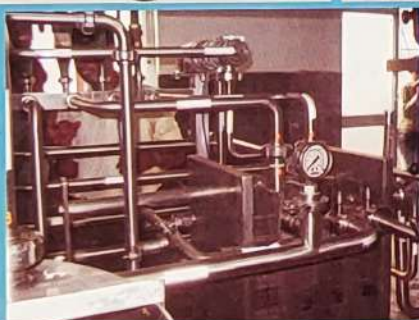


Concepts in Dairy and Food Engineering



Sanjaya K Dash
Kalpana Rayaguru
Md. Khalid Khan



College of Agricultural Engineering and Technology
Orissa University of Agriculture and Technology
Bhubaneswar- 751 003

Chapter 1

INTRODUCTION

(What is milk, Production status and importance of milk in national scenario, Definition of some common forms of milk/ milk products, Quality parameters of milk)

What is milk

Milk may be defined as the whole, fresh, clean lacteal secretion obtained by the complete milking of one or more healthy milch animals, excluding that obtained within 15 days before and 3 days after calving or such periods as may be necessary to render the milk practically colostrums free and containing the minimum prescribed percentage of milk fats and S-N-F.

(Milk in technical aspect is defined as the whole, normal, clean and fresh lacteal secretion obtained by milking a healthy animal 72 hours after calving.)

Importance of milk in national scenario

- Presently India is the largest producer of milk in the world, and the annual milk production was 121 million tonnes during 2010-11.
- India has about three times as many dairy animals as the USA, which produce around 75 million tons milk, over 80 per cent being kept in herds of 2 to 8 animals.
- Annual milk yield per dairy animal in India is about one tenth of that achieved in the USA and about one fifth of the yield of a grass-fed New-Zealand dairy cow.
- A peculiar feature in our country is the wide variation between regions in respect of consumption of milk.

Table 1.1 Milk production in India

Year	Production (million tonnes)	Per capita availability (g/day)
1991-92	55.7	178
1995-96	66.2	197
2000-01	80.6	220
2005-06	97.1	241
2006-07	100.9	246
2007-08	104.8	252
2008-09	108.5	258

Source: Department of Animal Husbandry, Dairying & Fisheries, Ministry of Agriculture, Govt. of India (May, 2010).

*The per capita availability in different states vary widely.

- In 2001-02 India became the world leader in milk production.
- Recommended value of milk consumption is 250-450 g. (Minimum recommended by NIN is 80 to 310g/capita-day.
- Per-capita availability in India was only 114 g in 1975.

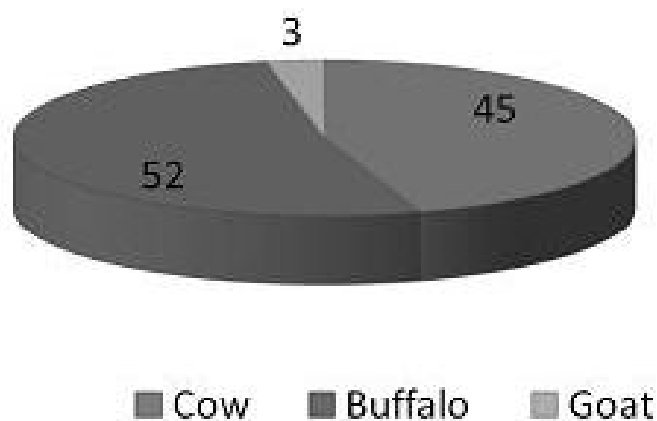


Fig. 1.1 Species contribution in India (in percentage)

Table 1.2 World Top 10 Cow's Milk Producing Countries in 2008 (Tonnes)

Country	2006	2007	2008
USA	82,463,031	84,189,067	86,178,896
India	41,148,000	43,481,000	44,100,000*
China	32,257,300	35,574,326	35,853,665
Russian Federation	31,186,154	31,914,914	32,117,427
Germany	27,995,000	28,402,772	28,656,256
Brazil	26,185,564	26,944,064	27,752,000*
France	24,194,707	24,373,700	24,516,320
New Zealand	15,172,464	15,618,288	15,216,840
UK	14,316,000	14,023,000	13,719,000
Poland	11,982,393	12,096,005	12,425,300
World	558,826,488	571,403,458	578,450,488

The following points need consideration for improvement in dairy sector

- Low milk yielding capacity of average Indian cow.
- Shortage of feed and fodder.
- Lack of organized milk production and collection, restricted transport facilities (especially refrigerated).
- Shortage of processing and marketing organizations.
- Poor quality milk, wide spread adulteration and lack of quality consciousness among the majority of consumers.

Definition of some common forms of milk/ milk products

Market milk	Refers to fluid whole milk that is sold to individuals usually for direct consumption. It excludes milk consumed on the farm and that used for the manufacture of dairy products.
Pasteurized milk	It is the milk, which has been heated (processed) for at least 30 minutes at 63°C or 15 sec at 72°C (or any time temperature combination that is equally efficient in approved and properly operated equipment). After pasteurization the milk is cooled immediately to 5°C or below.
Sterilized milk	Milk which has been heated to a temperature of 100°C or above for such lengths of time that it remains fit for consumption for at least 7 days at room temperature (Usually the process condition is 108-111°C for 25-30 min).
Homogenized milk	It is the milk which has been treated in such a manner as to ensure break up of fat globules to such an extent that after 48 hours of storage no visible cream separation occurs in the milk and the fat percentage of the milk in the top 100 ml of milk in a quart bottle or of proportionate volumes in containers of other sizes does not differ by more than 10% of itself from the fat percentage of the remaining milk as determined after thorough mixing (In sufficiently homogenized milk, the fat globules are subdivided to 2 microns or less in diameter).

Soft-curd milk	It is the milk that forms a soft curd when coagulated with rennet or pepsin under standard procedure (Curd tension <25 g). Soft curd milk is characterized by low casein content and low Ca content.(Mothers' milk is best for infants because it forms a soft curd when coagulated in the stomach and is apparently more quickly digested than cow or buffalo milk). Curd tension of human milk: 0 g, Boiled cow milk: 3 g, Homogenized milk : 14.5 g, Pasteurized milk: 44.5 g, Raw milk : 55g).
Flavored milk	Milk to which some flavors have been added. When the term 'milk' is used, the product should contain a fat per cent at least equal to the minimum legal for the market milk. But when the fat level is lower (1-2 per cent), the term drink is used.
Vitaminized milk	Milk in which one or more vitamins have been added.
Irradiated milk	Milk in which Vitamin D content has been increased by exposure to U-V rays.
Mineralized milk	Milk in which minerals have been added (Addition of vitamins and minerals to milk is known as fortification and such milk is called fortified milk).
Frozen concentrated milk	The milk is partially concentrated and solidified by freezing.
Fermented milk	Milk that has been made by employing selected microorganisms to develop the characteristic flavor and/or body and texture. (Fermentation has been defined as the metabolic process in which chemical changes are brought about on an organic substratum, whether carbohydrates, proteins or fat, through the action of enzymes liberated by specific microorganisms. In milk, the most important fermentation is the lactic acid fermentation or souring of milk).
a. Natural butter milk	It is a by-product of churning cream for butter making. Ripened cream, which has undergone a clean, lactic fermentation, is usually preferred.
b. Cultured butter milk	Obtained by inoculation and incubation of pasteurized skim milk with lactic starter.

c. Acidophilus milk	Produced by development in milk of a culture of <i>Lactobacillus acidophilus</i> (It is claimed that acidophilus milk is therapeutic and has health promoting properties.).
d. Yoghurt	Manufactured by using whole or partially defatted milk containing small amounts of skim milk powder or concentrate. The fat content of yoghurt may vary from 0-5% and the solids content 9-20% (Fermented by <i>L. bulgaricus</i> and <i>Str. Thermophilus</i> .).
Standardized milk	Whose fat and solids not fat (SNF) has been adjusted to a predetermined level.
Reconstituted milk	Milk prepared by dispersing whole milk powder (also called dried whole milk) in water approximately in the proportion of 1 part powder to 7-8 parts water (Usually spray dried milk is used since it is more soluble and produces less sediment.).
Recombined milk	Product obtained when butter oil (also called dried or anhydrous milk fat), skim milk powder and water are combined in the correct proportions to yield fluid milk (at least 3% fat and 8.5% SNF).
Toned milk	Milk obtained by addition of water and skim milk powder to whole milk (at least 3% fat and 8.5% SNF). In practice, whole buffalo milk is admixed with reconstituted spray dried skim milk for its production.
Double toned milk	Same as toned milk, but minimum 1.5% fat and 9.0% SNF.
Humanized milk	When cow or buffalo milk is so modified in its chemical composition that it resembles human milk.
Filled milk	Same as recombined milk, except that the fat is derived from a vegetable source.
Imitation milk	A product resembling milk, but of non-dairy origin.
Vegetable toned milk	The milk protein of skim milk powder is substituted by vegetable protein isolated from groundnut.

Soyamilk	Made from soybean
Cream	It is the portion of milk, which is rich in milk fat (when milk fat is concentrated in to a fraction of the original milk, the portion is known as cream). According to PFA rules (1976), cream, excluding sterilized cream is the product of cow or buffalo milk or a combination thereof which contains not less than 25% milk fat (The milk fat in cream varies from 18-85%; the SNF constituents occur in lower proportions than in milk.)
Butter	May be defined as a fat concentrate which is obtained by churning cream, gathering the fat into a compact mass and then working it. According to PFA rules (1976), table butter is the product obtained from cow or buffalo milk or a combination there of, with or without the addition of common salt and annatto or carotene, a coloring matter. It should be free from other animal fats, wax and mineral oils, vegetable oils and fats.
Butter oil	Refers to the fat concentrate obtained mainly from butter or cream by the removal of practically all the water and SNF content. The term milk fat, anhydrous milk fat, dry butter fat and dehydrated butter fat are used synonymously for butter oil, but the raw material for their preparation is usually cream.
Cheese	A product made from curd (obtained from milk) by coagulating the casein with the help of rennet or similar enzymes in the presence of lactic acid produced by added or adventitious microorganisms, from which part of the moisture has been removed by cutting, cooking and /or pressing, which has been shaped in a mould and then ripened by holding it for some time at suitable temperature and humidity.(According to PFA rules, (hard) cheese means the product obtained by draining after coagulation of milk with a harmless milk-coagulating agent, under the influence of harmless bacterial cultures). It shall not contain any ingredient not found in milk, except coagulating agent, NaCl, CaCl ₂ , etc.

Condensed milk	Products obtained by evaporating part of the water of whole milk, or fatty or partly skimmed milk with or without the addition of sugar. (The term condensed milk is commonly used when referring to “full cream sweetened condensed milk” while the term evaporated milk is commonly used for “full cream unsweetened condensed milk”. Skimmed milk products are known as sweetened condensed skim milk and unsweetened condensed skim milk, respectively.
Dried milk	Dried milk or milk powder is the product obtained by the removal of water from milk by heat or other suitable means, to produce a solid containing 5% or less moisture. The dried product obtained from whole milk is called dried whole milk or whole milk powder (WMP), that from skim milk is known as dried skim milk (SMP) or not fat dry milk (NFDM) from defatted milk.
Khoa / Mawa	Refers to partially dehydrated whole milk product prepared by continuous heating of milk in a big kettle over a direct fire, while also constantly stirring-cum-scrapping till it reaches a semi-solid (doughy) consistency. There after, the pan contents are removed from the fire and worked up into a solid mass known as khoa pat.(According to PFA rules, khoa is the product obtained from cow or buffalo (or goat) milk or a combination thereof by rapid drying. The milk fat is not less than 20 % of the finished product.
Khurchan	This is concentrated sweetened whole milk product prepared by simmering milk without stirring it in a big kettle, so as to allow for the simultaneous formation of a thick creamy layer of skin on the surface of the milk and slow evaporation of the water, after which sugar is added to the concentrated product. A thorough mixing of the product follows this.

