BUTTER MANUFACTURING

Churning

- ✓ The purpose of churning is to destroy the 5 to 10 μ thick fat globule membrane in which the butterfat exists partly as a liquid.
- ✓ Liquid fat should leave the fat globules and combine to form fat agglomerates or butter granules.
- ✓ For agglomeration of fat globules into butter granules to take place, it is necessary that part of the fat be in crystalline form.
- ✓ The rapid motion of the fat globules in relation to each other, aided by collisions with surfaces and by high turbulence causes the fat crystals to penetrate the membranes as these becomes progressively thinner.
- ✓ Agglomeration is difficult at too low a temperature when the proportion of liquid fat is too low and equally difficult at too high a temperature when all the fat is in liquid form.
- ✓ Churning is affected by
    - Proportion of fat which has crystallized out
    - Size and shape of the crystals
    - Fat content of the cream
    - Composition of the fat
    - Degree of ripening
- ✓ Higher the fat content of the cream the lower should be the churning temperature.

Methods of Butter making

Batch Method

- ✓ Butter has been made in cylindrical wooden drums rotating around a horizontal axis.
- ✓ The process was as follows:
- ✓ The churn, which had a diameter of up to 2 m and length, was 2.5 m was filled to 45% of its volume.
- ✓ Longitudinal running battens were fixed to the inside surface of the churn.
- ✓ These battens promote the formation of foam and of butter granules.
- ✓ The churn rotated at a rate of about 20 rpm and the churning time was about 45 min.
- ✓ After the removal of buttermilk the butter granules were twice washed with a quantity of water approximately equal the quantity of cream.
- ✓ The granules were then worked for up to 60 min by grooved rollers rotating in opposite directions (rate of revolution about 30-50 rpm).

- ✓ One or more pairs of these working rollers were installed in the drum at a short distance form the wall and they were rotated with the drum.
- ✓ The rollers are connected with the power unit through a gear mechanism at the back end of the churn.
- ✓ The butter is carried up, forced between rollers and kneaded to a homogenous condition.
- ✓ The rate of revolution during working was only 2 to 5 rpm.
- ✓ The chief disadvantage of the roller type churn is the danger of contamination from butter squeezed into, and then expelled from the roller bearings.
- ✓ Butter churns without working rollers were also introduced.
- ✓ In some of these, a trolley containing the rollers was introduced into the churn through an opened end wall when working was to start, or the inner wall of the churn was fitted with battens and so-called turning vanes.
- ✓ The purpose of these fitting was first to whip the cream and then to work the butter after the butter granules had formed.
- ✓ During this process the lumps of butter were lifted and allowed to drop until a homogeneous butter with the desired moisture content was obtained.
- ✓ The rate of revolution was 25 rpm.
- ✓ The rollerless churns were the transition to be currently used churns for batch processing.
- ✓ These were made from stainless steel and only the cylindrical barrel shaped ones having interior fittings.
- ✓ There are three designs: cubical, cylindrical and double cone.
- ✓ They have no interior fittings and revolve at 20 to 30 rpm.
- ✓ The axis of rotation is not in the centre and the movement around the axis causes the cream to churn.
- ✓ About 45% volume of the churn is filled with cream.
- ✓ The cream is well whipped by the corners, edges and other irregularities in the churn.
- ✓ The degree of mixing depends on the amount of cream in the churn and on the rate of revolution.
- ✓ The optimum number of rpm for efficient churning varies with the diameter of the churn.
- ✓ The speed should be such that the cream is carried up some distance with the churn before it falls away by the action of gravity.
- ✓ Large churns are rotated at smaller speed than small churns.

- ✓ Too low a speed would give insufficient turbulence whipping to the cream.
- ✓ Too high speed cause for more centrifugal force than gravity force and the cream will stick to the periphery and rotate there with the drum.
- ✓ The best conditions for churning, i.e. maximum turbulence, are achieved when the force of gravity just exceeds the centrifugal force.
- ✓ Conditions are

