BUTTER MANUFACTURE

(Butter and its principal constituents, Butter making process, Continuous flotation churn, Butter yield calculations)

Before, we start discussing about butter manufacture; let us have a understanding of some related milk products/ by products which often confuse us.

Butter. It is essentially the fat of milk. It is usually made from sweet cream and is salted. Salt-less (sweet) butters are also available.

Butter can also be made from acidulated or bacteriologically soured cream.

(Now a day, bacterial acidifying and heat treatment are more common.)

Milk fat. This is the lipid component of milk and milk-derived products. It is mostly comprised of triglycerides.

Butterfat. It is almost synonymous with milk fat; all fat components in milk that are separable by churning.

Anhydrous milk fat (AMF). This is the commercially prepared extraction of cow's milk fat, found in bulk or concentrated form (comprises of 100% fat, but not necessarily all of the lipid components of milk).

Butter oil. Synonymous with anhydrous milk fat.

Fig.9.1 Butter is liked by people of all ages and class

A more accepted definition of butter is as follows.

Butter is essentially a water-in-oil emulsion, comprising of more than 80% milk fat, but also containing water in the form of tiny droplets, perhaps some milk SNF, with or without salt (sweet butter).

An emulsion usually has two phases, viz. the continuous phase, the dispersed phase and there is also a supporting emulsifier. Milk is an emulsion of oil in water, whereas butter is an emulsion of water in oil.

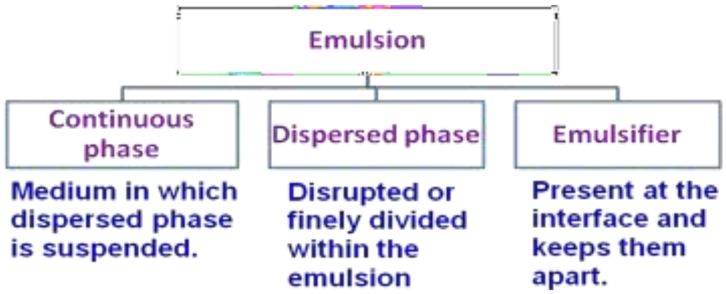

Fig. 9.2 Different phases (constituents) of an emulsion.

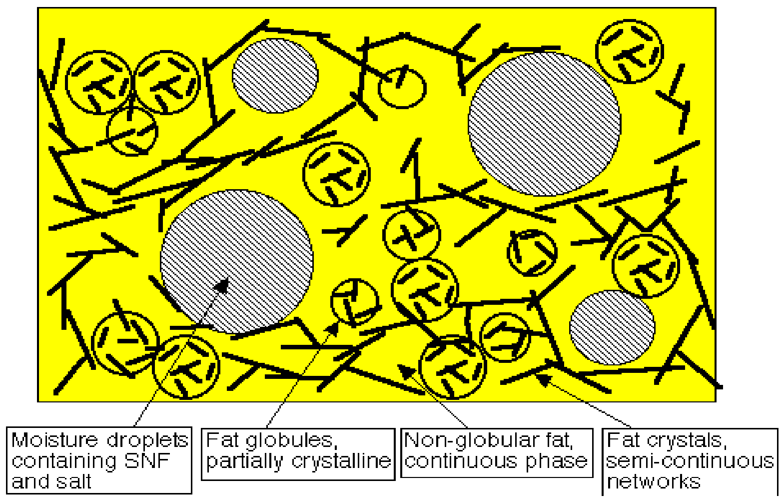

Fig. 9.3 Butter structure

Table 9.1 gives the major constituents of butter.

Table 9.1 Principal constituents of butter

Main Constituent	Normal salted butter	Indian butter
Fat	80 – 82 %	80.2%
Water	15.6 - 17.6%	16.3%
Salt	about 1.2%	2.5%
Protein, Ca, P	about 1.2%	1.0%

In addition, butter also contains fat-soluble vitamins A, D and E.

- As per PFA rules (1976), table /creamy butter should contain not less than 80% fat, not more than 1.5% curd and not more than 3% common salt.
- Butter should have a uniform color, be dense and taste clean.
- The water content should be dispersed in fine droplets so that the butter looks dry.