Rabri	This is especially prepared, concentrated and sweetened whole milk product, containing several layers of clotted cream. While the milk is slowly evaporated (without being stirred) at simmering temperature in a kettle over an open fire, pieces of skin, which form on the surface of the milk, are continuously broken up and moved to cooler parts of kettle. When the volume of milk has been considerably reduced, sugar is added to it; thin layers of clotted cream are immersed in the mixture and the finished product is obtained by heating the whole mass for another short period.
Kulfi	This is an indigenous ice cream frozen in small containers. While the milk is boiling, it is sweetened by addition of sugar and the product is concentrated to approximately 2:1. After the concentrate has cooled, malai (indigenous cream), crushed nuts and a flavor (commonly rose or vanilla) are added to it. The mix is placed in a triangular, conical or cylindrical moulds of various capacities made from GI. The moulds are closed on top by placing small discs over them and the edges made air tight with wheat dough (Modern moulds are made of plastic, with screw cap plastic tops). The mix-in-moulds is frozen in a large earthen vessel containing a mixture of ice and salt in the ratio of 1:1.
Malai	Creamy layer formed on the surface of milk, which has been heated, very slowly to boiling temperature and then left to cool undisturbed. The creamy layer is then screamed off. Owing to the higher fat content and larger fat globules, buffalo milk gives higher yields and is used for the preparation of <i>malai</i>. According to PFA rules, <i>malai</i> refers to the product rich in butter fat prepared by boiling and cooling cow or buffalo milk or a combination thereof. It should not contain less than 25 % milk fat.

Dahi (Curd)	Prepared from pasteurized or boiled milk by souring, natural or otherwise, by a harmless lactic acid or other bacterial culture. Dahi should also contain same percentage of fats and SNF as the milk from which it is prepared. Broadly speaking, Curd can be classified into two types: (i) For churning into desi (or indigenous) butter (makkhan); (ii) For direct consumption (a) whole milk dahi, skim milk dahi, and (b) sweet (or mildly sour) dahi, sour dahi, sweetened dahi.
Srikhand	It is a semi-soft, sweetish-sour whole milk product prepared from lactic fermented curd. The curd is partially strained through a cloth to remove the whey and thus produce a semi-solid mass called chakka (the basic ingredient for Srikhand). The chakka is mixed with the required amount of sugar etc. to yield srikhand. The srikhand is further desiccated over an open pan to make the Srikhand wadi sweet.
Panir	Refers to the indigenous variety of rennet-coagulated, small sized soft cheese.
Makkhan	Refers to the country / desi butter normally obtained by churning whole milk curd (dahi with crude indigenous devices. Not less than 76% fat)
Ghee	Clarified butter fat prepared chiefly from cow or buffalo milk. Not less than 99-99.5% fat.
Chhana	Chhana refers to the milk solids obtained by the acid coagulation of boiled hot whole milk and subsequent drainage of whey (commonly used are lactic acid and citric acid). It has less than 70% moisture and not less than 50% milk fat of the total dry matter.
Whey	The drained water obtained as a by-product of cheese making is known as whey. It is rich in lactose, different salts, TS and SNF.

Quality parameters of milk

When we buy milk, a lot of quality parameters come to our mind either in direct form or indirect form. For example, the property of milk in terms of its composition, microbial load, freshness are a group of quality parameters. Another set of quality parameters may be the effect on environment, ethics, ecology, etc. All these quality parameters affect our acceptability or otherwise for the milk. Figure 1.2 gives a representation of the different quality parameters of milk affecting the consumer acceptance.

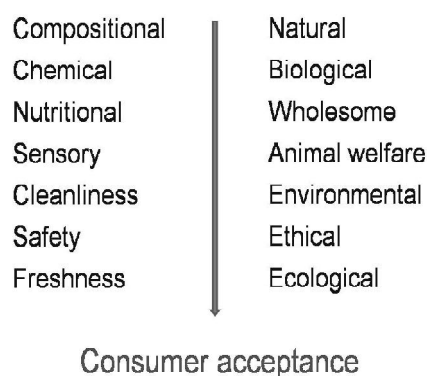


Fig. 1.2 Quality parameters of milk affecting the consumer acceptance

CHECK YOUR PROGRESS

1. Define and distinguish between the different forms of milk and milk products ?
2. Write a two page note on dairy development in India and Odisha since independence. (The answer should include the following:
 - Development of milk production since independence (India and Odisha)
 - Development of dairy processing industry in India and Odisha.
 - References

Chapter 2

PROPERTIES OF MILK

(Important constituents of milk, Important properties of milk, Why these properties are important for us, Selection of metals for dairy industry)

IMPORTANT CONSTITUENTS OF MILK

The different constituents of milk can be shown as in Fig. 2.1

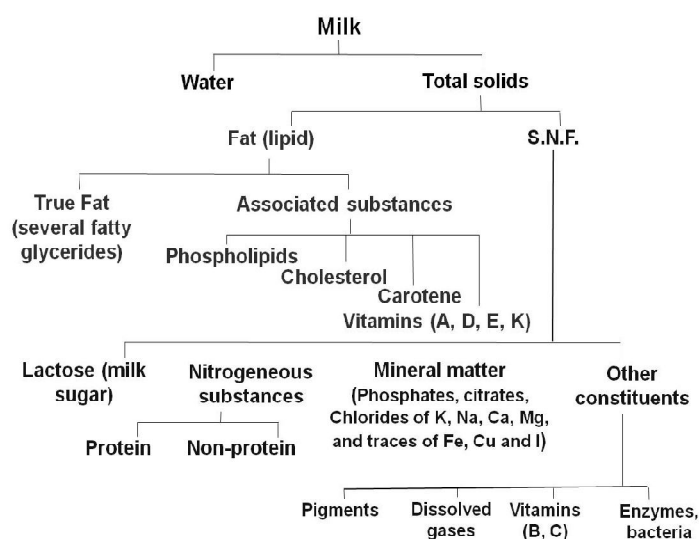


Fig. 2.1 Constituents of milk

Remember.....

- Milk contains all essential amino acids in fairly large quantities.
- It is an excellent source of Ca and P, both of which together with vit D are essential for bone formation.
- It is a good source of vit A (provided the cow is given sufficient green feed and fodder), vit D (provided the cow is exposed to enough sunlight), thiamine, riboflavin, etc. But milk is deficient in vit C.
- Milk fat, besides giving energy contains significant amount of essential fatty acids (linoleic and arachidonic), which give the characteristic flavor.
- Lactose (carbohydrate) provides energy. It also helps to establish a mild acidic reaction in the intestine (which checks the growth of proteolytic bacteria and facilitates assimilation).

The composition of milk varies with many factors, the most important of them being the species and breed of the animal. Table 2.1 gives an idea of the variations in major constituents of milk.

Table 2.1 Variation in major constituents of different milk

Source of Milk	Water	Fat	Protein	Lactose	Ash
Buffalo	84.2	6.6	3.9	5.2	0.8
Camel	86.5	3.1	4.0	5.6	0.8
Cow (Indian)	86.07	4.9	3.42	4.91	0.7
Cow (Foreign)	86.6	4.6	3.4	4.9	0.7
Goat	86.5	4.5	3.5	4.7	0.8
Human	87.7	3.6	1.8	6.8	0.1
Skim milk	90.6	0.1	3.6	5.0	0.7
Butter milk	91.0	0.4	3.4	4.5	0.7

Factors affecting composition of milk

- Species
- Breed: In general breeds giving more amount of milk yield a lower percentage of fat.
- Individuality
- Interval of milking (Longer interval implies more milk with a lower fat test).
- Completeness of milking: If the cow is completely milked the test is normal, or else, the test is lower.
- Irregularity of milking.
- Disease and abnormal conditions.
- Portion of milking: Fore-milk is low in fat content (less than 1%), while strippings are the highest close to 10%. Other milk constituents are slightly affected on a fat free basis.
- Stage of lactation: The change from colostrum to milk takes place within few days.
- Yield: For a single cow, there is a tendency for increased yields to be accompanied by a lower fat percentage and vice versa.
- Feeding: Has temporary effects.
- Season: The percentage of both fat and solids-not-fat (SNF) show slight but well defined variations during the course of year.
- Age: The fat per cent in milk declines slightly as the cow grows older.

- Condition of cow at calving: A cow would yield milk with higher fat per cent if it is healthy.
- Excitement
- Administration of drugs and hormones.

There may also be variations in composition of milk obtained from a specific animal in day to day milking.

Energy values of different milk constituents

As mentioned above, the milk is a rich source of energy. The energy values of different milk constituents are as follows.

- Milk fat : 9.3 Cal/g,
- Milk protein : 4.1 Cal/g,
- Milk sugar : 4.1 Cal/g

Thus, with the available constituents, 100 g of cow milk usually gives 75 Cal and that of buffalo milk gives 100 Cal.

What is colostrum

During approximately the first three days of lactation, the buffalo/ cow secretes colostrum. This is very vital for the newborn calf and its composition reflects the calf's need. Colostrum contains the important proteins; the immuno-globulins, which are the newborn calf's source of antibodies. The content of iron and copper is markedly higher in the colostrum as compared to normal milk.

The average composition of colostrum is as follows.

Water: 73%	Fat: 9.55%
Total Protein: 9.59%	Lactose: 7.54%
Vitamin A: 1.8 µg/kg	

Changes of milk due to boiling

When the milk is boiled there are several changes in it due to the presence of different constituents. These changes are mainly in the following form.

- Decrease in the percentage of cream
- Decrease in curd tension
- Decomposition of proteins
- Destruction of enzymes

- Darkening of the color of milk
- Coagulation of albumin and formation of a scum on the surface
- Acquiring a cooked taste
- Precipitation of Ca and Mg salts
- Breaking up of fat globules
- There may be stone formation in milk during heating.

Stone formation in milk

If the milk being processed has had no previous heat treatment, there are two types of deposits on the heat exchanger/ container surface. This is known as stone formation in milk or fouling.

1. Fouling at low temperatures

- The soft, voluminous, curd-like material, which starts to form when the temperature exceeds about 75°C.
- It is at its maximum in the temperature range 95-110°C, and then reduces in amount at higher temperature.
- This type of deposit restricts the flow passages area and causes increase in the operating pressure.
- It has high protein content (50-70%), and a lower mineral content (30-40%).

2. Fouling at high temperatures

- Deposits formed at higher temperatures
- Increases in quantity up to the highest temperature reached in the heat exchanger.
- Hard and granular in structure containing mineral (70-80%) and protein (10-20%).
- This deposit interferes more with heat transfer than with flow, and hence to reach the required processing temperature, the temperature of the heating medium has to be increased to an undesirable extent.

Both types (1 & 2) of deposit contain negligible amount of fat (about 5%), and protein and minerals are the main constituents. The amount of fouling depends greatly on the pH of raw milk. As the pH falls below about 6.5, a large amount of deposit is formed. Milk with high contents of β -casein are more prone to deposit formation. but the addition of pyrophosphates to milk brings about a significant improvement.

IMPORTANT PROPERTIES OF MILK

The knowledge of different properties of milk and milk products are required to design the processing and storage structures for milk. The important properties are discussed below.

Density and specific gravity

The knowledge of density is important to

- monitor changes during processing
- check adulteration
- separate the different constituents of milk (by methods such as centrifugation, cyclone separation, etc.)
- transport liquid milk as well as processed milk products (by different methods as pneumatic/hydraulic transportation, etc.)
- design and develop storage structures for milk and milk products

The density and specific gravity of milk is usually given at 15.6°C (60° F). (The specific gravity of water is usually expressed at 4°C).

The specific gravity of some major milk constituents are: water: 1.00; fat: 0.93, protein: 1.346, lactose: 1.666, salts: 4.23, and SNF: 1.616. As we have already discussed that the milks obtained from different animals vary in composition, the densities will also vary.)

The density of milk of different animals are given below.

- Cow milk : 1.028-1.03
- Buffalo milk : 1.03-1.032
- Skim milk : 1.035-1.037
- Milk powder (bulk density) : 0.83

(Milk powder has a porosity of 43-51%)

Though the buffalo milk contains higher fat, still due to higher SNF, the specific gravity is more than cow milk.

Determination of specific gravity of milk by lactometer



Fig. 2.2 A lactometer immersed in a cylinder

- A lactometer (or galactometer) is a hydrometer used to test milk.
- The specific gravity of milk does not give a conclusive indication of its composition since milk contains a variety of substances that are either heavier or lighter than water. Additional tests for fat content are necessary to determine overall composition.
- The specific gravity of milk should not be determined for at least one hour after it is drawn from the animal, or else, a lower than normal value will be obtained.
- Quevenne is an arbitrary scale used with hydrometers or lactometers in the determination of the specific gravity of milk. degrees Quevenne = 1000 (specific gravity - 1).
- The specific gravity of milk is calculated by dividing the Quevenne's degree by 1,000 and adding 1. i.e. if the Quevenne reading is 31, then

$$\text{specific gravity} = (31/1000) + 1 = 1.0031$$

Correction for temperature

The lactometers are normally standardized at a particular temperature (say 60°F or 15.6°C). If the temperature is above or below the standard temperature of 60°F, the lactometer reading should be corrected by adding 0.1 to the lactometer reading or 0.0001 to the specific gravity for each °F above 60°F and vice versa for lower temperatures.

