Unit V – Topic II
CREAM SEPERATION – PRINCIPLES & ITS TYPES

Introduction

When milk is allowed to stand un-disturbed for some time, an upward motion of the fat globules takes place, leading to the formation of a surface layer on milk in which the percentage of fat is considerably increased. This upward motion of fat based on the fact that milk fat is lighter than the skim milk portion. At 16°C, the average density of milk fat is 0.93 and of skim milk is 1.0404. Therefore when milk (a mixture of fat and skim milk) is subjected to either gravity or centrifugal force, the two components, cream (fat-rich portion of milk) and skim milk (reduced-fat portion of milk), by virtue of their differing densities, separate from each other.

Purpose of cream separation

1. To obtain a fat-reduced or fat-free milk

2. To concentrate milk fat for the production of high-fat products

3. To standardize the fat content of milk

4. To recover fat from milk

The cream separation process has significant economic importance, as it controls the efficiency of the fat separation. The key objective is to manufacture skim milk with the lowest possible fat content, which corresponds to good separation efficiency. Knowledge of the basics of the fat separation is important for an optimal de-creaming process. Cream separation is based on the facts that fat exists in poly-disperse system in an emulsified state and that the specific density difference between milk fat (p = 0.93 g/cm3) and skim milk (p = 1.035 g/cm3) is fairly large. Basically two processes for fat separation are possible, natural de-creaming and separation with machines. Natural creaming has no industrial significance.

4.2. Separation Processes

There are two methods of cream separation viz.,

· Gravity Method

· Centrifugal Method

4.2.1. Cream separation by gravity method

When milk is allowed to stand undisturbed for some time, there is a tendency of fat to rise. The velocity or rate at which the fat globules rise is given by the following equation, which is known as Stoke's Law:

V = (2/9) * Gr2 * (ds - df) / N

Where,

V = rate of rise of fat globule in centimeter per seconds

r = radius of fat globule

G = Force of gravity (981 dynes)

η= Viscosity of skim milk

ds = density of skim milk

df = density of fat globule

From, Stoke's Law it is observed that theoretically velocity increases with:

a. Increasing radius of fat globule,

b. Increasing difference in densities of skim milk and fat

c. Decreasing viscosity of skim milk

However, in practice the factors affecting the rate of rise of fat in gravity method of separation are:

- Size of fat globules: As the size of fat globules increases, the rate at which fat rises also increases. Larger fat globules rise faster than smaller ones. Thus, in buffalo milk gravity creaming occurs faster due to the larger fat globules than those in cow milk.
- Temperature: As temperature increases, viscosity decreases.
- Clumping: A clump or cluster acts like a single globule in so far as movement through skim milk is concerned. Thereby the effective 'r' is increased, which in turn increases velocity, as shown below

Effect of size of fat globules on its rate of rise	
Diameter of fat globule or cluster (μm)	Rate of rise (mm/h)
3.2 41.0	1.26 242

There are five various methods for separating the cream using gravity method:

i. Shallow Pan Method: Milk is allowed to stand in a pan of 10 cm depth and 45-60 cm diameter at 7°C for 24 h. During this time, cream rises to the surface.

ii. Deep Pan Method: Milk is allowed to stand in pan of 20" depth and 8 to 12" diameter at 10°C for 24 h. These tall cans have glass on one side of can and a faucet placed near the bottom. Skim milk is drawn through the faucet.

iii. Water Dilution Method: Milk is diluted with water and allows standing for 12 h at 37.7°C temperature. Water would make the milk less viscous, thus facilitating the rising of the fat globules.

iv. Scalding Method: Heating and cooling of milk slowly causes the formation of cream layer at surface of milk

v. Jersey Creamery Method: Milk is heated to 40°C using hot water in the jacketed vat and then cool to 10°C using chilled water in place of hot water in the jacket of Vat. The cream will be separated rapidly on cooling, immediately after heating the milk, by increasing the difference in densities of milk fat and serum.

Gravity method being very slow, it is no longer used commercially for cream separation.

4.2.2 Cream separation by centrifugal method

Milk is fed to machine through flow regulator. Milk comes to regulating chamber from milk basin by milk faucet. When milk enters the revolving bowl through milk regulator of machine, it is subjected to a gravity and centrifugal force. Centrifugal force is about 3000 to 6000 times more than gravitational force. Fat (0.9) and skim milk (1.037) are varying in their specific gravity. When fat and skim milk are subjected to centrifugal force, the difference in density affect the fat and skim milk i.e. (heavier Portion) affected more intensely than the fat (lighter portion). So skim milk is forced to the periphery and fat portion (cream) moves towards the centre. Cream and skim milk forms separated vertical walls within the bowl and goes out through separate outlets near the axis of rotation. The cream outlet is at higher level than skim milk outlet. The rate or movement of a fat globule in machine is estimated by following Stoke's equation.

$$V = r2 *((as - df) / n) * N2 * R * K$$

Where,

V = rate of movement of a single fat globule

r = radius of fat globule

ds = density of skim milk

df = density of fat

N = Revolution per minute of bowl

R = Distance of fat globule from axis of rotation.

