FE 483 FOOD ENGINEERING OPERATION LABORATORIES
Experiment: Cream Separation & Churning

Purpose of the experiment:
The aims are:
to separate cream from milk and to obtain milk fat by application of churning process.
to produce butter and pure fat using churning.

Centrifugation

Centrifugal separation is a process used quite often in the dairy industry. Some uses include:

1. clarification (removal of solid impurities from milk prior to pasteurization)
2. skimming (separation of cream from skim milk)
3. standardizing
4. whey separation (separation of whey cream (fat) from whey)
5. bactofuge treatment (separation of bacteria from milk)
6. quark separation (separation of quark curd from whey)
7. butter oil purification (separation of serum phase from anhydrous milk fat)

Principles of Centrifugation

The rate of separation in a suspension of particles by way of gravitational force mainly depends on the particle size and density. Particles of higher density or larger size typically travel at a faster rate and at some point will be separated from particles less dense or smaller. This sedimentation of particles, including cells, can be explained by the Stokes equation, which describes the movement of a sphere in a gravitational field. The equation calculates the velocity of sedimentation utilizing five parameters

$$V_o = \frac{(ds - dw)\, g\, D^2}{18\mu}$$

ds = density of solid, g/cm^3, dw = density of water, g/cm^3
g = gravity, 980 cm/s^2, D = particle diameter in centimeters
μ = molecular viscosity, g/(s)(cm), Vo = terminal settling velocity, cm/s
From the Stokes equation five important behaviors of particles can be explained:
1. The rate of particle sedimentation is proportional to the particle size.
2. The sedimentation rate is proportional to the difference in density between the particle and the medium.
3. The sedimentation rate is zero when the particle density is the same as the medium density.
4. The sedimentation rate decreases as the medium viscosity increases.
5. The sedimentation rate increases as the gravitational force increases.

Most particles are so small that gravitational force is insufficient to overcome the random molecular forces of particles to influence separation. Centrifugation, the name given to separation applications which involve spinning around an axis to produce a centrifugal force, is a way to increase the magnitude of the gravitational field. The particles in suspension experience a radial centrifugal force moving them away from the axis of rotation.2 The radial force generated by the spinning rotor is expressed relative to the earth's gravitational force and therefore is known as the relative centrifugal force (RCF). The RFC force acting on particles is exponential to the speed of rotation (defined as revolutions per minute; rpm).

Doubling the speed of rotation increases the centrifugal force by a factor of four. The centrifugal force also increases with the distance from the axis of rotation. These two parameters are of considerable significance when selecting the appropriate centrifuge. RCF is dependent on the speed of rotation in rpm and the distance of the particles from the center of rotation.

Centrifugal force (m/s2) = $r(\omega)^2$

r = radial distance from centre and ω = angular velocity (rad/s) and N is the revolution per minute

$$\omega = \frac{2\pi N}{60}$$

Now EFC is inserted into velocity of separation equation instead of g to fins the separation velocity under the effect of centrifugal force.

Separation

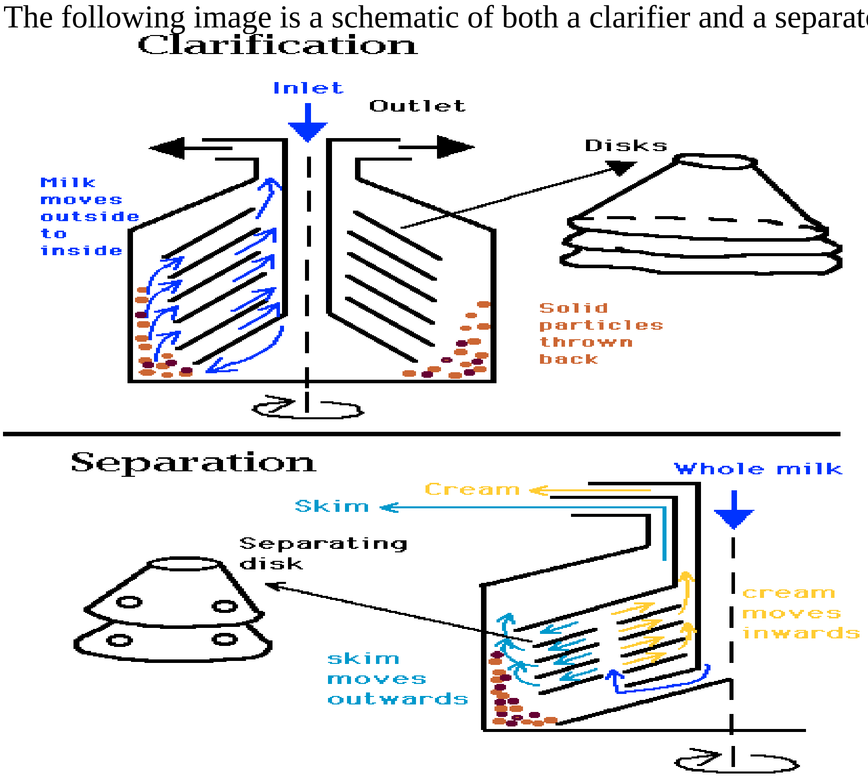
Centrifuges can be used to separate the cream from the skim milk. The centrifuge consists of up to 120 discs stacked together at a 45 to 60 degree angle and separated by a 0.4 to 2.0 mm gap or separation channel. Milk is introduced at the outer edge of the disc stack. The stack of discs has vertically aligned distribution holes into which the milk is introduced.