- The consistency should be smooth so that the butter is easy to spread and melts readily on the tongue.

BUTTER MAKING PROCESS

- Even in the 19th century, butter was still made from cream that had been allowed to stand and sour naturally.
- The cream was then skimmed from the top of the milk and poured into a wooden tub.
- Butter making was done by hand in butter churns.
- The natural souring process is, however, a very sensitive one and infection by foreign micro-organisms often spoiled the result.
- The commercial cream separator was introduced at the end of the 19^{th} century, the continuous churn was commercialized by the middle of the 20^{th} century.

Fig. 9.4 An old domestic butter churn

There are four types of butter making processes:

- Traditional batch churning from 25- 35% milk fat (mf) cream;
- Continuous flotation churning from 30-50% mf cream;
- The concentration process, whereby "plastic" cream at 82% mf is separated from 35% mf cream at 55°C and then this oil-in-water emulsion cream is inverted to a water-in-oil emulsion butter with no further draining of buttermilk;
- The anhydrous milk fat process, whereby water, SNF, and salt are emulsified into butter oil in a process very similar to margarine manufacture.

Fig. 9.5 shows the butter making process. The different unit operations are elaborated below. The butter milk is obtained as a by-product in the butter making process.

Collection of raw material and standardization

- The cream can be either supplied by a fluid milk dairy or separated from whole milk by the butter manufacturer.
- The cream should be sweet (pH >6.6, TA = 0.10-0.12 %), not rancid and not oxidized.
- The cream is cooled and kept in a transitional storage tank where the fat content is analyzed, and if necessary, adjusted to the desired value.

Pasteurization

- It is usually done at 82-88°C or more.

  (The high temperature is needed to destroy enzymes and micro-organisms that would impair the keeping quality of the butter.)

- The skim milk from the separator is pasteurized and cooled before being pumped to storage. It is usually concentrated and dried.