K = Constant

N = Viscosity of skim milk

It will be seen from the above that the speed (rate) of cream separation is increased by:

· greater radius of the fat globule

· greater difference in density between skim milk and fat

· greater speed of the bowl

· greater size of the bowl

· lower viscosity of skim milk

4.3 Characteristics of gravity and centrifugal methods

Gravity and centrifugal cream separation compare as shown below:

Particulars	**Gravity Method**	**Centrifugal Method**
Nature of force causing Separation	Gravitational force	Centrifugal force
Speed of separation	Extremely slow	Practically instantaneous
Direction of movement of fat and skim milk particles	Vertical	Horizontal
Bacteriological quality of cream or skim milk	Low	High
Fat % of cream	10-25% only	18-85 %
Skim milk	0.2 % above	0.1 or below
Scale of operation	Small	Large

Fat % recovered in cream	not more than 90	99-99.5

When the centrifuge bowl, filled with liquid, is put into rotation, the liquid surface level is lowered at first, and a rotation paraboloid is created. With an additional increase in revolutions, the surface level is lowered to the rotation axis and then rises in parallel. At corresponding high revolutions in the bowl a liquid ring is created. Imagine particles of skim milk and fat with the same particle diameter in a rotating liquid, the resulting force acts toward the inside. It corresponds to the force, according to motion theory, which is required to accelerate a body moving in a circle and maintain it in an orbit. This force is called the centripetal force (Fep); it is opposite to the centrifugal force Fef. In this example, the skim milk particles enter a phase in which the forces are in balance, as Fep = Fef. Because of their lower specific density, less centrifugal force is exerted on fat particles of equal size, resulting in Fep > Fef. The difference in force here is very small, so the fat particles migrate slowly toward the inside.

Cream Separators in Dairy Industry

There are two basics types of separators depending on their mode of operation

1. Hand operated and

2. Power driven

The power driven cream separators are further classified as:

1. Open-bowl separator

2. Semi-closed or semi-hermatic separator

3. Closed bowl or Hermatic separator

4. Self-desludging separator

5.2.1 Open bowl separators

These are characterized by an open top milk inlet and pressure less, skim milk and cream outlets open to atmosphere. The main parts of a cream separator are: Supply can/milk basin, milk faucet, regulating chamber with float, cream screw and skim milk screw, cream spout and skim milk spout, Separator bowl (consisting of bowl shell, milk distributor, discs and rubber ring), spindle, gears, crank handle and bowl nut. The base consists of horizontal, vertical drive prime consisting of electrical motor, centrifugal pump, drive shaft with a worm wheel. The vertical drive prime consists of a shaft known as bowl spindle. At the top of the bowl spindle a separator bowl is mounted. Power is transmitted

from worm to a worm gear connecting to the spindle. Discs, shaped as cones, are stacked in into disc assembly and placed in the bowl shell.

Milk is introduced on to vertically aligned distribution holds in discs at a certain distance from edge of discs from start. Under influence of centrifugal force the particles and droplets of milk will begin to settle either outward or inward in separation channels radially according to their densities related to continuous medium. There are up to 120 discs are arranged one over other and, angle of inclination is 45-60° to the horizontal. Outward diameters of discs are between 200-300 mm. Disc are generally made up of stainless steel and wall thickness will be around 0.4 mm. The space between discs varies the flow through narrow gaps in laminar flow ensuring the separation. Larger gaps between discs are necessary if there is a danger of clogging. Disc bowls used have an rpm of 5500-6000 and at mass rate flow of 20,000 liters per hour. The space between the discs must be increased if the cream of high fat % content is to be obtained. In a normal cream separator, clogging can expected if fat in cream is above 55%-60%. The required high fat content can be obtained only after subjecting the cream again to fat separation. Suppose milk is to separate below 25°C then the distance between the discs must be increased due to higher viscosity. The number of discs in cream separator relates to its capacity.

In gravity fed type cream separator, a supply tank is mounted on bowl unit. It consists of two separate outlets one for cream and another for skim milk. To handle small capacity units, a screw arrangement is provided on cream line just at the outlet point. This cream screw helps manipulate the flow rate of cream.

