9 Homogenization

Homogenization of milk causes disruption of milk fat globules into smaller ones. The milk fat–plasma interface is thereby considerably enlarged, usually by a factor of 5 to 10. The new interface is covered with milk protein, predominantly micellar casein.

9.1 OBJECTIVES

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. All in all, prevention of partial coalescence usually is the most important purpose of homogenization; a cream layer *per se* is not very inconvenient, because it can readily be redispersed in the milk.
3. *Creating desirable rheological properties:* Formation of homogenization clusters (Section 9.7) can greatly increase the viscosity of a product such 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 participate in the aggregation of the casein micelles.
4. *Recombining milk products:* Recombination is discussed in Section 16.3. At one stage of the process, butter oil must be emulsified in a liquid such as reconstituted skim milk. A homogenizer, however, is not an emulsifying machine. Therefore, the mixture should first be preemulsified, for example, by vigorous stirring; the formed coarse emulsion is subsequently homogenized.

9.2 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. Figure 9.1A gives a flowchart; for the moment, we will leave the second stage aside. The principle of operation of the valve is illustrated in Figure 9.1B. The valve has been dimensioned in such a way that the pressure in the valve (p_2) equals about zero at a reasonable homogenizing pressure ($p_{hom} = p_1$), such as $p_{hom} > 3$ MPa. Actually, p_2 tends to become negative, which implies that the liquid can start boiling; in other words, cavitation can occur. (Cavitation is the formation and sudden collapse of vapor bubbles caused by pressure fluctuations.)

During homogenization, the liquid upstream of the valve has a high potential energy. On entering the valve, this energy is converted to kinetic energy (according to the rule of Bernoulli). The high liquid velocity in the very narrow opening in the valve leads to very intense turbulence; the kinetic energy of the liquid is now dissipated, that is, converted to heat (thermal energy). Only a very small part of the kinetic energy, generally less than 0.1%, is used for globule disruption, that is, for conversion into interfacial energy. The net amount of energy dissipated per unit volume (in $J \cdot m^{-3}$) numerically equals p_{hom} (in $N \cdot m^{-2}$). If the specific heat of the liquid is c_p, the temperature rise as caused by homogenization will be p_{hom}/c_p. For milk, $c_p \approx 4 \times 10^6$ $J \cdot m^{-3} \cdot K^{-1}$; thus $\Delta T \approx p_{hom}/4$ if p_{hom} is expressed in MPa, and T is expressed in K.

The passage time of the liquid through the valve is very short, generally less than 1 ms. As a result, the average power density $\bar{\varepsilon}$ (which is the energy

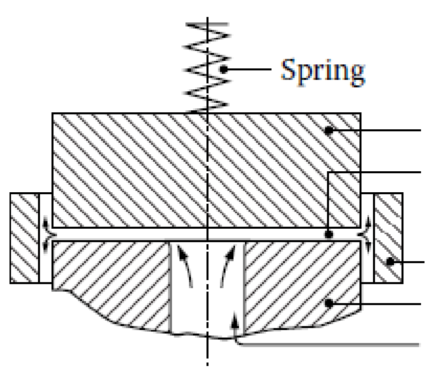

FIGURE 9.2 Cross section of a flat homogenizer valve (near to scale, but the spacing between valve and seat is much smaller than drawn).

Factor affecting homogenization / fat globule size

- Fat content in milk
- Quantity of milk
- Temperature
- Homogenization pressure
- Type and performance of homogenizer
- Stages of homogenization