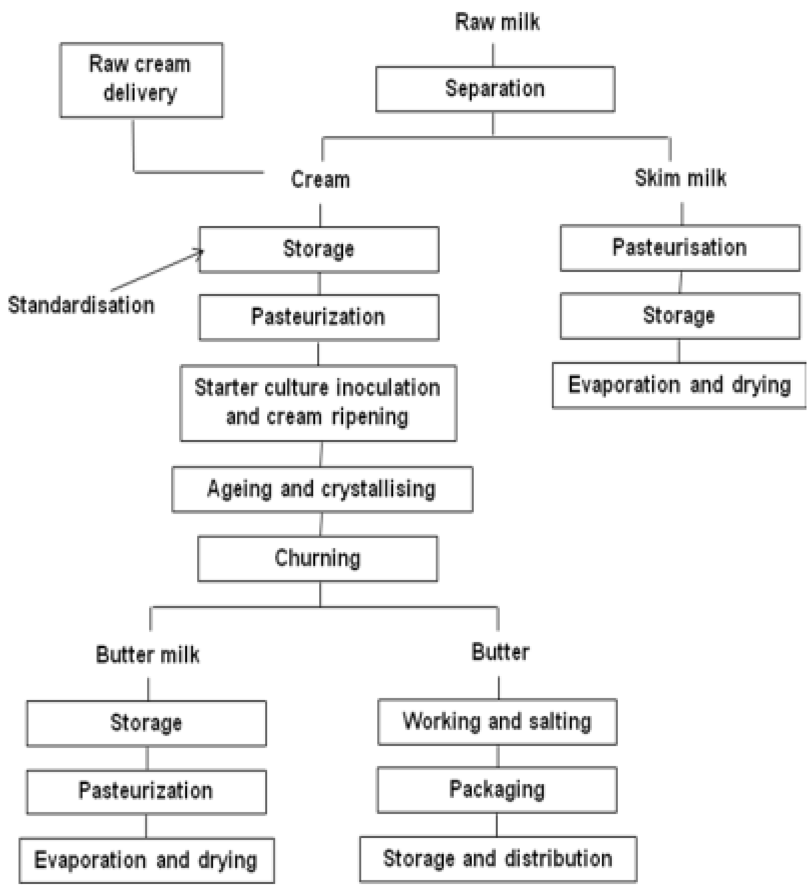

Fig. 9.5 Butter making process

Ripening

- Ripening is the fermentation of cream with the help of desirable starter culture.
- Mixed cultures of Streptococci cremoris, Str. Lactis, Str. diacetyl lactis, Leuconostoc citrovorum, Leuc. destranicum, are used.
- The cream is ripened in 2 stages; 1st stage at 21°C to pH 5.5 and then 2nd stage at 13°C to pH 4.6.
- (Most flavor development occurs between pH 5.5-4.6. The lower the temperature during ripening, the more is the flavor development relative to acid production. Ripened butter is usually not washed or salted.)

- The typical flavor of butter from ripened cream is mainly by the effect of diacetyl (biacetyl) and to a smaller extent of acetic and propionic acids.
- The average normal diacetyl content of ripened cream butter is 2.5 ppm and rarely over 4 ppm.

Ageing and crystallizing

- In the ageing tank, the cream is subjected to a program of controlled cooling that helps to give the fat the required crystalline structure. (The program is chosen to accord with factors such as the composition of the butterfat.)
- The optimum temperature for Indian condition is usually 5-10°C.
- The time requirement is 12 - 15 h (at least 2-4 h).
- 0.2 % citric acid or sodium citrate may be added for flavor.

Churning

- Churning of cream consists of agitation at a suitable temperature until the fat globules adhere forming larger and larger masses, and until a relatively complete separation of fat and serum occurs.
- In the churning process, the cream is violently agitated for 5-10 min to break down the fat globules, causing the fat to coagulate into butter grains, while the fat content of the remaining liquid (buttermilk) decreases.

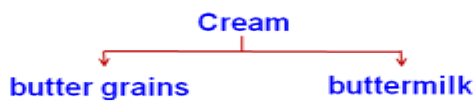

Fig. 9.6 Cream is separated to butter grains and butter milk

- Optimum churning temperature: 9-11°C.
- From the aging tank, the cream is pumped to the churn or continuous butter maker via a plate heat exchanger, which brings it to the requisite temperature.

The butter churns are available in different configurations as shown in Figs. 9.7 and 9.8.

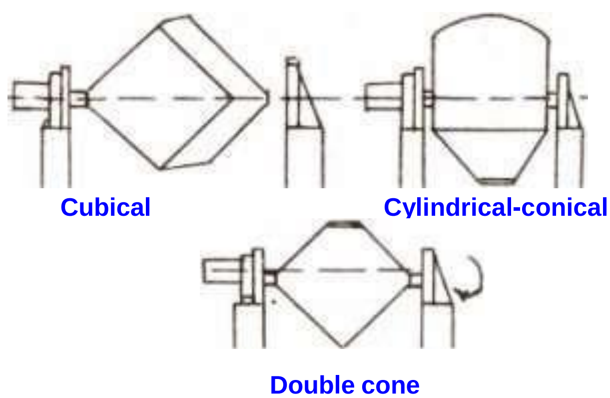

Fig. 9.7 Different configurations of butter churns

Fig. 9.8 Commercial Butter churns

Churning- the effect of temperature

- High cooling and ageing temperature requires less churning period, yield large fat losses in butter milk. Butter gets a soft greasy texture.
- Improper cooling and ageing of the cream does not allow the fat to be sufficiently solid, and the fat loss in buttermilk will be excessive, and the butter obtained will have an unsatisfactory, weak body.
- Low cooling and ageing temperature prolongs the churning period, decrease fat losses, produce a firm body, that has a satisfactory standing up capacity.
- Cooling to abnormally low temperatures, and ageing near that temperature causes the fat globules to become so firm that they bond together during churning only with difficulty, thus, the churning process is prolonged. Butter becomes too brittle.

Working and salting

The working of the butter is done for the following reasons.

