Paper 7: Technology of Milk and Milk Products

Module no. 6: Cream Separation in Dairy Industry

Introduction

Milk from the cattle contains a number of large and small butter-fat particles held in suspension. They are lighter in weight than the other parts of the whole milk. When milk is left standing, the milk portion low in fat (like skim milk) gradually settles at the bottom because it is heavier. On the other hand, butter-fat surfaces to the top through buoyancy. When the bulk of the fat globules find their way to the top, they constitute ó*Malai*ô (like cream), which consists largely of the fat particles.

Why separate cream from milk?

All the commercial available cream is obtained by mechanical separation. Separation of whole milk produces two fractions. The fraction, which contains fat in highly concentrated form, is called cream while the other fraction, which is a non-fat fraction, is termed as skim milk. The fat content of cream can be varied, depending on the need, from 20 to as high as 80% fat. Cream is used for making ice cream, butter, ghee and Anhydrous milk fat in the dairy plants. Some portion of cream is utilized for dressing the product in bakery and coffee making. Cream can also be sold as ómarket creamô such as Table/coffee cream, whipping cream, single cream, double cream, cultured cream, etc.

History of Cream separator

In 1877, the attention of Dr. De Laval, a young Swedish engineer, was called to the subject of centrifugal cream separation, and eventually he evolved the first continuous cream separator, which discharged the cream and skim-milk separately while the milk was being fed into the machine; all these took place without stopping the machine or interrupting the operation. Thereafter, modifications were carried out and now we have the ôTri-purpose cream separatorô which performs three important functions viz., clarification of milk, separation of whole milk and standardization of milk. Next came the ôHermetic cream separatorô, which was made air-tight through use of seals so that air was excluded during separation which improved the óskimming efficiencyô. Still more recent was the introduction of óSelf-delsudging cream

separatorô which allowed the operators to run the cream separator for very long hours of operation without stopping the machine for removal of the ósludgeô, which otherwise decreases the flow as well as adversely affects óskimming efficiencyô.

Principle of centrifugal cream separation

On application of centrifugal force, the skim-milk particles, being heavier, were forced against the bottom side of each disc, traveling toward the periphery of the bowl, while the cream particles moved along the upper side of each disc toward the center of the cream separator. In this way there was no conflict of cream and skim-milk, for easy discharge through two different outlets placed one over the other.

Cream separation is a phenomenon by which the milk is separated in to cream and skim milk by centrifugal force. The centrifugal force is thousand times greater than gravitational force. The milk enters the rapidly revolving bowl of the separator. It is then acted upon by centrifugal force. The inflow of milk is channelized to the outer wall of the bowl and fills it from outside towards the centre. The centrifugal keep on continuously and act upon to partition the serum and cream. The milk serum has higher specific gravity (1.036) than that of fat (0.9). Obviously serum is thrown towards the outer periphery and channelized to skim milk outlet, while the cream is channelized to the central core and forced out through cream outlet.

In the mechanically operated cream separator, the separation of fat is achieved by application of the centrifugal force. The centrifugal force acting on the system is about 3000-6000 times greater than the gravitational force. Hence the separation of fat, as governed by the Stokeôs law, is faster than the gravity separation method. Fat globules of smaller size separate at 6500 times faster in a centrifuge rotating at 5400 rpm than compared to under gravity. The Stokeôs law as applied to centrifugal separation process is expressed by the following equation:

$$\nu = \frac{2r^2 (ds\text{-}df) \times 4\pi^2 RN^2}{9\eta}$$

Where,

ν = Velocity of movement of fat globule

r = Radius of fat globule

ds = Density of skim milk

df = Density of fat

N = Speed of bowl (rpm)

R = Distance of fat globule from the axis of rotation

N = rotational frequency in revolutions/sec.