Example: If the meter reading becomes 31.0 at 66°F, what is the specific gravity of milk?

Solution:

The corrected lactometer reading is $31.0 + 0.6 =$ or 31.6

Specific gravity: $1 + 31.6/1000 = 1.0316$

In another method, the instrument is graduated into a hundred parts. Milk is poured in and allowed to stand until cream has formed. The depth of the cream deposit in degrees determines the quality of the milk.

Another instrument, invented by Doeffel, is two inches long, divided into 40 parts, beginning at the point to which it sinks when placed in water.

Some other types of hydrometers

- Alcoholometer : to measure alcoholic strength of liquids
- Saccharometer : to measure amount of sugar in a solution
- Thermohydrometer : that has a thermometer enclosed in the float section
- Barkometer : to measure strength of tanning liquors used in tanning leather
- Battery hydrometer : charge of a lead-acid battery can be estimated from the density of the sulfuric acid solution used as electrolyte.
- Antifreeze tester : to test the quality of the antifreeze solution used for engine cooling.

Total solids and total SNF

The total solids and solids not fat (SNF) are determined as follows (The method is known as Gerber method).

$$\text{Percentage total solids} = 0.25 D + 1.22 F + 0.72$$

$$\text{Percentage SNF} = 0.25 D + 0.22 F + 0.72,$$

In the above equations, $D = 1000(d - 1)$, where d = specific gravity of sample of milk at 20°C , and F is the fat percentage in sample.

Case I: What is the amount of total solids and SNF with a milk having 3% fat and density of milk is 1016 kg/m^3 (@ 20°C).

Solution:

$$D = 1000(1.016 - 1.00) = 16$$

$$\text{Per cent total solids} = 0.25(16) + 1.22(3) + 0.72 = 8.38$$

$$\text{Per cent SNF} = 0.25(16) + 0.22(3) + 0.72 = 5.38$$

Freezing point

Due to the dissolved solids in liquid milk and milk products, the freezing points are normally lower than the freezing point of pure water. In fact, more the concentration of solids, more will be the freezing point depression. The freezing points of different types of milk are as given in Table 2.2.

Table 2.2. Freezing points of different types of milk

Type of milk	Freezing point
Fresh whole milk	-0.506°C to -0.504°C
Indian cow milk	-0.547°C
Buffalo milk	-0.549°C
Evaporated milk	-1.4°C
Sweetened milk	-15.12°C to -12.04°C

Souring results lowering in freezing point due to increase in the amount of soluble molecules. Hence unsoured samples should be tested for determination of freezing point. Another important point is that the volume of milk is always increased when it is frozen.

The knowledge of freezing point of milk is important as it is employed for detection of adulteration.

Boiling point

As mentioned above, the boiling point of milk is also little higher than that of pure water due to the dissolved solids.

For normal milk at atmospheric pressure, the boiling point is around 100.5°C (100.2-101°C). As a thumb rule, when the concentration is doubled, the boiling point rises by about 0.5°C, and if the concentration is 3:1, the boiling point rise is 0.8°C.

The addition of solids, salts, sugars, acids, etc. raises the boiling point. The boiling point also varies with composition and pressure.

Specific heat

The specific heat of milk varies depending upon the fat content and temperature. The general values are as follows.

Whole milk : 3.89-3.93 kJ/ kg-°K (0.93-0.94 kCal/kg-°K);

Skim milk : 3.97 kJ/kg-°K (0.95 kCal/kg°K)

Thermal conductivity

The thermal conductivity of milk is found out by Lamb's equation, which is as follows:

$$K=0.0801 + 0.568 M_w$$

Here M_w is the moisture fraction (i.e. expressed in decimals)

Acidity and pH

The milk is acidic and the average natural acidity is as follows.

Cow milk : 0.13 to 0.14% (natural acidity)

Buffalo milk : 0.14 to 0.15%

The developed or real acidity is due to lactic acid formed as a result of bacterial action on lactose on milk. The titrable acidity is the sum of developed and natural acidity.

The pH is another measure of acidity and the pH values of milk are as follows.

Normal fresh sweet cow milk : 6.4-6.6

Buffalo milk : 6.7-6.8

Higher pH value of milk indicates udder infection and the lower value indicates bacterial action.

The acidity and pH of fresh milk varies with species, breed, individuality and stage of lactation and as well on health of animal.

Viscosity

The materials of high viscosity would require a large surface, slow moving type agitator to move them properly. Besides, viscous materials cause a slow moving film on heating and cooling surfaces, and thereby reduce the rate of heat transfer. The pump pressure for forcing the liquid through pipe lines will also increase. Table 2.3 gives the average values of viscosity of milk at different temperatures.

Table 2.3 Viscosity of milk forms (Viscosity in Pa.s)

Type of Milk	Temperature, °C			
	10	20	40	80
Whole milk	2.79	2.12	1.24	0.68
Skim milk	2.44	1.74	1.03	0.53
Whey	1.71	1.26	0.82	0.68

The above table is a representative one and there can be variations. The viscosity of milk also varies according to composition, age and treatment.

The viscosity of milk can increase during processing and storage. In particular, the increase of viscosity is observed during

- Increase in concentration
- Homogenization
- Ageing at low temperature.

The milk and milk forms can be categorized as Newtonian and Non-Newtonian fluids as follows.

Newtonian fluids: milk, skim milk, cheese, whey permeate, etc.

Non-Newtonian fluids : suspensions, pastes, emulsion, etc.

Surface tension

Surface tension is the force per unit length acting on a length of surface of a body or the work done in increasing its surface area under isothermal conditions. The surface tension forces are responsible for the finely dispersed liquids to form spherical droplets (minimum surface area to volume ratio).

Table 2.4 Surface tension of some commodities

Material	Surface tension, mN/m
Water	72.6
Cow milk	52
Buffalo milk	50.5
Whey	0.68

Color of milk

- The color of milk is a blend of individual effects produced by: (1) colloidal casein particles and dispersed fat globules, both of which scatter light, and (2) carotene (to some extent xanthophylls), which imparts a yellowish tint.
- Thus, the color of milk ranges from yellowish creamy white (cow milk) to creamy white (buffalo milk).
- The intensity of the yellow color of the cow milk depends on the factors such as breed, feed, size of fat globules, fat per cent in the milk, etc.
- Greater intake of green feed results in deeper yellow color of milk.
- Larger the fat globules and higher fat percentage will impart a greater intensity of yellow color.
- Skim milk has a bluish and whey a greenish yellow color.

Refractive index

The average refractive index of cow milk and buffalo milk at 40°C are as follows.

- o cow milk : 1.3461
- o buffalo Milk : 1.3477

- Total refraction is sum of individual refractions of the constituents present in the solution.
- The measure of refractive index can be used to determine adulteration, especially watering. However, the freezing point is more reliable than refractive index for determination of adulteration.

Flavor

- It is composed of smell (odor) and taste.
- The flavor of milk is a blend of sweet taste of lactose and salty taste of minerals, both of which are damped down by proteins.
- The phospholipids, fatty acids and fat of milk also contribute to the flavor.

Usually the changes in flavor/ abnormal flavor in milk occur due to:

- Type of feed
- Chemical composition as well as chemical changes
- Season
- Stage of lactation
- Condition of udder
- Sanitation and other conditions during milking and subsequent handling of milk, during storage
- Bacterial growth
- Addition of foreign material
- Absorbed materials

Agitation

The agitation of dairy products containing butter fat should be gentle but complete and uniform. Severe agitation causes clumping and churning of butter fat and disturbances in cream formation. Insufficient agitation will cause localized overheating and burning of products. Pressure intensifies the churning effect of agitation.

Expansion of milk

Milk product which have entrapped air in them greatly increase in volume as the temperature rises. The expansion of milk is of practical significance because of its bearing on the capacity of tanks.

Overrun

When air is incorporated into a whipped or frozen product, the density decreases. The amount of entrapped air incorporated is measured as overrun.

$$\text{Overrun} = \frac{\text{Wt of original liq} - \text{Wt of same vol of aerated prod}}{\text{Wt of original liquid}} \times 100$$

$$\text{Overrun} = \frac{\text{Increase in volume}}{\text{Original volume}} \times 100$$

Overrun of 2-3 times the total solid contents are recommended. Too low overrun yields a heavy product. Too high overrun gives too light and fluffy product.

Foaming of milk

Pure liquids do not foam and the foaming of solution is correlated with the surface activity of the solutes. The following table shows the different types of materials/ constituents forming the foam.

Less Foam	Transient Foam	Persistent foams
Mixtures of liquids of similar chemical type and surface tension Aqueous solutions of highly hydrophilic solutes, e.g. sucrose.	Solutes, which lower the surface tension moderately	Solutes, which lower the surface tension strongly in dilute solution, e.g. proteins.

Effect of metal on milk

Milk reacts on certain metals, so that a small amount of the metal is dissolved in it. The metallic salts thus formed may give rise to a “metallic” taste in the milk.

Factors influencing the degree of action by milk on metal

- Temperature of milk
- Period of contact
- Cleanliness and polish of metal
- Amount of free air in milk
- Acidity of milk
- Presence of sugar

Desirable characteristics of metals for dairy equipment

- Non-toxic
- Insoluble (in milk or its products)
- Non-absorbent
- Highly resistant to corrosion
- Good agents of heat transfer
- Easy to clean and keep bright

- Low cost
- Durable
- Light, yet strong

SELECTION ON METALS FOR DAIRY EQUIPMENT

Many types of materials can be used for the milk handling and processing equipment, but the main consideration should be that the metal should not adversely affect the quality of milk. The following points will help in understanding some basic considerations for selection of metals for milk processing equipment.

- Most dairy equipment are made up of 18:8 (18 Cr and 8 Ni) stainless steel (s.s.).
- Copper is used for brines as brine frequently corrodes the 18:8 metal and holes may form.
- A nickel alloy called Inconel (80 Ni, 14 Cr and 6 Fe) is preferred to s.s. in that it can be more readily soldered where soldering is preferred to welding. However, this is not used with brine (salt solution).
- Aluminum also has considerable uses. But it is corroded by ordinary alkaline dairy cleaners and sterilizers. (So plants using aluminum equipments have to use an aluminum cleanser throughout the plant, which is somewhat expensive.)
- Soldering is widely used in fabrication of dairy equipments ($\frac{1}{2}$ tin and $\frac{1}{2}$ lead). Welding is used to join s.s. parts.
- Small traces of copper, iron and zinc induce oxidized flavor.
- Iron induces fishy flavor in butter.
- Also the presence of iron metal acts as a catalyzer, which accelerates the rate of oxidation of the butter fat in the milk.
- For freedom from metallic off-flavors, there must be no exposed copper or copper containing alloy. A perfectly tinned surface or some of the s.s. of the same composition are safe.
- Silver, lead and mercury are poisonous.
- Tin is quite soluble in milk, but luckily it does not cause off flavors. It can be removed by refining.
- Aluminum is moderately soluble, but does not affect flavor materially. It can be easily repaired.
- Corrosion passivity of metals are also required.

CHECK YOUR PROGRESS

1. What are the important properties of milk, which affect the processing?
2. How the density and viscosity of milk affect the milk processing operations?
3. What are the factors that affect the flavor and color of milk ?
4. Why the freezing temperature of the milk is slightly lower than water ?
5. Why the boiling temperature of the milk is slightly higher than that of water ?
6. Name the desirable characteristics of metals to be used in milk processing equipment.
7. Explain the working principle of a lactometer ?

Chapter 3

PROCESS FLOW CHARTS AND PLANT LAYOUT

(Flow chart, Different unit operations in milk processing with the help of flow charts, Know how to draw the flow charts and plant layouts)

FLOW CHART

A flow chart is a representation of sequence of operations in a processing plant or in a process. For example, if we want to prepare dried vegetables, the sequence of operations will be sorting, washing, peeling, slicing and then drying either under sun or in a mechanical dryer. But we may also think of blanching of the vegetable or treat with sulphur dioxide depending on the characteristics of the commodity and product. Thus if we prepare a flow chart of these processes, the flow chart may look somewhat like as in Fig. 3.1.

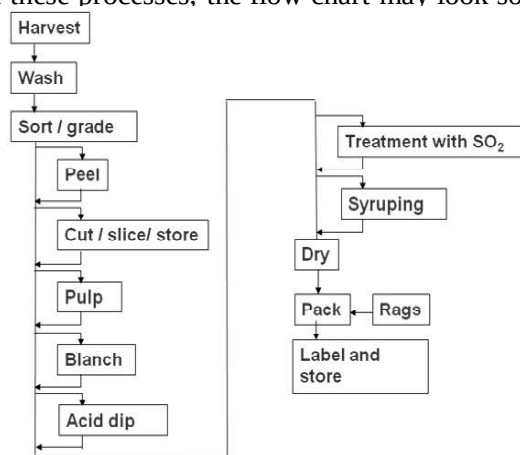


Fig. 3.1 Flow chart for vegetable dehydration

For preparation of a flow chart, first of all we have to know the sequence of operations. Or in other words, we can know the proper sequence of operations and better understand the process, if we have a flow chart of the process. We can also know the critical control points and we also know where to improve.

