Service, homogenized milk is milk which has been treated in such a manner as toensure breakup of the fat globules to such an extent that after 48 hours’ quiescent storage no visible cream separation occurs on the milk; and the fat percentage of the milk in the top 100 ml of milk in a quart bottle, or of proportionate volumes in containers of other sizes, does not differ by more than 10 per cent of itself from the fat percentage of the remaining milk as determined after thorough mixing (De, 2001).

## Objectives of Homogenization

Homogenization results in milk or milk products in which the fat globules are reduced in size tosuch an extent that no visible cream separation occurs in the milk. This process basically results in milk of uniform composition or consistency and palatability without removing or adding any constituents. Homogenization increases the whiteness of milk, because the greater number of fat globules scatters light more effectively. Homogenized milk is less susceptible to oxidized flavor, and the softer curd formed by it when entering the stomach aids digestion (Miller *et al.*, 2007).

Homogenization is applied for any of the following reasons:

**1. Counteracting creaming:** To achieve this, the size of the fat globules should be greatly reduced. A cream layer in the product may be a nuisance for the user, especially if the package is nontransparent.

**2. Improving stability toward partial coalescence:** The increased stability of homogenized fat globules is caused by the reduced diameter and by the acquired surface layer of the fat globules. Moreover, partial coalescence especially occurs in a cream layer, and such a layer forms much more slowly in homogenized products.

**3. Creating desirable rheological properties:** Formation of homogenization clusters can greatly increase the viscosity of a productsuch as cream. Homogenized and subsequently soured milk (e.g., yogurt) has a higher viscosity than unhomogenized milk. This is because the fat globules that are now partly covered with casein micelles in the aggregation of the casein micelles.

**4. Recombining milk products:** At one stage of the process, butter oil must be emulsified in a liquid suchas reconstituted skim milk. A homogenizer, however, is not an emulsifying machine. Therefore, the mixture should first be pre-emulsified, for example, by vigorous stirring; the formed coarse emulsion is subsequently homogenized (Walstra *et al.*, 2006).

**Homogenizer**

Homogenizers are high pressure, reciprocating pumps each having a sanitary head upon which the homogenizing valves are mounted. Positive displacement pumps are necessary to supply the feed to the valve. Homogenizers generally have either three or five pistons, driven from a crank shaft through connecting rods (Ahmad, 2012).

This is a machine which causes the sub-division of fat globules. It consists of a high pressure through a narrow opening between the homogenizing valve and its seat; the fat globules in the milk are thereby sub-divided into smaller particles of more uniform size. The homogenizing valve is held down by a heavy pressure spring against the seat of the valve. The valve and its seat are made of extremely hard material (e.g. stelite) and the contact faces are carefully ground so that the valve sits accurately on its seat. Homogenizers are either single stage or double stage (De, 2001).

**Operation of the Homogenizer**

Homogenizers of the common type consist of a high-pressure pump that forces the liquid through a narrow opening, the so-called homogenizer valve.

The disintegration of the original fat globules is achieved by acombination of contributing factors such as turbulence and cavitation. This is accompanied by a four- to six-fold increase in the fat/plasma interfacial surface area. 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 (Figure 1).

Homogenization is done by forcing all of the milk at high pressures through a narrow slit, which is only slightly larger than the diameter of the globules themselves. The velocity in the narrowest slit can be 100 to 250 m/s. This can cause high shearing stresses, cavitation and micro-turbulence. The globules become deformed, then become wavy and then break up (Ahmad, 2012).