$$m\omega^2 R < m.g$$

$$(2\pi n)^2 R < g$$

$$n < \frac{1}{2\pi}\sqrt{\frac{g}{R}} = \frac{1}{2\sqrt{R}}$$

Where n= speed in rpm

R = radius in m

m = mass in g

- ✓ After the butter granules have formed the butter is worked.
- ✓ This is done at a considerably lower rate of revolution and requires about the same time as churning, i.e. 30 to 50 min.
- ✓ To prevent the butter granules sticking to the walls of the churn the surface of the wall is somewhat roughened.
- ✓ The best working temperature is between 18-22 ^{o}C
- ✓ The temperature of the butter is controlled by spraying water over the churn as it rotates.
- ✓ The energy consumption is about 7 to 11 kWh per 1000 kg of butter.
- ✓ Of this about 90% are used in churning, and 10%in working.
- ✓ The lower values are for cream with a higher fat content.
- ✓ Other factors which affect the power consumption are:
    - the pre-treatment of the cream,
    - the type of cream,
    - the design of the churn (type, size, speed),
    - length of churning time and
    - variations in temperature of churning.

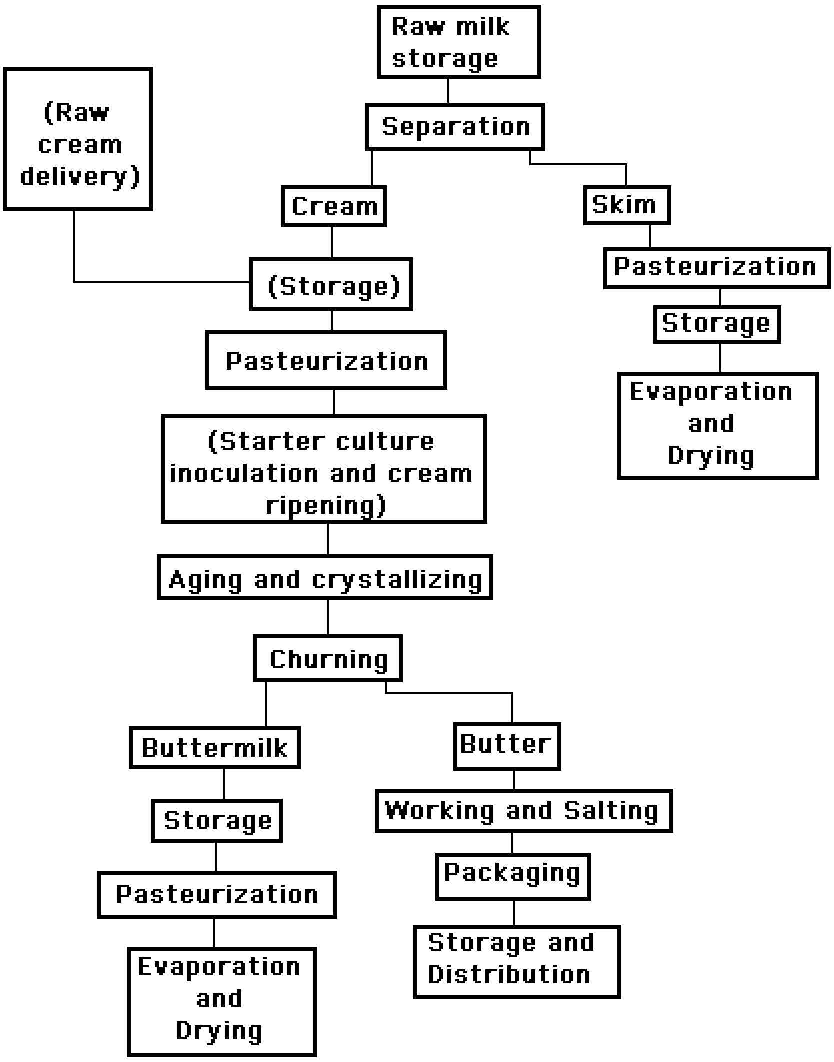
Continuous Method:

Continuous butter making may be based on one of three main principles:

1. Churning or frothing: This method is based on aggregation of the fat globules in the cream to butter grain under the action of air present in the cream, as utilized by the

Fritz process. Contimab, Westfalia, Fritz-Eisenreich, and Silkborg are based on this principle.

2. Concentration and phase reversal: In this method, the combined effects of cooling and working, the concentrated cream bring about a direct conversion of the cream to butter, bypassing the butter grain stage. The Alfa and Maleshin processes use this principle.
3. Emulsification: In this process, the basic materials are liquid butter-fat and serum. These components are re-emulsified, after which the emulsion is cooled and worked. The principle is used by Creamery Package and Gold's Flow process.