The flow chart also helps in identifying each unit operation in the process which helps in proper selection of equipment and better management of man and machines. For example, the type of equipment that will be required for the preparation of dehydrated vegetables will be as follows.

Equipment required for vegetable dehydration

- Wash tanks or special washers
- Knives, peelers, small peeling machines
- Fruit and vegetable choppers, cutters, slicing and dicing machines
- Pulpers, liquidizers, steamers, or at a large scale, pulper-finishers
- Boiling pan, heat source, wire basket or steamer

- Weighing scales or scoops, sulfuring cabinet or food grade plastic tank
- Weighing scales or scoops, boiling pan, heater, food-grade tank, muslin cloth filter
- Sun-drying, solar dryer, any type of suitable dryer
- Electric heat sealer for plastic bags

So now we have understood that the flow charts are very important for understanding and monitoring a process. In this section, we will discuss how the flow charts are prepared for some common milk processing operations. In fact this will also help you in understanding the methods of preparation of these specific products.

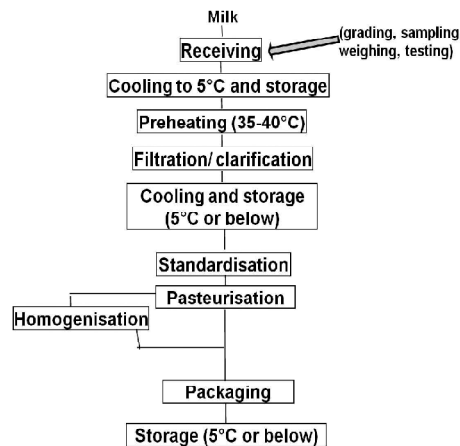


Fig. 3.2 Flow chart for preparation of pasteurized milk

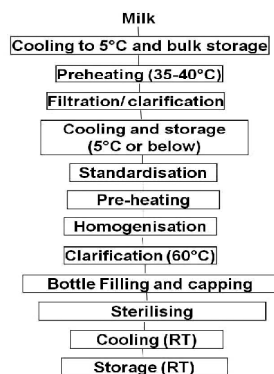


Fig. 3.3 Flow chart for preparation of sterilised milk (In-bottle sterilization)

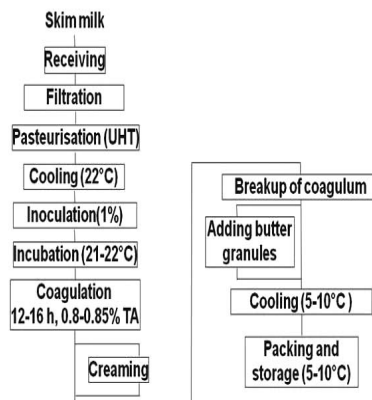


Fig. 3.4 Flow chart for preparation of flavoured milk

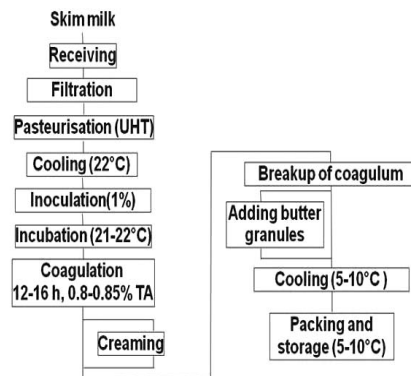


Fig. 3.5 Flow chart for preparation of butter milk

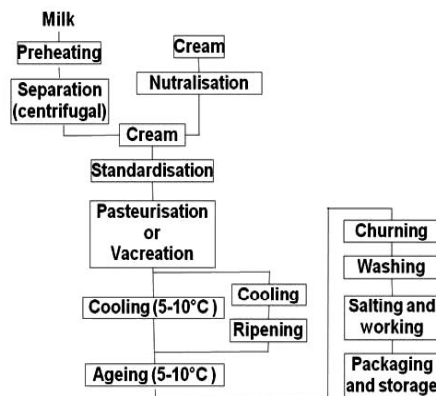


Fig. 3.6 Flow chart for preparation of butter



Fig. 3.7 Flow chart for preparation of ice cream

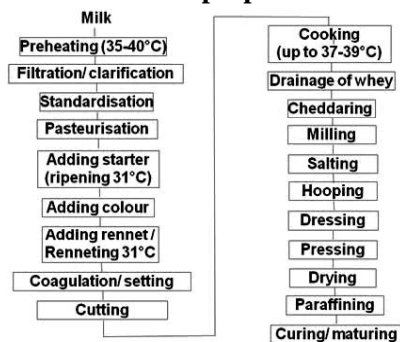


Fig. 3.8 Flow chart for preparation of cheddar cheese

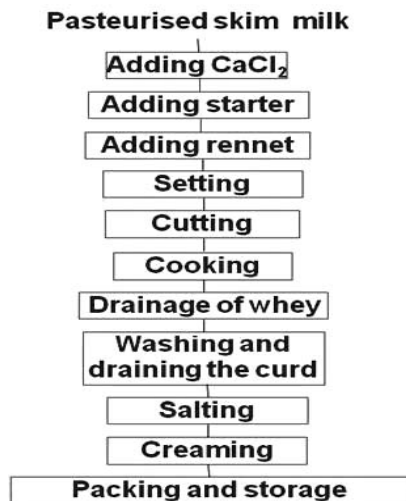


Fig. 3.9 Flow chart for preparation of cottage cheese

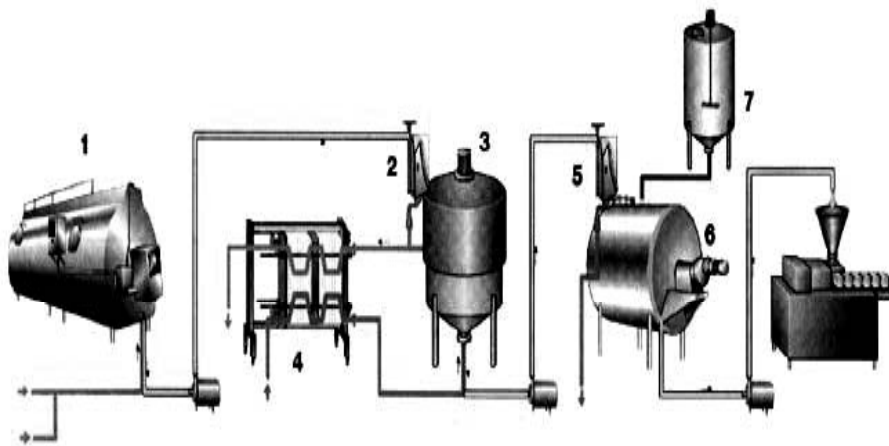


Fig. 3.10 Equipment flow chart for preparation of cottage cheese



Fig. 3.11 Flow chart for preparation of evaporated milk

PLANT LAYOUT

Plant layout is the arrangement of equipment/ machines/ facilities in a plant for the efficient functioning of the whole system with a view to maximize the profit.

We may consider any food processing operation as a transformation process. In a fruits and vegetables processing plant, the raw materials (raw fruits and vegetables) are transformed into finished product (processed fruits and vegetables) by a series of operations, whose sequence and numbers are specified for the input. For example, the sequence of operations that are carried out in an onion dehydration plant, can be shown as in Fig. 3.12.

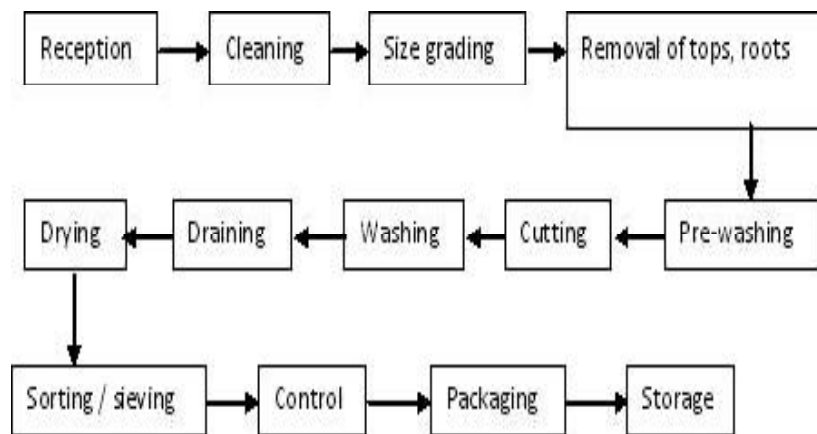


Fig. 3.12 Preparation of dehydrated onions

We can not change the sequence of these operations as per our desire. In this case, after receiving, the dust and dirt sticking to the surface of the onion bulbs must be cleaned first. Then the bulbs should be graded for size, then the tops and roots be removed, and so on. Therefore, for efficient utilization of energy, labor (these are the other inputs than the raw materials), and of course money, the cleaning section should be kept adjacent to the receiving section followed by the grading section, and so on.

Now, suppose we place the size grader between the receiving yard and the cleaning section or the drying section between the packaging section and storage section, what do you think will happen? It will unnecessarily increase the materials handling cost and time, and reduce overall performance. In addition, it will also cause collision between the workers and wastage of manpower and energy. Hence, we should arrange the work areas, equipment and auxiliary facilities judiciously in the processing plant such that the operation will be economical and the employees will feel safe and satisfying.

Thus, the arrangement of the different facilities and equipment in a food processing plant plays an important role in the overall viability of the project. This physical arrangement of the industrial facilities is known as **plant layout**. The arrangement also includes the space needed for material movement, storage, indirect labor and all other supporting activities, or services, as well as for operating equipment and personnel.

Advantages of good plant layout

In general, a good plant layout will permit simple and forward movement for the product and containers through the plant. Let us take a simple example.

In Fig. 3.13, I have shown you some equipment in boxes, in which the numbers show the sequence of operations. Say, the first operation (may be cleaning) will be done by the Equipment-1, the second operation by Equipment-2 and so on. The Equipment-6 does the packing and then the product has to be taken out of the factory. I have shown you four possible arrangements for these equipment. Which pattern or arrangement do you think will be the best to reduce the cost of operation and improve performance?

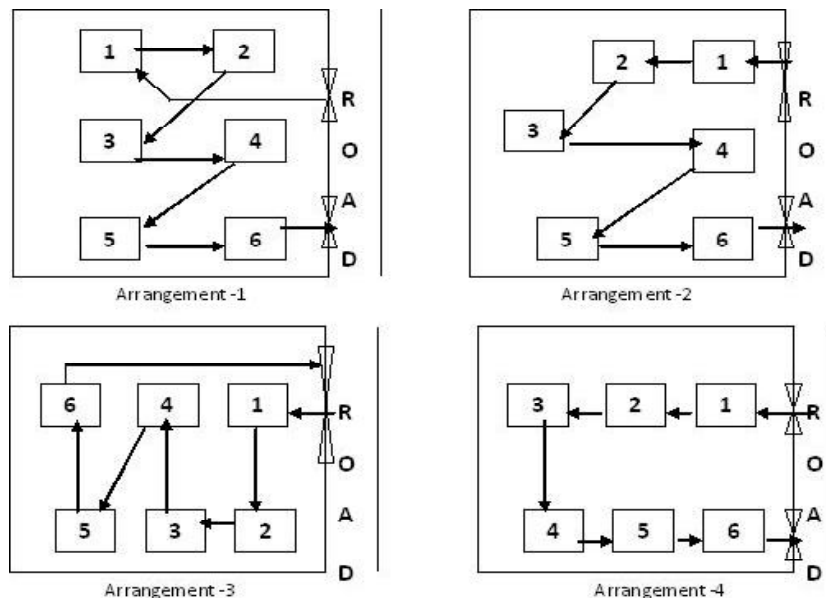


Fig. 3.13 Understanding what plant layout means

Obviously Arrangement No.4 will be the most ideal one. Remember, we are yet to learn the general guidelines for a good plant layout. However, you will definitely agree that if the machines are not properly arranged, as in the cases 1, 2 or 3, the total material movement inside the plant is unnecessarily increased. Besides, there is also crossing of the flow paths, which would interrupt a smooth operation.