η = Viscosity of skim milk

Generally the milk is preheated to 37-50^{o}C before separation for optimum results. This makes the process easier and more efficient as the warm milk is less viscous than the cold milk. In-flow of milk is regulated by adjusting the milk inlet valve to the separator. As the disk stack revolves the cream moves towards the center of the bowl and the skim milk is directed outwards towards periphery by the centrifugal force. Under normal conditions it produces skim milk and cream in the ratio of 90:10; variation in cream richness will vary these proportions.

Cream separator parts

The modern centrifugal cream separator consists of the following main parts:

- A bowl which can be rotated at a high speed (5000-6000 rpm) by means of suitable gears and power transmission mechanism.
- Arrangement for supplying milk to the bowl.
- Removing the cream and skim milk.
- Driving the machine.

Parts of a Cream Separator Bowl and accessories

Rubber ring/Gasket: It fits in the bottom of the bowl base and makes the bowl leak proof when bowl hood is placed on its top.

Bowl base: This houses the milk distributor as well as all of the discs on it. It also has got openings at the bottom of the spindle attached to the body at the centre, from where the milk being fed flows through.

Milk Distributor: It distributes the milk into the three notches present at the bottom periphery.

Bottom disc: It is different from the other discs. It has rivets/caulks on the outer as well as on inner surface; all the discs have three holes in them. The discs are also known as separating disc. The discs are conical in shape (cone angle approx. 60^{o}) with holes in them to channel milk through.

Intermediate discs: They are several in numbers. They are similar to the bottom disc except that these discs do not have rivets on its bottom side. They have rivets on the top side of disc only. The number of discs decides the capacity of the cream separator machine.

Top disc: It is also referred to as ôDividing discô since the distinction between the skim milk and cream outlet is made possible by this disc. The disc has a passage for the cream to come out from its neck. During separation the cream collected near the axis of the bowl, oozes out from the cream outlet. This disc has got a screw at its neck which can be manipulated to lower or increase the fat content of cream.

Bowl hood: It fits over the top and covers the entire bowl parts and fits into the bowl base at the bottom.

Bowl nut: It is fastened onto the bowl hood using a spanner. This keeps the entire assembly of bowl intact and maintains proper passage between each disc, if properly tightened.

Skim milk spout: The skim milk from the bowl moves between the top disc and inside wall of the bowl hood. Finally, the skim milk passes out through the space provided between the top disc and bowl hood, which connects with the skim milk outlet.

Cream spout: The cream coming out from cream screw located in the top disc is collected in the cream spout and is let out to a container.

Other parts of the Cream Separator

Supply can: It holds the milk to be separated.

Faucet: It is used for adjusting and even to start/stop the flow of milk from the supply can into the bowl.

Float: It allows only a definite quantity of inflow of milk into the bowl, housed in a regulator.

Type of Cream Separators

There are basically three types of cream separators. These are as follows:

Open design: The open design is the simplest and used only in small capacity machines. Milk enters through a stationary feed tube which projects at least halfway down the depth of the rotating bowl. At the point of entry, the milk is moving at high speed, but with zero rotation and accelerates to the speed of the bowl. Here, the chances of entrapment of air are more, adversely affecting the skimming efficiency.

Semi-enclosed (paring disc) design: The entry of milk into such separator is same as for open type. These separators are fitted with static paring disc (centripetal pumps) resembling the rotor of a centrifugal pump. In operation, each of the separated liquid products (cream, skim milk) rotates at the same speed as the bow. Rotational energy is converted into pressure and the products leave the separator with a pressure as high as 5 kg/cm^2.

Hermetic (air-tight) design: Entrainment of air in milk inhibits separation. The development of such hermetic separator is based on the provision of hermetic seals which effectively isolates the separator from the atmosphere. In contrast to open or semi-open separators, the milk is introduced into the separator from below via a hollow spindle in the central shaft. The milk gradually reaches the rotational speed of the separator in contrast to the open types when rapid acceleration takes place on reaching the distributor. Efflux of cream and skim milk takes place through hermetic seals under a moderate pressure. The effectiveness of a hermetic separator depends on the whole milk being air-free as it is fed to the separator.