- Working helps to obtain a homogenous blend of butter granules, water and salt.
- Forms a continuous fat phase containing a finely dispersed water phase. (During working, fat changes from globular to free fat. Water droplets decrease in size and should not be visible in properly worked butter.)
- Influences the characteristics by which the product is judged such as aroma, taste, keeping quality, appearance and color.
- Salt is used to improve the flavor and the shelf-life.
- Normally worked butter has 0.5-10 ml air per 100 g butter. Air content is important as it affects density of butter, microbial spoilage and oxidative spoilage.

- Overworked butter will be too brittle or greasy depending on whether the fat is hard or soft. Some water may be added to standardize the moisture content. Precise control of composition is essential for maximum yield.

Packaging

It is the unit operation to protect the butter during transit and storage.

CONTINUOUS FLOTATION CHURN

The schematic diagram as well as the exterior view of a continuous floatation churn are shown in Figs. 9.9 and 9.10.

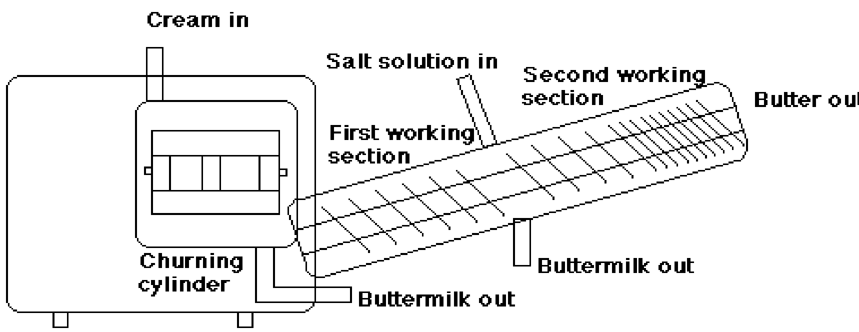

Fig. 9.9 Schematic diagram of a continuous Butter Churn

Fig. 9.10 Continuous Butter Churn (Exterior view)

The different operations that take place in a continuous butter churn are shown in Fig. 9.11.

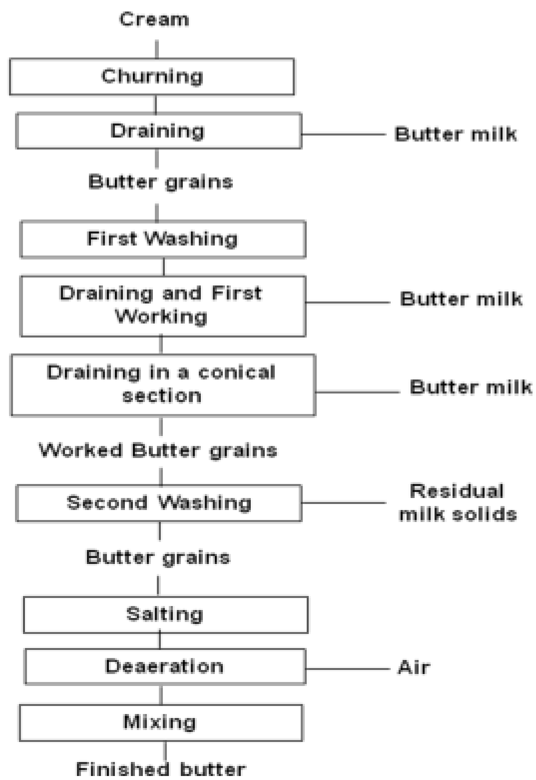

Fig. 9.11 Continuous Butter Churn

- The cream is first fed into a churning cylinder fitted with beaters that are driven by a variable speed motor.
- Rapid conversion takes place in the cylinder, and when finished, the butter grains and butter milk pass on to a draining section.
- The first washing of the butter grains takes place en route- either with water or recirculated chilled buttermilk.
- The working of the butter commences in the draining section by means of a screw, which also conveys it to the next stage.
- On leaving the working section, the butter passes through a conical channel so that any remaining buttermilk is removed.
- Immediately afterwards, the butter may be given second washing, this time by two rows of adjustable high-pressure nozzles.