The sequence of operations is one of the major criteria, but not the only criteria for designing plant layout, which we will discuss later in the unit. But as we are discussing about the advantages of a good plant layout, we see that a proper plant layout helps us in reducing cost of operation, which is very important for survival of any industry.

A good plant layout, in general, has the following advantages.

- Saving in floor space;
- Better utilization of machine and man power, and services;
- Reduced material handling, thus saving in labor and cost, less production delays;
- Reduced inventory in process, thus saving in investment and working capital;
- Increased output/ production per unit time, labor, money and energy; and
- Easier and better supervision

In addition to the above, a properly designed layout helps to maintain proper sanitation and safety standards in a plant. It reduces confusion between different sections of workers, and improves moral of the workers. All these factors directly affect the output. Careful layout planning can identify and remedy bottlenecks and trouble spots before the plant is built, and thus prevents troubles later.

Requirements / factors in planning layouts

As we have already discussed, the basic objectives of a good plant layout are smooth operation and reduced cost in handling and processing. Good layout must also include arrangement of specified areas for processing, storage and handling in efficient coordination. This should also consider the following factors.

- **Proper placement of equipment and conveying machines-** All the equipment and conveying machines should be arranged in proper coordination depending on the flow sequence and characteristics of equipment. Depending on requirements, the layout can be single level, multi storied, or combined designs.
- **Economic distribution of services-** The layout, in addition to proper placement of important equipment, should also have provision for efficient and economic distribution of water, process steam, power, and gas, etc. The distribution lines for these utilities should not interrupt the normal working of the people.
- **Suitable use of floor and elevation space-** This will depend on the type of food processing plant and the special facilities and equipment used for the system.
- **New site development or addition to a previously developed site-** If we want to plan the plant on a site, which already has some installed equipment, office rooms and storage godowns, etc., then the layout should consider these amenities. Our objectives will be to see that minimum alterations or modifications are made to the existing facilities without affecting the overall objective of the layout.

- **Future expansion-** The layout should have sufficient provision for future expansion. Suppose at this stage we are interested in a 1 tph (tonnes per hour) dehydration plant for ginger. But after some years, we want to increase the capacity to 4 tph or want to prepare dehydrated onion and garlic from the same plant. It requires installation of some more equipment. We will also need more space for go down and processing operations. In that case, we will be in trouble if the present arrangement doesn't have sufficient provision for expansion. Another alternative is to install a completely new plant in another location. It will involve some unnecessary cost and further it will also be difficult to manage two plants at two different locations. To overcome such type of difficulties, the layout should have provision for future expansion.
- **Waste disposal problems-** The layout should have adequate provision for disposal of solid, liquid and gaseous wastes. Or else, the project may not be even passed by the pollution control authorities.
- **Safety considerations-** We should keep the equipment or areas having chances of hazards like fire or explosion away from normal working of the people. For example, we should isolate the boiler room.
- **Other factors -** The building code requirement, weather conditions like extreme high or low temperatures, maximum wind speed in the area, etc. are some other factors which need to be considered during planning the layout.

Types of layouts

- There are generally two types of product flow in food processing industry, namely, **line flow process** and **intermittent flow process**. In the line flow process, the product flows from one operation to the next in a prescribed sequence as in the preparation of homogenized and pasteurised milk in an automatic dairy plant. The individual work tasks are closely coupled. There may be side flows, which impinge on this line, but they are integrated to achieve a smooth flow. In an intermittent flow process the production is carried out in batches at intermittent intervals. In this case, we can organize the equipment and labor into different work centers by similar types of skill or equipment. The product can be sent to any of the work centers as per requirement. For example, in a mango processing plant, the mango slices can be sent to a dehydrator for preparing dried mango slices or sent to the canning section for getting canned mango slices, or may be filled with syrup and frozen to prepare frozen mango slices. Similarly mango pulp can be processed in different work centers to get frozen mango pulp, mango squash, mango nectar, mango bar, mango powder or mango cereal flakes. Or, say the particular squash manufacturing section can be used for different commodities like mango, pineapple, lime or watermelon at different times. This often results in a jumbled pattern of flow. The volume of product handling can be changed easily in this type of flow.

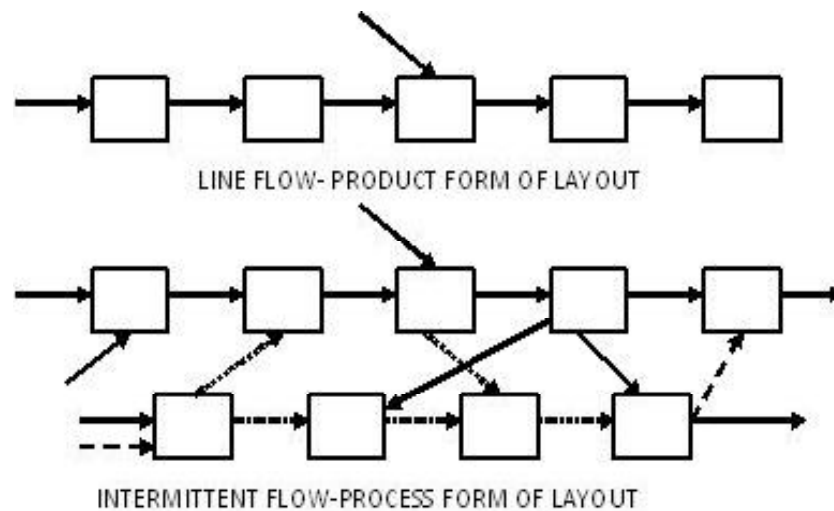


Fig. 3.14 Product form and process form of layout

- Based on the above classification of flow processes, the layouts also differ. The intermittent process is also known as a **process form of layout** as similar equipment and processing operations are grouped together. It is also known as 'layout by function'. The line flow is also called a **product form of layout** because various process equipment, and labor skills are put into sequence according to the way the product is made.
- When a product lacks standardization or the volume of product is low, the intermittent operation is economical and involves least risk. If an industry produces high volume of one or a few products, then layout by product or flow-line layout can be used. The equipment are placed in sequence, either on a straight line, or in shapes like U, L or convoluted or serpentine shape. As the raw material is processed, some products and by-products may move away from the principal direction of the flow.
- Many modifications to above flow patterns are possible. A **hybrid layout** is one, where some portions may be layout by process and some portions by product. Generally the small food processing plants have process form of layout, whereas bigger industries have hybrid layouts.
- Another type of classification of layout is single level, multi-storey or combined layout.

On the basis of the above two representative layouts have been given in Fig. 3.15 and 3.16. You will be visiting a dairy plant during this course and you will have to draw the layout plan of all the equipment and utilities in the plant. You will also have to carefully report whether the layout has taken into consideration all minute things and whether some modifications are needed in the layout of the plant.

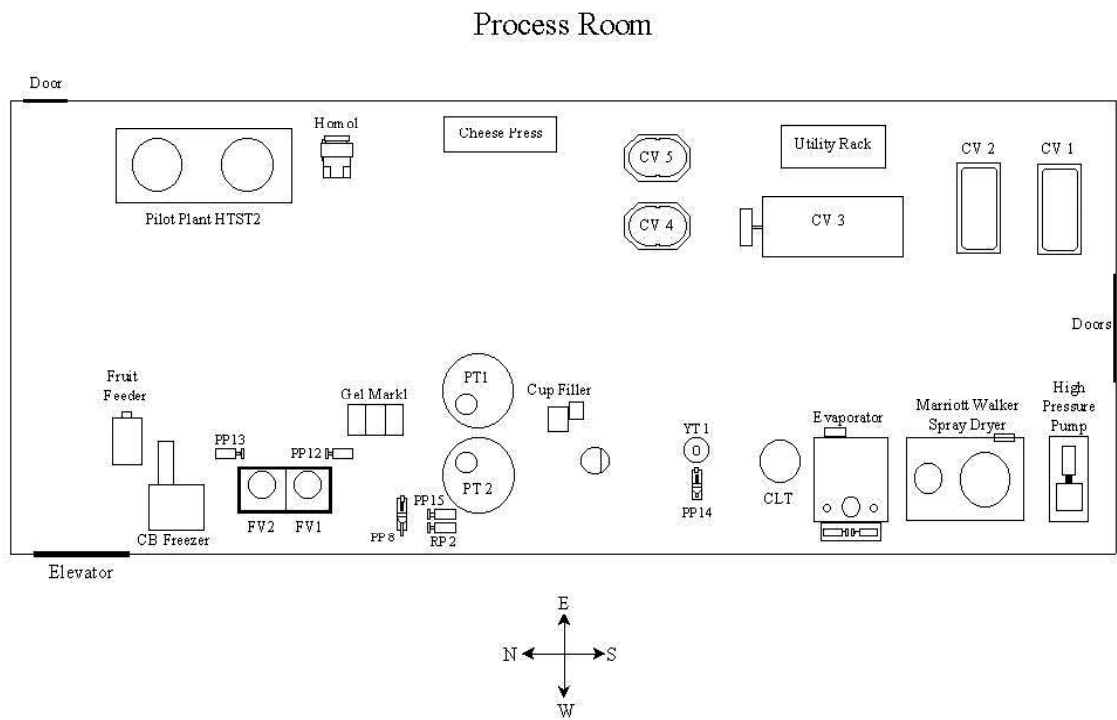


Fig. 3.15 An example of a plant layout

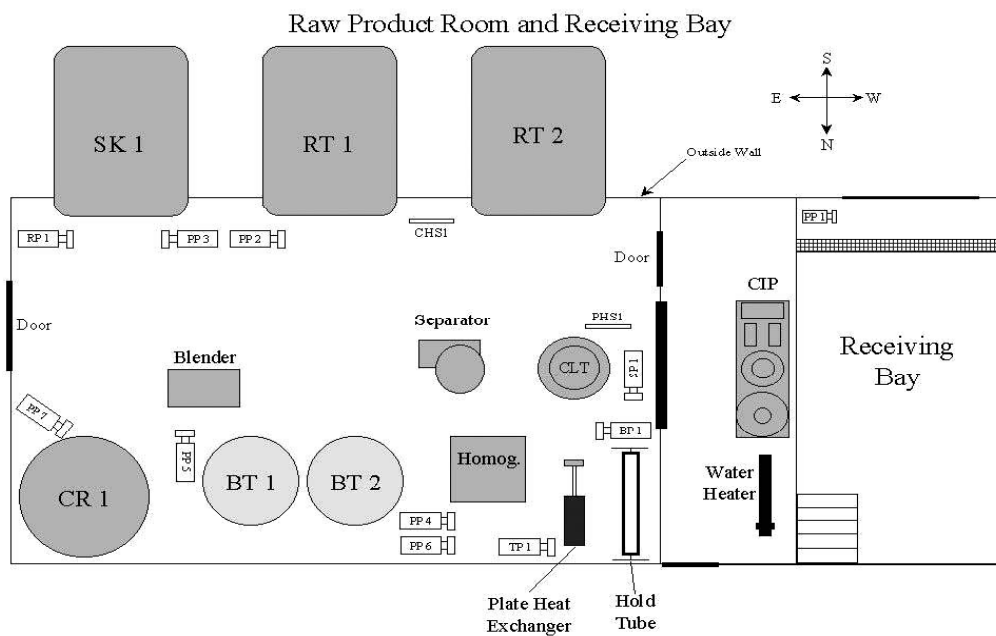


Fig. 3.16 An example of a plant layout

CHECK YOUR PROGRESS

1. Draw the layout of any dried vegetables manufacturing plant producing 100 kg product per day.
2. Draw the layout of a dairy plant that you have visited in your locality and give your critical comments about its layout modification.

The answers to the above questions should include the following.

- Flow chart
- Assumptions about capacity utilization, storage of raw and processed materials, etc.
- Type of equipment necessary
- Planning of equipment installation area
- Layout
- Your comments/analysis

Chapter 4

RECEPTION OF MILK

(Milk reception in cans, Receiving section for bulk milk, Milk transport tank, Storage tank, Process tank, Standardization of milk)

MILK RECEPTION FOR THE CANS

Milk is received in the processing plant from the primary producers or the milk collection centers. Usually they are transported by cans or bulk containers (milk transport tanks or vans).