Self-desludging Cream Separators

Some solid material (called sludge comprising of dirt, cellular material from blood and bacteria) collects on the outside of the spinning bowl and, if left, inhibits the efflux of skim milk and stops the separation process. The limited running time of separators led to the development of a mechanism for automatically removing the sludge without interrupting the operation of the machine. Such separators are called óself-desludgingô or óself-cleaningô separators. Slots are cut in the outside of the bowl, and are normally kept closed by a sliding bowl bottom which is elevated by the hydraulic pressure of running water in a reservoir underneath. When desludging is required, an hydraulically operated valve opens up and the reservoir drains to allow the bowl bottom to fall, thus opening the slots. The outward pressure on the sediment forces it outwards into an outer bowl. The action is very rapid and the slots being open for less than $1/5^{th}$ of a second. Discharges are normally programmed to occur at regular, pre-determined intervals.

Cold milk separators: Such separators are available that operate at feed temperature of 4-5^{o}C. These allow separation of milk as it is received at the factory, and although fat losses to skim milk are somewhat higher, they allow substantial savings in energy and capital costs. Such separators are especially beneficial for obtaining better whipping properties in ówhipping creamô since more phospholipids are retained in the separated cream, than those obtained with ówarm milk separatorô. The alteration in such separator is a wider disc spacing (approx. double) than conventional one to allow adequate flow of the more viscous cold cream.

Factors affecting separation and 'skimming efficiency'

The factors that dictate the efficient separation process and óskimming efficiencyô (i.e. minimum loss of milk fat with skim milk) are as follows:

Temperature of separation: Separation temperature of 45-55^{o}C has been found to give good results for a warm milk separator. Employing higher temperature ensures milk fat is in liquid condition, decreasing the viscosity of milk. Moreover, the difference in the density between fat and serum widens with rise in temperature.

Bowl speed: Skimming efficiency is quite adequate at moderate speeds of 4000-5000 rpm. It is important to maintain the bowl speed during operation. Hence, momentary deceleration that takes place during desludging operation should be restricted to minimum time period, since it can affect separation efficacy adversely.

Space between the discs: Theoretically, smaller the space between discs, the higher should be the efficiency of separation. However, it is important to maintain laminar flow conditions to obtain maximum efficiency of separation. For narrow spacings (< 0.2 mm), separation efficiency is independent of disc spacing.

Flow of milk through the separator: Better efficiency can be achieved with lower input feeds, as milk has more time within the separator to allow fat globules to segregate. However, the flow should not be too low to allow air entrainment, which adversely affects separation efficiency. In practice, as high a flow rate as possible should be aimed for, keeping into mind the manufacturerôs directives.

Condition of the milk: The factors which affect fat globule size distribution are breed of animal, stage of lactation, temperature history of the milk and handling of milk through agitation, pumping, aeration, etc. Smaller fat globule size of fat would tend to escape the centrifugal force (i.e. < 1 μm). The milk to be fed to a hermetic separator should be free from air entrapment as far as possible.

Condition of the cream separator: The cream separator parts (especially discs) should be handled properly especially during cleaning and keeping after cleaning so as to avoid any scratches on it. The cream separator assembly has to be fastened to the base in such a manner that there is no vibration during the operation (rotation).

Manipulating the richness of cream

There are provisions in cream separator to vary the fat content of cream, as desired by the operator. The cream may be separated to obtain as low as 25% fat to as high as 80% fat (i.e. plastic cream). The fat content of cream in a semi-enclosed separator may be controlled by

adjusting the back pressure of both the skim milk and the cream, although control is simplified by fitting an automatic control valve to the skim milk outlet pipe. Sufficient back pressure on the skim milk outlet usually results from downstream equipment such as a heat exchanger.

Conclusions

Cream separation is a very important processing step in dairy industry. Surplus fat from whole milk can be extracted in the form of cream, which can then be used to prepare fat-rich products like butter, ghee, anhydrous milk fat. The fat losses during cream separation need to be looked into and adequate precautions exercised will help in obtaining high ôskimming efficiencyô