The buttermaking process involves quite a number of stages. The continuous buttermaker has become the most common type of equipment used.

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.

If the cream is separated by the butter manufacturer, the whole milk is preheated to the required temperature in a milk pasteurizer before being passed through a separator. The cream is cooled and led to a storage tank where the fat content is analyzed and adjusted to the desired value, if necessary. The skim milk from the separator is pasteurized and cooled before being pumped to storage. It is usually destined for concentration and drying.

From the intermediate storage tanks, the cream goes to pasteurization at a temperature of 95oC or more. The high temperature is needed to destroy enzymes and micro-organisms that would impair the keeping quality of the butter.

If ripening is desired for the production of cultured butter, mixed cultures of S. cremoris, S. lactis diacetyl lactis, Leuconostocs, are used and the cream is ripened to pH 5.5 at 21oC and then pH 4.6 at 13oC. Most flavour development occurs between pH 5.5 - 4.6. The colder the temperature during ripening the more the flavour development relative to acid production. Ripened butter is usually not washed or salted.

In the aging tank, the cream is subjected to a program of controlled cooling designed to give the fat the required crystalline structure. The program is chosen to accord with factors such as the composition of the butterfat, expressed, for example, in terms of the iodine value which is a measure of the unsaturated fat content. The treatment can even be modified to obtain butter with good consistency despite a low iodine value, i.e. when the unsaturated proportion of the fat is low.

As a rule, aging takes 12 - 15 hours. From the aging tank, the cream is pumped to the churn or continuous buttermaker via a plate heat exchanger which brings it to the requisite temperature. In the churning process the cream is violently agitated to break down the fat globules, causing the fat to coagulate into butter grains, while the fat content of the remaining liquid, the buttermilk, decreases.

Thus the cream is split into two fractions: butter grains and buttermilk. In traditional churning, the machine stops when the grains have reached a certain size, whereupon the buttermilk is drained off. With the continuous buttermaker the draining of the buttermilk is also continuous.

After draining, the butter is worked to a continuous fat phase containing a finely dispersed water phase. It used to be common practice to wash the butter after churning to remove any residual buttermilk and milk solids but this is rarely done today.

Salt is used to improve the flavour and the shelf-life, as it acts as a preservative. If the butter is to be salted, salt (1-3%) is spread over its surface, in the case of batch production. In the continuous buttermaker, a salt slurry is added to the butter. The salt is all dissolved in the aqueous phase, so the effective salt concentration is approximately 10% in the water.

After salting, the butter must be worked vigorously to ensure even distribution of the salt. The working of the butter also influences the characteristics by which the product is judged - aroma, taste, keeping quality, appearance and colour. Working is required to obtain a homogenous blend of butter granules, water and salt. During working, fat moves from globular to free fat. Water droplets decrease in size during working and should not be visible in properly worked butter. 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.

The finished butter is discharged into the packaging unit, and from there to cold storage.

Butter Yield Calculations

Technological limits to yield efficiency are defined by separation efficiency, churning efficiency, composition overrun, and package over fill.

1. Separation efficiency (Es):

- represents fat transferred from milk to cream

$$Es = 1 - fs/fm$$

where fs = skim fat as percent w/w fm = milk fat as percent w/w

Separation efficiency 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%.

2. Churning Efficiency (Ec):

- represents fat transferred from cream to butter

$$Ec = 1 - fbm/fc$$

where fbm = buttermilk fat as percent w/w

fc = cream fat as percent 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%.

3. Composition Overrun

% Churn Overrun

= (Kg butter made - Kg fat churned)/Kg fat churned x 100 %

% Composition Overrun

= (100 - % fat in butter)/% fat x 100 %

4. Package Fill Control

= (actual wt. - nominal wt.)/nominal wt. x 100%

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

5. 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; % loss minimal in large scale continuous processing.

6. Plant Overrun

-Plant efficiency or plant overrun is the sum of separation, churning, composition overrun and package fill efficiencies. In summary the theoretical maximum efficiency values are:

Separation Efficiency 98.85

Churning Efficiency 99.60

Composition overrun (% 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.