Fig. 4.1 Milk can (usual capacity 20-40 litres)

- The first stage of reception involves emptying of cans over the tip tank or weigh tank. Emptying cans over the tip-tank can be done either by hand, or by hand assisted method or by mechanical methods (inverter). The process of inversion may be a serious source of contamination of the tipped milk by soil from can exteriors.
- In some canneries, the can is not completely inverted (the base of can is never directly above the surface of milk).
- After weighing and recording of consignment, the contents are discharged into a tank immediately below the tip-tank, from which the milk is pumped through a cooler to a storage tank.
- Where milk is measured volumetrically, the cans are tipped directly to the tip tank from which milk is pumped to the cool



Fig. 4.2 Weigh tank

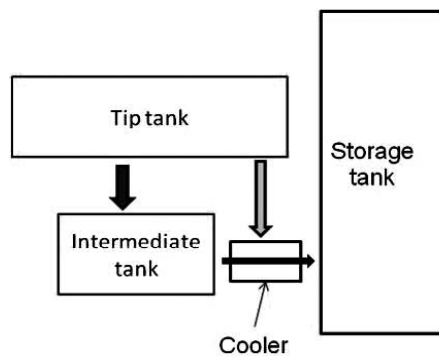


Fig. 4.3 Arrangement of tanks in milk reception section



Fig. 4.4 Bulk milk Coolers

The following approach is done for the mechanization of milk reception sections of dairy plants.

- Power driven or gravity roller conveyors are used for conveying of the milk cans.
- Tipping may be manual or completely automatic.
- The inverted can is moved in that position to the drainage rack and into can washer.

RECEIVING SECTION FOR BULK MILK

The receiving section for the bulk milk may be divided into three subsections as follows.

- Preparing to unload
- Unload
- Weigh

The different activities carried out in these subsections are shown in Fig. 4.5.

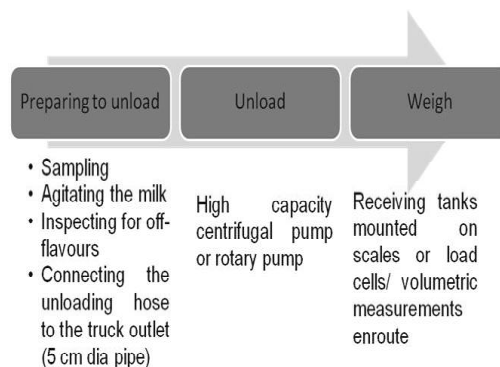


Fig. 4.5 Activities during the receiving of milk

Modern dairy plants use air operated valves to control flow in the receiving operation and CIP systems for tankers, tanks and pipelines. Unloading is done by large stationary pump. Plastic hoses are used for the purpose.



Fig. 4.5 Milk reception for bulk milk containers

Methods for measuring bulk milk

- Weighing or measuring tankers
- Weighing in receiving or storage tanks (with load cells)
- Metering
- Liquid level measurement in storage tank
- Weighing of trucks on scales before and after emptying
- Sanitary meters are used in a number of plants, in which the measurement is by determining volumetric displacement, mass flow rate or velocity.

MILK TRANSPORT TANKERS

- Usually the milk tankers have capacities of more than 12000 ltr (7500-25000 ltr).
- The basic features of milk transport tanks are:
 - Inner shell of stainless steel (18% Cr and 8% Ni)
 - Intermediate thick insulation layer (cork, plastic foam, mineral wool, etc.)
 - Outer jacket (ordinary carbon steel, Al, s.s.)
 - Necessary fittings
- Stainless steel is preferred for long life, low maintenance cost, and excellent appearance, but they are costlier.
- If the milk tank incorporates a pump, hose, flow meter, or other utensils necessary for collection of milk, then it is called *bulk milk pick-up tank*.

There are three important considerations during unloading from milk transport tanks

- Safety
- Temperature
- Agitation

The agitation of milk is very important and is required when the milk is to be delivered to two or more storage tanks. Further, when the milk is stored for some time, the fat will have a tendency to settle and there will be non-uniform distribution of milk fat in the milk. In that case agitation is required for uniform butter-fat distribution. For the purpose, built in electrically driven horizontal agitators are provided in the milk tanks.

STORAGE TANKS

In a dairy plant, storage tanks are used for raw products, pasteurized products and for processed products as well.



Fig. 4.6 Different applications of storage tanks

Storage tanks for raw milk

Usually milk is held up to a maximum of 72 hours between reception and processing in the tank. The tanks may be cylindrical or oval. They may also be horizontal/ vertical.

The storage tanks are often kept outdoors with heads extended through the wall into processing room.

Main considerations

The temperature and sanitation are the two main considerations in a milk storage tank.

Temperature. Milk temperature is maintained at less than 7°C.

Sanitation

- Tanks must be designed for sanitizing, preferably for CIP.
- Surfaces must be smooth, polished and welds in particular have to be made flush, polished and pickled.
- All closed type tanks must be equipped with a manhole, either round (dia about 450 mm) or oval in shape, to permit access to the interior for cleaning and inspection. These are fitted with swing covers.
- Head space of approximately 15 cm.

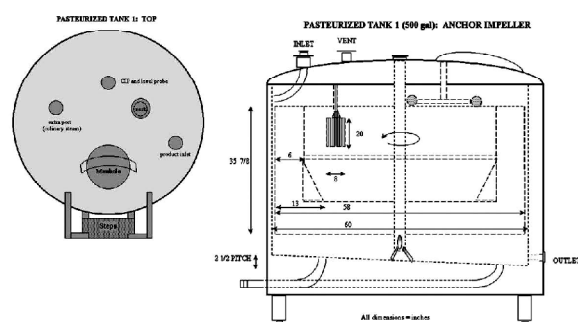


Fig. 4.7 Different parts and accessories of milk storage tanks

Storage tank- accessories

- A curved filling pipe which guides the milk towards the wall (for foam free entry of milk). It is always better to fill the tank from below.
- Viewing ports and lights, spray heads and rotating heads (for cleaning) in the head space.
- Air vent (with screen) of sufficient size to prevent excessive pressure during filling and vacuum during emptying.
- Thermometer probes
- Liquid level gauges (may be a sanitary float with external indicator)
- Agitators (for assuring uniform composition to aid in standardizing, and to improve cooling efficiency in refrigerated storage tanks- may be vertical/ horizontal).

Milk silo

The milk silos are usually of the capacities of 50,000-100000 tonnes. The silos are useful in that they can hold large amount of product in less area. Other considerations are

- Bottom slope 6%.
- Control panel to show temperature, pressure, etc.
- Electrode at the drainage line to indicate when tank becomes empty.



Fig. 4.8 Milk Silos

The milk silos should be provided with some device for agitation to avoid cream formation. The following points should be considered while providing the agitators in the tank.

- Agitation should be smooth. Vigorous agitation causes aeration of milk and fat globule disintegration. Aeration also exposes the fat to lipase in the milk.

- Propeller agitator is preferred.
- For very tall tanks, two agitators may be provided at different levels.

Refrigerated storage tank

- Must cool the milk to a required temperature in a specified time.
- Must maintain the milk below a specified temperature.
- Must maintain the milk below a designated maximum when milk is added.
- In most cases, there is a jacket around the tank for circulation of chilled water or refrigerant.

Process tanks

- Used for treatment of product.
- Examples are ripening tanks for butter cream and for cultured products such as yoghurt, and crystallization tanks for whipping cream, and tanks for preparing starter culture.

Aseptic tank

- Used to store UHT processed milk if it is necessary to have an intermediate tank between sterilizing plant and packaging machine.
- When part of a plant is out of operation (for instance when it has to be cleaned or because there has been a breakdown), a total shut down is not necessary.
- Should have strong and thick walls (as it has to be sterilised together with product pipes by dry steam at pressure of 3 to 5 kg/cm², before it can be used).
- There should be cooling jacket for cooling the milk immediately after steam sterilization.
- Before the UHT milk enters the tank, it must be ventilated with sterile air to drain away any condensate which may have formed.



Fig.4.9 Processing tanks for milk

STANDARDIZATION OF MILK

Standardization of milk can be defined as the process of adjusting the fat concentration of milk. As we have discussed earlier, in India the standardized milk has 3% fat and 8.5% SNF. So it is usual that when the dairy plant receives milk with higher fat content, they take out some of the fat by the process of cream separation and send the 3% fat milk to market. In certain situations, the cream and SNF are added to skim milk to prepare milk with desired fat content. We will discuss about the standardization process with some examples.

Case I. You have received 100 kg of cow milk with 4.5% fat. How much water is to be added to it to make it to 3% fat?

By using mass balance equation, you can calculate the amount of water to be removed.

The raw material has 4.5% fat and the final fat requirement is 3%.

Let the amount of water added be 'x'

So, we have, $100 \times 4.5\% = (100+x)3\%$, i.e. $100(0.045) = (100+x)(0.03)$

or, $100 + x = 4.5 \div 0.03 = 150$

or, $x = 50$ kg

Hence, 50 kg of water is to be added to make the fat to 3%.

Case II. You have 100 kg of cow milk with 4.5% fat, if you add 20 kg of water in that, what will be the final fat percentage?

You have 4.5% fat in 100 kg milk

Now, you have added 20 kg of water to it,

So, the final fat percentage = $(4.5 \div 120) \times 100 = 3.75\%$.

Case III. You are having 100 kg of the milk with 2% fat. What should you do to get the final fat of 3%?

In 100 kg you have 2% fat.

The final fat percentage will be 3%, so you must remove some water from it or add some cream to it.

If you will be removing water then as per mass balance

$$100 \times 0.02 = (100-x) \times 0.03$$

$$\text{So, } 100 - x = 66.6$$

$$\text{So, } x = 33.4 \text{ kg}$$

That is, you will have to remove 33.4 kg of water from the milk to bring it up to 3% fat.

Remember that in all the above cases we have used the mass and component balance equations as

$$F = P+V \quad (A)$$

$$F.X_f = P.X_p \quad (B)$$

Case IV. What should be the ratio of the milk with 4.5% fat and water to be added so that the final milk is of 3% fat?

In this case we can directly apply the mass (in this case, fat) balance equations.

$$(F_1 \times X_{F1}) + (F_2 \times X_{F2}) = P \times X_p$$

Here F_1 corresponds to 4.5% fat milk, F_2 corresponds to water and P corresponds to final milk.

So, we have to calculate $F_1 : F_2$

Also, $F_1 + F_2 = P$.

We can write the above equation as

$$(F_1 \times X_{F1}) + (F_2 \times X_{F2}) = (F_1 + F_2) \times X_p$$

$$\text{or, } (F_1 \times 0.045) + (F_2 \times 0) = (F_1 + F_2) \times 0.03$$

$$0.015 F_1 = 0.03 F_2$$

$$\text{or, } F_1 : F_2 = 2 : 1$$

Case V. What should be the ratio of milk with 3% fat and cream with 45% fat to get the final milk with 4.5% fat?

Using the mass balance equation,

$$(F_1 \times X_{F1}) + (F_2 \times X_{F2}) = P \times X_p$$

Here $X_{F1} = 0.03$, $X_{F2} = 0.45$ and $X_p = 0.045$

We have to calculate $F_1 : F_2$

Also, $F_1 + F_2 = P$.

$$\text{Now, } F_1(0.03) + F_2(0.45) = P(0.045)$$

Substituting $P = F_1 + F_2$

$$F_1(0.03) + F_2(0.45) = F_1(0.045) + F_2(0.045)$$

$$0.405 F_2 = 0.015 F_1$$

$$\text{Or, } F_1 : F_2 = 0.405 : 0.015$$

$$\text{i.e. } F_1 : F_2 = 27 : 1$$

Case VI. If you add 27 kg of 3% fat milk with 1 kg of 45% fat milk, then what will be the final fat percentage?

This is the case to check whether the calculations made in the previous case are correct.

As per the mass balance equation,

$$27 \times (0.03) + 1(0.45) = 28 \times X_p$$

$$X_p = (0.81 + 0.45) / 28 = 0.045 \text{ or } 4.5\%$$

So, the final percentage of fat is 4.5%.

Case VII. What should be the ratio of milk with 1.5% fat (doubled toned milk) and 80% cream to get the final milk with 3% fat?

Using the mass balance equation,

$$(F_1 \times X_{F1}) + (F_2 \times X_{F2}) = P \times X_p$$

Here $X_{F1} = 0.015$, $X_{F2} = 0.8$ and $X_p = 0.03$

We have to calculate $F_1 : F_2$

Also, $F_1 + F_2 = P$.

Now, $F_1(0.015) + F_2(0.8) = P(0.03)$

Substituting $P = F_1 + F_2$

$$F_1(0.015) + F_2(0.8) = F_1(0.03) + F_2(0.03)$$

$$0.77 F_2 = 0.015 F_1$$

Or, $F_1 : F_2 = 0.77 : 0.015$

i.e. $F_1 : F_2 = 51.333 : 1$

The above problems in case V and VII can be solved easily by another method as follows.

The steps are as follows.