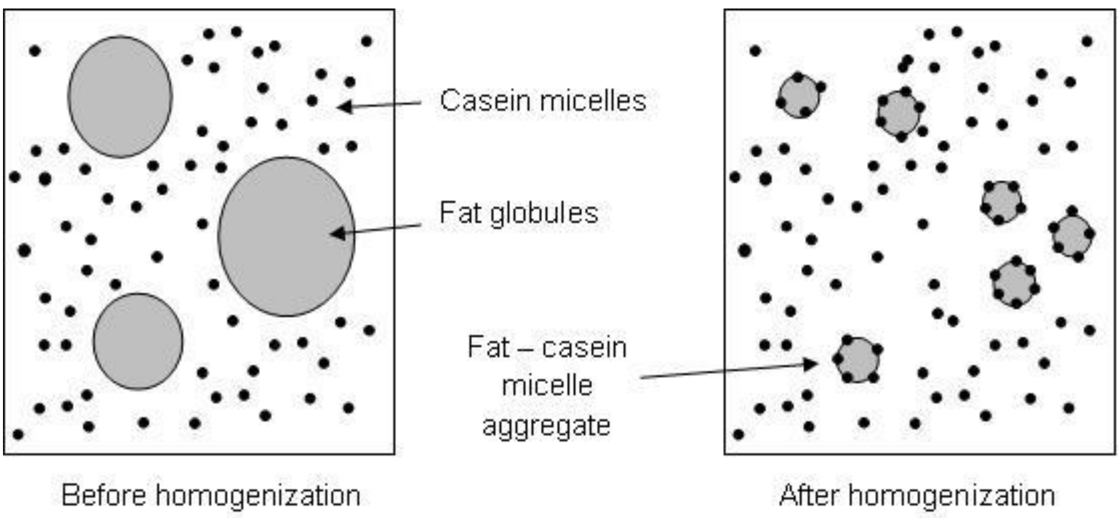


**Figure 1**. Effect of homogenization on fat and casein fractions in fluid milk

**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 onthe homogenising 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 (Bylund, 2003).

**The homogenizer in a processing line**

In general, the homogenizer is placed upstream, *i.e.* before the final heating section in a heat exchanger. 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 with special piston seals, sterile steam condenser and special aseptic dampers.

However, downstream location of the homogenizer is recommended for indirect UHT systems when milk products with a fat content higher than 6-10 % and/or with increased protein content are going to be processed. The reason is that with increased fat and protein contents, fat clusters and/or agglomerates (protein) form at the very high heat treatment temperatures. These clusters/agglomerates are broken up by the aseptic homogenizer located downstream (Bylund, 2003).

**Full stream homogenization**

Full stream or total homogenization is the most commonly used form of homogenization of UHT milk and milk intended for cultured milk products.

The fat content of the milk is standardized prior to homogenization, as is the solids-non-fat content in certain circumstances, e.g. in yoghurt production.

**Partial homogenization**

Partial homogenization is used to save on energy and machinery. The milk is separated into skim milk and cream, and the cream is homogenized and mixed with the separated milk (Walstra *et al.*, 2006).

Partial stream homogenization means that the main body of skim milk is not homogenized, but only the cream together with a small proportion of skim milk. This form of homogenization is mainly applied to pasteurised market milk. The basic reason is to reduce operating costs. Total power consumption is cut by some 80% because of the smaller volume passing through the homogenizer (Bylund, 2003).

**Single-stage and two-stage homogenization**

Homogenizers may be equipped with one homogenising device or two connected in series, hence the names single-stage homogenization and two-stage homogenization.

In both single-stage homogenization and two-stage homogenization, the whole homogenization pressure (P1) is used over the first device. In single-stage homogenization, the back pressure (P2) is created by the process. In two-stage homogenization the back pressure (P2) is created by the second stage. In this case the back pressure can be chosen to achieve optimal homogenization efficiency. Using modern devices, the best results areobtained when the relation P2/P1 is about 0.2. The second stage also reduces noise and vibrations in the outlet pipe (Bylund, 2003).

Single-stage homogenization may be used for homogenization of products with high fat content demanding a high viscosity (certain cluster formation).

Two-stage homogenization is used primarily to reach optimal homogenization results and to break up fat clusters in products with a high fat content.

**Factors affecting Homogenization**

**1.Temperature of homogenization:** The milk should, at the time of homogenization, be at a temperature above the melting point of fat, viz., above 33$^0$C. This is because fat should be in the liquid state for proper sub-division. The enzyme lipase should be inactivated, preferably prior to homogenization or immediately afterwards. This can be achieved by heating the milk to a temperature of 55$^0$C. In routine practice, the milk is heated to 65-70$^0$C for homogenization. The danger zone for lipase activity, viz., temperature 38-49$^0$C, should be avoided during or after homogenization (De, 2001).

**2.Pressure of homogenization:** In a single stage, up to 6 per cent fat milk, usually 2000-2500 psi pressure is sufficient. Higher pressures may increase the tendency for the milk to curdle when cooked, due to the increased destabilizing effect on milk-proteins. For liquid products with more than 6 per cent fat, two-stage homogenization is needed to prevent fat clumping: 2000 psi at the first stage and 500 psi at the second stage (De, 2001).