Under the influence of centrifugal force the fat globules (cream), which are less dense than the skim milk, move inwards through the separation channels toward the axis of rotation. The skim milk will move outwards and leaves through a separate outlet.

Clarification

Separation and clarification can be done at the same time in one centrifuge. Particles, which are denser than the continuous milk phase, are thrown back to the perimeter. The solids that collect in the centrifuge consist of dirt, epithelial cells, leucocytes, corpuscles, bacteria sediment and sludge. The amount of solids that collect will vary; however, it must be removed from the centrifuge.

The following image is a schematic of both a clarifier and a separator.



More modern centrifuges are self-cleaning allowing a continuous separation/ clarification process. This type of centrifuge consists of a specially constructed bowl with peripheral discharge slots. These slots are kept closed under pressure. With a momentary release of pressure, for about 0.15 s, the contents of sediment space are evacuated. This can mean anywhere from 8 to 25 L are ejected at intervals of 60 min. For one dairy, self-cleaning translated to a loss of 50 L/hr of milk.

BASIC PROCESSES FOR BUTTER PRODUCTION

Churning

Batch production

The cream is churned after temperature treatment and after souring where applicable. Butter is traditionally made in cylindrical, conical, cubical or tetrahedral churns with adjustable speed. Axial strips and dashers are fitted inside the churn. The shape, setting and size of the dashers in relation to the speed of the churn are factors that have an important effect on the end product. Modern churns have a speed range that permits selection of the most suitable working speed for any set of butter parameters. The size of churns has increased greatly in recent years. Churns of 8 000– 12 000 litres' capacity or more are used in large central creameries. Before transfer to the churn the cream is stirred and the temperature adjusted. The churn is usually filled to 40 – 50% to allow space for foaming.

Butter formation

The fat globules in cream contain both crystallized fat and liquid fat (butter oil). The fat crystals have to some extent become structured so that they form a shell, although a weak one, closest to the membrane of the fat globule. A foam of large protein bubbles forms when the cream is agitated. Being surface active, the membranes of the fat globules are drawn towards the air/water interface and the fat globules are concentrated in the foam. When agitation continues, the bubbles become smaller as the protein gives off water, making the foam more compact and thereby applying pressure on the fat globules. This causes a certain proportion of the liquid fat to be pressed out of the fat globules and some of the membranes to disintegrate. The liquid fat, which also contains fat crystals, spreads out in a thin layer on the surface of the bubbles and on the fat globules. As the bubbles become increasingly dense, more liquid fat is pressed out and the foam is soon so unstable that it collapses. The fat globules coagulate into grains of butter. At first these are invisible to the naked eye, but they grow progressively larger as working continues.

Working

Working takes place when the buttermilk has been drained off. The buttery grains are pressed and squeezed to remove the moisture between them. The fat globules are subjected to a high pressure and liquid fat and fat crystals are forced out. In the resulting mass of fat (eventually the continuous phase) the moisture becomes finely dispersed by the working process, which is continued until the required moisture content is obtained. The finished butter should be dry, i.e. the water phase must be very finely dispersed. No water droplets should be visible to the naked eye. The moisture content should be checked regularly during working and adjusted so that it complies with the requirements for the finished butter.

Vacuum working

Working at reduced air pressure is a method that is frequently used. The result is a butter that contains less air and it is therefore somewhat harder than normal. In vacuum-worked butter the air amounts to about 1% by volume as compared with 5 – 7% for normal butter.

Procedure: Measure the whole milk volume, density, fat content and solid-non-fat (SNF) amounts. Weigh the beaker which cream will be inserted in it. Warm the milk to 45^{o}C. Adjust the separator. Drop the milk into the separator; get the cream and skim milk. Weigh the cream to obtain amount of the cream. Measure the density, fat and SNF amounts of skim milk. Put all cream into churn and dilute with chilled water (around three times of the cream). Churn the mix around for 30-45 min. Stop the churning (generally bean sized fat globules formed during the churn). Take the globules into weighed beaker and get the amount of fat. Put the beaker over an electrical oven to melts the fat, and then leave the fat into refrigerator over night. Look at the fat separation and separate the milk fat by decantation.

Homework:

Calculate the amount of fat in cream, and milk fat using the data obtained during the experiment.

Derive the equation of sedimentation velocity of a fat globule in a centrifugal force field.

Calculate the efficiency of the separation.

The reports should contain purpose, introduction (not from this sheet), experiment, discussion, calculation, and the references.