1. First we draw a square as shown below.
2. On the left top and bottom corners, we write the fat percentage of the raw materials.
3. At the centre of square we write the final fat percentage.
4. Then we write the differences in between the fat percentages on the other corners.
5. The values that we get on the opposite corners are the ratios of the materials to be added.

As an illustration, let us resolve the case VII.



The values will be as shown in Figure. Remember that on the extreme right top corner 1.5 is the difference between 1.5 and 3, and the right bottom corner value 77 is the difference between 80 and 3. Thus the ratio of 1.5% milk and 80% cream will be 77:1.5 or 51.33:1.

In this case 77 kg of 1.5% fat milk will be added to 1.5 kg of 80% cream to make 78.5 kg of 3% fat milk.

This method is known as Pearson's square method.

Case VIII. What should be the ratio of 3% fat milk and 65% cream to make a product of 5% fat milk?

We can solve this type of problem by using “Pearson’s square” method.



So after writing all the values in the square, we can straight away write that 60 kg of 3% fat milk will be added to 2 kg of 65% fat cream to give 62 kg of 5% fat milk.

Case IX. What should be the ratio of 3% fat milk and 88% cream to make a product of 3.5% fat milk?

You may draw the figure accordingly to find that 84.5 kg of 3% fat milk will be added to 0.5 kg of 88% cream to get 85 kg of 3.5% fat milk.

CHECK YOUR PROGRESS

1. Write short notes on
 - a) Milk reception by cans
 - b) Receiving of bulk milks
 - c) Milk transport tanks
 - d) Accessories in storage tank (explain and indicate why they are essential)
 - e) Sanitation of milk storage tank
2. What are the methods for measuring bulk milk?
3. What are the important considerations during unloading of bulk milk tanks?
4. Explain the different types of milk silos.
5. What should be the ratio of skim milk (0.5% mf) and 82% cream to make a product of 3% fat milk?
6. In the above example, what will be the proportions, if we want to make 2.5% fat milk.

Chapter 5

PASTEURIZATION

(Objectives of pasteurization, Pasteurization requirements for milk, Methods and equipment for long hold batch type pasteurization, HTST pasteurization, UHT pasteurization)

Pasteurization is the process of heating the product to a predetermined temperature and holding it until all or nearly all objectionable microorganisms, which may be present, are killed. (This was developed by Louis Pasteur, 1960)

Objectives of pasteurization

- To make the product safe for human consumption by destroying the pathogenic organism, which may be present.
- Improves preservation quality by destroying almost all spoilage organisms.
- Helps to retain good flavor over a longer period of time.

Pasteurization requirements for milk

Pasteurization by heating and time treatments are a compromise among bacterial killing along with a number of other factors such as taste, phosphate inactivation, cream line reduction, etc. The target microorganism for milk processing is *Micobacterium tuberculosis* (TB germ). The following Table 5.1 shows how the pasteurization process has been standardized considering these factors. Accordingly, the methods of pasteurization can be given as in Table 5.2.

Table 5.1. Standardization of pasteurization requirements for milk

Requirement	30 min	15 sec
Kill TB germ	138°F	158°F
Phosphate inactivation	142°F	160°F
Pasteurization requirement	145°F (63°C)	161°F (72°C)
Creamline reduction	146°F	162°F

Table 5.2. Methods of pasteurization for milk

Methods	Treatment
Long hold batch type / Vat pasteurization	63°C-30 min
High temperature short time (HTST) pasteurization	72°C-15 s
Ultra high temperature (UHT) pasteurization	88°C-3 s

However, the time and temperature combination maintained in a dairy plant may vary from the above Table values depending on the initial microbial load and other considerations.

LONG HOLD OR VAT PASTEURIZATION

The long hold or vat pasteurization is a batch type method where the pasteurization is carried out at 63°C for 30 min. The basic operations involved in a vat pasteurizer are given in Fig. 5.1.

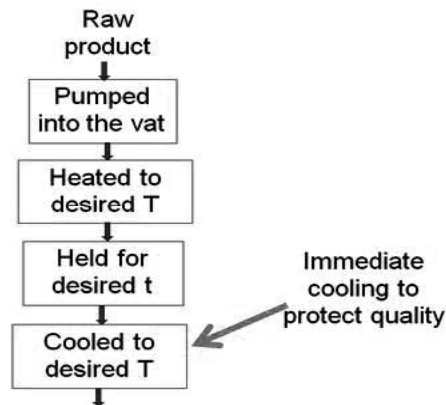


Fig. 5.1 Basic operations in a vat pasteuriser

Types of vat pasteurizers (Classification based on flow of heating medium)

1. Spray type
2. Flooded type
3. High velocity flooded type

General requirements

The following are the requirements for a successful batch pasteurization process.

- **Rapid heating:** Generally the circulation of heating medium is started as soon as filling of the vat is begun, thus shortening the heating time.
- **Immediate cooling:** In some designs the cold water is circulated over the outside of the inner lines as soon as the holding period is completed, so a part of cooling can be done in the vat itself.
- **Heating medium** should be only a few degrees warmer than milk to prevent formation of milk stones on heating surfaces and cause minimum injury to cream line or flavour.
- **Agitation.** Agitation of milk within a certain degree helps in improving the heat transfer.
 - Agitation is easier in case of hot fluid than cold ones.
 - Agitation should not develop foam and it should not injure the cream line.
 - Viscosity of the fluid greatly affects the type of agitator.
 - Less viscous materials require small diameter high speed agitator. Highly viscous materials require slow speed large surface blade type agitators.

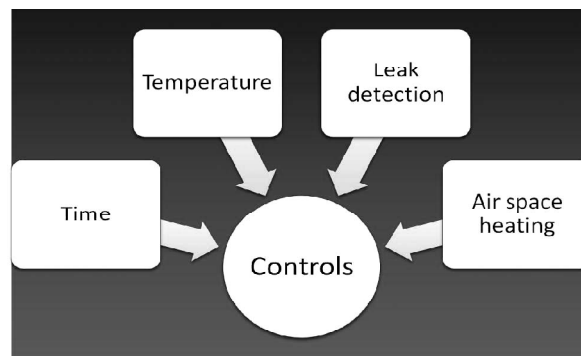


Fig. 5.2 Pasteurizer Controls

For vat pasteurizers, an electric or air operated control can be connected with a timing clock so that the heat is shut off when the proper milk temperature has been reached and a bell rings when the proper length of holding time has elapsed. Also temperature of heating water can be controlled during the holding period.

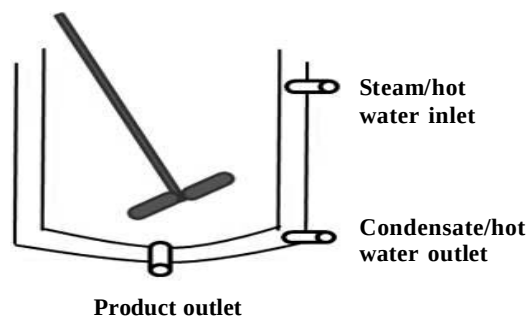


Fig. 5.3 Schematic representation of a long hold batch type pasteurizer

Advantages

- Well suited for small plants, low volume products
- Variety of products can be handled.
- Well suited for cultured products such as bottle milk, sour cream, etc.
- Simple controls
- Low installation cost

Disadvantages

- Batch type
- Slow process
- As the controls are mostly manual, it requires constant attention.
- Both heating and cooling are relatively expensive (as we do not have heat regeneration).

HTST PASTEURIZATION

High temperature short time pasteurisers are usually continuous flow systems using heat exchangers. Generally plate type heat exchangers with regenerative heating, heating and cooling systems are used.

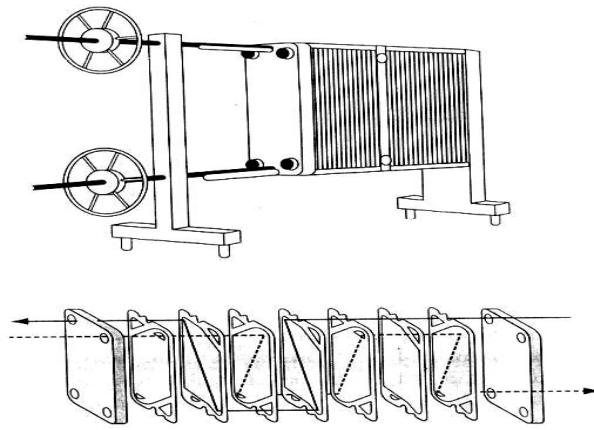


Fig. 5.4 Plate heat exchanger

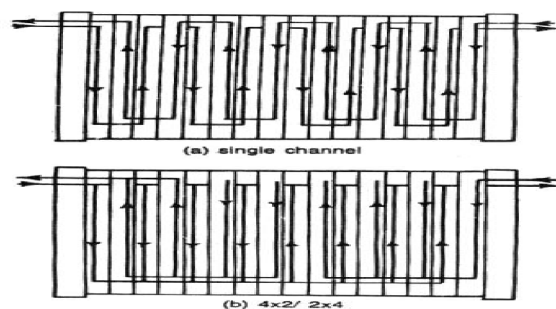


Fig. 5.5 Flow pattern in plate heat exchangers

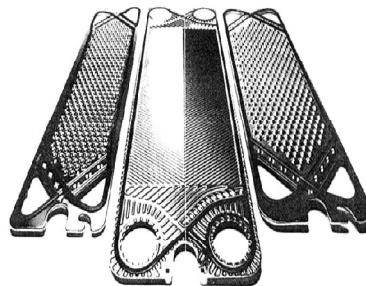


Fig. 5.6 Types of plates used in plate type heat exchanger

Basic components of HTST pasteurization system

The HTST pasteurization process and its basic components are shown in Fig. 5.7. First from a constant level tank, milk is pumped by a booster pump into a heat exchanger to heat it with the help of pasteurized milk to about 60°C. As the pasteurized milk is used for heating the raw milk and there is no external heating source, we call that a regenerative heater. The regenerator reduces the actual heat requirement for pasteurization and hence is very important for the overall cost effectiveness of the system. Then the milk enters into the heater where the temperature of milk is raised to the actual pasteurization temperature. The milk then passes through the holder, where the milk temperature is maintained for the specific time so that pasteurization is completed. Then the pasteurized milk goes to the regenerator so that it gives away some heat to the raw milk. It is also simultaneously cooled so that the refrigeration requirement is reduced. After the regenerator, the pasteurized milk goes to a chiller, where the milk temperature is reduced to about 4-5°C.

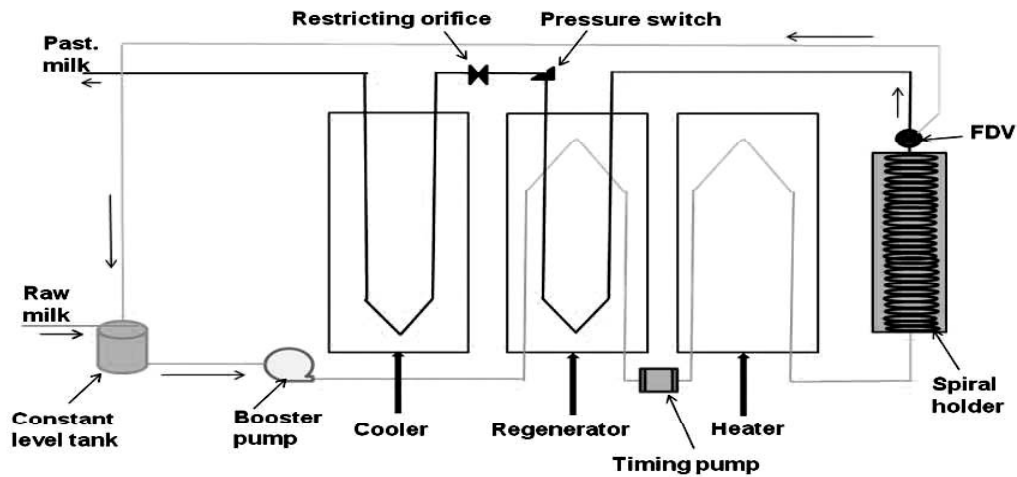


Fig. 5.7 HTST pasteurization process



Fig. 5.8 A HTST pasteurizer

For HTST pasteurization, the following controls are very important.

- Flow rate
- Temperature
- Pressure

Control for flow rate

- The flow rate is regulated by a metering or timing pump
- A positive displacement pump of rotary or piston type is used.
- Often variable speed drives are used to change the rate of flow when desired.
- Pump must be sized and perfectly driven such that flow rate does not exceed the actual, i.e. the holding time is not below legal minimum.

Control for temperature

- Control of temperature includes means for maintaining a uniform product temperature at or above the legal minimum at a safe value.