**Effect of homogenization**

The effect of homogenization on the physical structure of milk has many advantages:

- 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 mouth feel
- Better stability of cultured milk products
- No formation of cream layer/plug
- Produces soft curd and is better digested; hence recommended for infant feeding

However, homogenization also has certain disadvantages

- Increased cost of production
- Increased sensitivity to light influences, leading to taste defects such as “rancid”, “soapy” or “oxidized”.
- 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.
- Raw milk is unsuitable for homogenization as the flavour deteriorates rapidly due to lipase action.

**Homogenization efficiency**

Homogenization must always be sufficiently efficient to prevent creaming. The result can be checked by determining the homogenization index, which can be found in the manner described in the following example:

A sample of milk is stored in a graduated measuring glass for 48 hours at a temperature of 4-6$^0$C. The top layer (1/10 of the volume) is siphoned off, the remaining volume (9/10) is thoroughly mixed, and the fat content ofeach fraction is then determined. The difference in fat content between thetop and bottom layers, expressed as a percentage of the top layer, isreferred to as the homogenization index. The index for homogenised milk should be in the range of 1 to 10 (Bylund, 2003a).

**Determination of creaming Index**

Low creaming index is an indication of good homogenization. Sterilized milk may be graded as under for the quality of homogenization, as described in BIS, (1981):

| Quality of homogenization | Creaming index |
|---|---|
| Excellent | Upto 10 |
| Good | 11 to 20 |
| Fair | 21to 30 |

| | |
|---|---|
| Bad | Over 30 |

**Procedure**

50 ml of milk sample at 20±1$^{0}$C added in three glass tubes (with outside diameter 24 mm, length with stopper 245 mm and graduated from 0 to 50 ml). Centrifuge for 15 min at 1000 rev/min. Using separate pipette, take 5 ml sample from upper part of tubes, carefully taking the cream that adheres to walls o the tube and transfer into a container (sample I). The empty the three tubes into a separate container (sample II). Measure the fat content of sample I and II by Gerber method.

Calculation

$$Creaming\ index = \frac{A - B}{B} X\ 100$$

Where,

A= Fat content of sample I, and

B= Fat content of sample II

**Farrall Index**

The homogenization efficiency of milk also analysed using the Farrall index method as outlined by Trout (1950). It is a microscopic method. A Farrall index ranging from 5 to 7 implied "excellent" homogenization efficiency. Index exceeding 10 indicates inefficient homogenization (Patel, 1999).

**References**

Ahmad T (2012). Homogenization-Centrifugation. In: Dairy Plant Engineering and Management. 10$^{th}$ chapter. 8$^{th}$ Edn. Kitab Mahal, Allahabad, India. pp. 237-247.

Bylund G (2003). Homogenizers. In: Dairy Processing Handbook. Chapter 6.3. Teknotext AB (Ed.) Tetra Pak Processing Systems ABS-221 86 Lund, Sweden. pp. 115-122.

Bylund G (2003a). Pasteurized Milk Products. In: Dairy Processing Handbook. Chapter 8. Teknotext AB (Ed.) Tetra Pak Processing Systems ABS-221 86 Lund, Sweden. p217.

De S (2001). Special Milks. In: Outlines of Technology. 1$^{st}$ Ed., Oxford University Press- New Delhi. pp 93-97.

Bureau of Indian Standards (1981). Hand book of Food Analysis. Part XI, Dairy Products. Manak Bhawan-9, Bahadur shah Jafar Marg, New Delhi, India. p. 115.

Miller G D, Jarvis J K and McBean L D (2007). The Importance of Milk and Milk Products in the Diet. In: Hand book of Dairy Foods and Nutrition. 3rd Edn. Chapter 1. National Dairy Council. Taylor & Francis Group, LLC. Boca Raton London New York. p. 21.

Patel H G (1999) Process standardization for manufacture of *Basundi*. Pd.D., Thesis. S M C College of Dairy Science, Anand Agricultural University, Anand, Gujarat, India.

Trout G M (1950). Homogenized Milk. A Review and Guide, Michigan State College Press, Michigan.

Walstra P, Wouters J T M and Geurts T J (2006). Homogenization. In: Dairy Science and Technology. Second Edn. Taylor & Francis Group, LLC. Boca Raton London New York. p. 279