  (The water pressure is so high that the ribbon of butter is broken down into grains and consequently any residual milk solids are effectively removed).
- Following this stage, salt may be added through a high-pressure injector.
- The third section in the working cylinder is connected to a vacuum pump. Here it is possible to reduce the air content of the butter to the same level as conventionally churned butter.

- In the final or mixing section, the butter passes a series of perforated disks and star wheels. There is also an injector for final adjustment of the water content.

  (Once regulated, the water content of the butter deviates by less than ±0.1%)

- The finished butter is discharged in a continuous ribbon from the end nozzle of the machine and then into the packaging unit.

BUTTER YIELD CALCULATIONS

The following expressions are used for representing different efficiencies in butter manufacture:

Separation efficiency (E_s). It represents fat separated from milk (for cream).

$$E_s = 1 - f_s / f_m$$

f_s = skim fat as per cent w/w

f_m = milk fat as per cent w/w

- E_s depends on initial milk fat content and residual fat in the skim.
- Assuming optimum operation of the separator, the principal determining factor of fat loss to the skim is fat globule size.
- Modern separators should achieve a skim fat content of 0.04 - 0.07 per cent.

Churning efficiency (E_c). It represents fat separated from cream (for butter).

$$E_c = 1 - f_{bm} / f_c$$

f_{bm} = buttermilk fat as per cent w/w

f_c = cream fat as per cent w/w

- Maximum acceptable fat loss in buttermilk is about 0.7% of churned fat corresponding to a churning efficiency of 99.3% of cream fat recovered in the butter.
- Churning efficiency is highest in the winter months and lowest in the summer months.
- Fat losses are higher in ripened butter due to a restructuring of the FGM (possibly involving crystallization of high melting triglycerides on the surface of the globules).
- If churning temperature is too high, churning occurs more quickly, but fat loss in buttermilk increases.
- For continuous churns, assuming 45% cream, churning efficiency should be 99.61-99.42%.

Composition overrun. It represents extra materials in butter than butter fat.

$$\%\text{composition over run} = -\frac{(100 - \%\text{fat in butter})}{\%\text{fat in butter}} \text{x}100$$

Churn overrun. It represents the extra yield of materials obtained in butter after churning.

$$\%\text{churn over run} = -\frac{(\text{Kg butter made} - \text{kg fat churned})}{\text{kg fat churned}} x100$$

Package fill control

$$\text{Package fill control} = \frac{(\text{Actual weight} - \text{nominal weight})}{\text{nominal weight}} x100\%$$

An acceptable range for 25 kg butter blocks is 0.2-0.4% overfill. Overfill on 454 g prints is about 0.6%.

Other factors affecting yield

- Shrinkage due to leaky butter (improperly worked)
- Shrinkage due to moisture loss; avoided by aluminum wrap.
- Loss of butter remnants on processing equipment;

Plant overrun

Plant efficiency or plant overrun is the sum of separation, churning, composition overrun and package fill efficiencies.

The theoretical maximum efficiency values are as follows:

Separation efficiency	98.85
Churning efficiency	99.60
Composition overrun (per cent fat)	23.30
Package overfill	0.20

These values can be used to predict the expected yield of butter per kg of milk or kg of milk fat received.

Example: If the fat percentage in different fractions of milk/ milk derivatives are as follows: milk (3.9%), skim milk (0.05%) cream (45%), butter milk (0.2%) and butter (81.5%), then the efficiencies will be as follows.

$$E_s = 1 - {}^{0.05}\!/_{3.9} = 98.7\%$$

$$E_c = 1 - {}^{0.2}\!/_{45} - 99.55\%$$

$$\%\text{composition over run} = -\frac{(100-81.5)}{81.5} x100 = 22.7\%$$

If 100 kg of milk is used, 8.56 kg of cream would be produced and 4.72 kg butter would be produced from that.

This is the theoretical yield based on no losses.

The mass balance of fat shows that 98.63% of the fat ended up in the butter, 0.14% of the fat ended up in the buttermilk and 1.23% of the fat ended up in the skim.

Thus, % churn overrun = (4.72 - 3.9)/3.9 = 21.02%