Precautions for Efficient Working of open bowl separator

1. Proper assembling and fitting of different parts

2. Proper lubrication in machine

3. Quality of milk to be separated

4. Temperature of milk (30-40°C)

5. Speed of the bowl

6. Uniformity in speed of bowl

7. Uniform supply of milk

8. Sanitary condition of machine

The disadvantage with this separator is that lot of excess foaming in skim milk.

5.2.2 Semi-closed separators

These are the separators with milk feed at atmospheric pressure and paring discs located in the cream and skim milk outlets which discharge into closed pipes at elevated pressure. The milk inlet is so designed as to prevent any air getting into the milk stream. This helps to prevent foaming in cream and skim milk.

This paring disc converts rotational energy of milk and cream to a linear kinetic energy. They are constructed like the impeller of centrifugal pump and dipped in rotating ring of liquid. The liquid is made to flow with a high peripheral speed into channel openings of the paring discs. These discs are fixed to the feed pipe. The liquid enters horizontally along spiral channels, which are divided, and flows vertically through the discharge channel in the shaft of the paring disc. Here the kinetic energy is converted into peripheral energy and 2.5-5 bar pressures can be generated depending on the rotational speed and diameter of paring disc. The generated pressure can be used to push the exiting cream and skim milk through variable flow. Restrictive devices and outlets can be used to generate back pressures which can control flow so that a fairly accurate control of fat content is feasible.

5.2.3 Closed bowl or hermetic separators

In these separators, milk inlet and the cream and skim milk outlets are all connected to closed pipe lines. The milk is transferred in a closed pipeline under pressure, which is mostly flow controlled. This design is normally used for self-cleaning (self-desludging) separator; i.e., the dirt is discharged periodically without interruption of the process.
With closed separators incorporation of air is nearly totally excluded, which results in the following advantages:
(a) Gentle treatment of the milk in the bowl, as its entire volume is occupied by the liquid
(b) High skimming efficiency (up to 0.005% of fat in skim milk)
Closed bowl separators are usually provided with self desludging mechanisms

The separator shown in Figure 5.1 is also equipped with a self-cleaning bowl. The dirt (which is separated from the milk) is collected in a bowl (which is conical to the outside) and is ejected periodically through ports. This permits the separator to be included in a CIP circuit without requiring time for disassembly. The operating time is independent of the sludge container capacity which permits a multi shift continuous operation.

5.3 Construction and Working Principle of Cream Separator Bowl

Whole milk is fed via the central pipe to the distributor at the bottom of disc stack and is subjected to rotation. The distributor serves as the base for the assembly of 110-130 discs. The coarse dirt particles settle down in the conical bottom part, i.e the sludge space. The milk flows upwards through the openings in the discs which are inclined towards the rotational axis. Thus, in the disc assembly, milk rises in channels, which are parallel to the rotational axis. The channels are formed by the rising holes of the disks and the milk is distributed in thin layers in the space between the disks, (distance of 0.5-1.0 mm). It is here that separation of milk into cream and skim milk takes place and at the same time the dirt is deposited as slime in the sludge space.

The heavier part of the liquid (skim milk) moves toward the outside, and the cream (which is lighter) moves in the opposite direction toward the center. In a slit between the bowl base and the disc inner rim, the cream rises to the cream retention chamber and goes into the cream outlet. After passing the disk space, the skim milk goes into the bottom part of the bowl and flows as a liquid ring into the slit between the bowl cover and the separation disks into the skim milk chamber. The separator discs serve to keep the skim milk separate from the cream. The skim milk is then directed via the paring disc of the skim milk chamber into the skim milk outlet. As explained above, the fixed separator discs have the effect of a rotating centrifugal pump, so that in each chamber the required pressure (for transporting the liquid) is generated.

5.4 Self Desludging Separator

Working principle of the self desludging separator bowl: The particulate impurities such as dust and cellular material from blood are dense solid material and hence collects on the outside of the rotating bowl. If left like that, it fill up the sludge space and inhibit the flux of skim milk there by hindering the separation process. Self desludging separator does not permit the accumulation of sludge in the bowl. Self Desludging ia a mechanism for automatically removing solid material without having to interrupt the operation of the separator. Slots are cut in the outside of the bowl and are normally kept close by a sliding bowl bottom which is elevated by hydraulic pressure of running water in a reservoir underneath. Intermittently hydraulically operated valve opens up and the reservoir drains to allow the bowl bottom to fall and this causes opening of these slots. The outward pressure on the sediment forces it into the outer bowl. The valve then closes to allow the reservoir to refill and the slots to close. The action is very rapid and it discharges at regular intervals, which depends upon the volume of sediment, space in the separation bowl and condition of the milk.