- It should divert the flow back to the system if the temperature at the end of holder is below legal minimum.
- Usually a safety thermal limit recording controller is used. (It makes a continuous record of the temperature and marks the time when the flow diversion valve operates.)

Control for pressure

The pressure control is important in the following three sections.

- In the regenerators
- In the flow diversion valve
- In the diverted milk lines (for homogenization, etc.)

Pressure related problem in the regenerator

The different causes and effects of pressure related issues in a pasteurization system are given in Fig. 5.9. As it can be seen, the centrifugal booster pump takes care of the pressure related problems in the regenerator. Besides, there are three more devices as the timing pump, pressure switch and the restrictor, the functions of which are given below.

- Timing pump: It assures that the pasteurized product side is always under higher pressure than the raw side in the regenerator.
- Pressure switch: It will allow the pump to run only when the pressure in pasteurized side is at least 1 psi more than the raw side.
- Restrictor: It is an additional device to satisfy the minimum 1 psi difference if the cooler section does not produce enough back pressure on the pasteurized side.

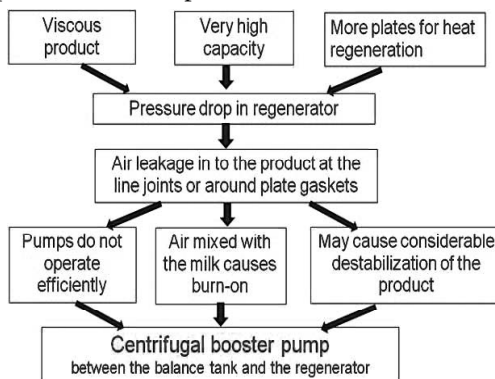


Fig. 5.9 Use of booster pump in a pasteurization system

Pressure management in the flow diversion valve

- The thermal limit recorder not only makes a record of the temperature of the milk, but also indicates, records and controls the action of the flow diversion valve.

Pressure management in diverted milk line

- The other pressure management is needed on the diverted milk line, since it may affect the holding time during diversion.

- If the holding time during diverted flow is shorter than that in forward flow, a restricting orifice should be placed in the divert line.

Main parts of HTST pasteurizer

Now that we have discussed the process and the controls required during the process, we can write down the main parts of HTST pasteurizer as follows.

- Constant level tank
- Regenerator
- Booster pump
- Timing pump
- Heater
- Holder
- Flow diversion valve
- Pressure switch
- Restricting orifice
- Cooler

Important accessories

- Leak detector valves at all inlet and outlet pipes.
- Air space heaters (Air space heating is done by introducing steam above the level of the product).

Advantages of HTST pasteurization

- Uniform treatment.
- Temperature is regulated at close limits and overheating is prevented.
- Economical than batch systems (due to regenerative heating).

Disadvantages

- The system is complicated.
- Not portable.
- Installation cost is more.

ULTRA HIGH TEMPERATURE (UHT) PASTEURIZATION

As we have discussed previously, the UHT pasteurization process involves heating the milk at a temperature of 88°C for 3 sec. The equipment is much the same as the HTST units and the controls are also similar, but the operating temperature is higher. The holder is much smaller for smaller pasteurizing time.

Advantages

- Better texture of milk due to short holding time
- Greater bacterial destruction is possible.

When UHT treatment is needed for greater bacterial destruction or its beneficial effect on the body and texture of ice cream, then the treatment may be given following regular pasteurization.

Pasteurization and homogenization

- Since nearly all fluid milk and ice cream mix etc. are homogenized, homogenizers are integrated to the continuous pasteurization process.
- As the homogenization temperature must be at least 60°C, the homogenizer must be located either between the regenerator and heater or after the heater.
- The equipment, when installed, should not reduce the holding time below the legal minimum either when they are operating or when they are at rest.
- The capacity of the homogenizer can seldom be synchronized exactly with the timing pump unless a vented cover or other relief valve is employed, and then the pump operates at slightly greater capacity than the homogenizer.
- The usual practice now a day is to use homogenizer having 3-8% greater capacity than the maximum flow rate of the system. They are equipped with a recirculation, by-pass loop from the discharge line to the suction feed line.
- Here the timing pump regulates the flow rate of the system at all the times.

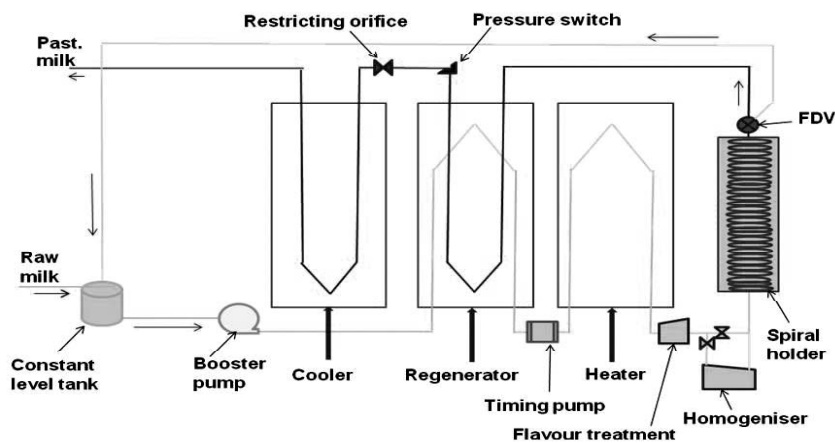


Fig. 5.10 Homogenizer incorporated in HTST pasteurization system

Like homogenizers, clarifiers and separators may also be integrated into the lines of HTST and UHT systems.

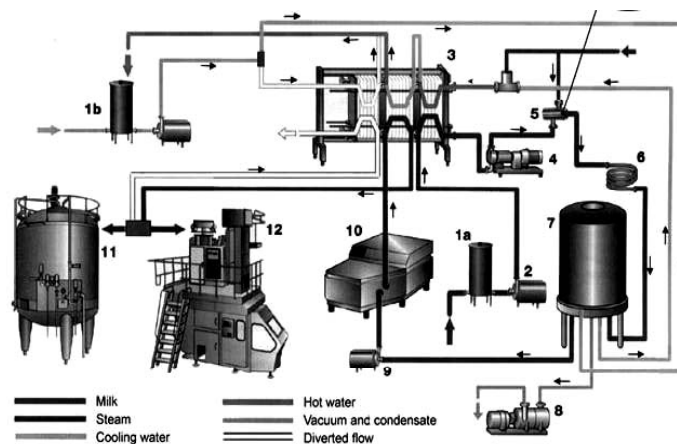


Fig. 5.11 UHT process with heating by direct steam injection combined with plate HE

(1a: Balance tank milk, 1b: Balance tank water, 2: Feed pump, 3: Plate heat exchanger, 4: Positive pump, 5: Steam injection head, 6: Holding tube, 7: Expansion chamber, 8: Vacuum pump, 9: Centrifugal pump, 10: Aseptic homogenizer, 11: Aseptic tank, 12: Aseptic filling)

Uperization (Ultra-pasteurization)

This is another method of pasteurization and the unit operations involved in the process are given in Fig. 5.12.

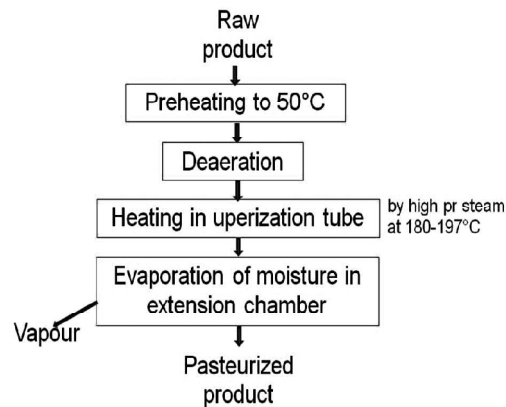


Fig. 5.12 Uperization process

The process involves heating the milk with high pressure steam at 180-197°C. The milk is heated to 150°C for less than 1 sec to obtain the desired effect of pasteurization.

Vacreation

- The process of heat treatment under vacuum in stainless steel chamber is known as vacreation.
- Vacreation is normally done for cream used in manufacture of butter.

The purpose of vacreation is to

- Kill bacteria,
- Inactivate enzyme,
- Remove undesirable odors and flavors,
- Deaeration to expel dissolved air and finely dispersed bubbles.

The system consists of a product feed pump, steam pressure controller, a temperature-recorder controller, vacuum controller, milk inlet controller, concentration ratio controller. The equipment is called 'Vacreator' (trade name adopted from Protech engineering, NZ).

Care and maintenance of pasteurizing equipment

- Keep all surfaces clean
- Routine preventive maintenance and adjust controls
- Proper care and lubrication of gasket
- Lubrication of motor, pump and other necessary equipments
- Thermometers and control equipments should be checked for accuracy. Replace if out of tolerance.

Flavor treating system of milk

The milk may contain flavors, which are mainly as follows.

- Flavor which is made of volatile component
- Weed and feed flavor

When it is desired to remove flavor, the following methods are adopted.

- Aeration
- Vacuum flashing or distillation
- Steam injection followed by vacuum washing

The volatile substances can be removed by aeration. The fat and soluble flavors are removed by steam washing method.

Types of flavor treating equipment

Vacuum alone type

- Deaeration with no vaporization of the product
- Vaporizing unit

Steam vacuum unit

- Temperature control steam supply type
- Excess steam supply type / steam washing

The vaporizing unit is placed immediately after the flow diversion valve.

CHECK YOUR PROGRESS

1. Explain the differences between blanching, pasteurization and sterilization.
2. Explain the basis of selection of temperature and time for pasteurization.
3. What are the different methods of vat pasteurization ? Explain the specific care to be taken during batch type pasteurization with a mention of the pasteuriser controls.
4. What are the relative advantages and disadvantages of batch pasteurisers over continuous pasteurisers ?
5. Draw the flow chart of HTST pasteurization system and explain the flow process.
6. How the temperature, flow rate and pressure are controlled in HTST pasteurisers ?
7. Mention the different component of an HTST pasteuriser and explain the function of each component.
8. What are the relative advantages and disadvantages of HTST pasteurisers over batch pasteurisers?
9. Write a short note on UHT pasteurization.
10. What type of heat exchangers are used in UHT pasteurization systems ? Explain briefly the working principle of those heat exchangers.
11. Mention the special cares needed if you want to incorporate a homogeniser in the HTST system.

Chapter 6

STERILIZATION

(Objectives of sterilization, Methods of sterilization, In-bottle sterilization, UHT sterilization, Means to reduce fouling in heat exchangers)

Objective of sterilization

The sterilization is the process of heating to a high enough temperature (usually more than 100°C) for specific time to kill almost all bacteria. The sterilized milk can be stored at room temperature for a long period of time.

The sterilization of milk has the following characteristics.

- Temperature more than 100°C is used in the process.
- No chilling is required for storage. Excellent storage life at room temperature.
- High operating pressure is employed to prevent milk from boiling at the processing temperature.

Methods of sterilization

In general there are two methods of sterilization.

Conventional method: Packaging is done before heat treatment. The processing is usually carried out at 105-110°C for 30-45 min. It is also known as In-bottle sterilization.

UHT or aseptic method: Packaging is done after heat treatment. The ultra high temperature short time (UHTST) and very high temperature short time (VHTST) processes come under this category. The processing is at 135-150°C for 1-20 seconds. Then the commodity is packed aseptically.

The difference between the conventional method and aseptic processing method can be better understood with the help of Fig. 6.1.

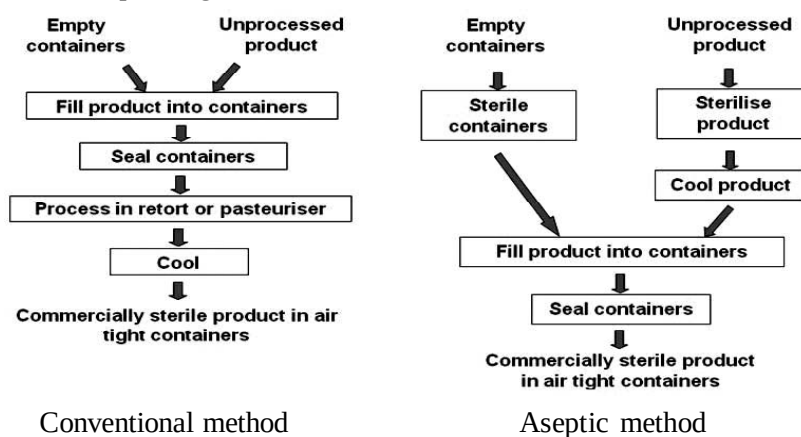


Fig. 6.1 Difference between conventional and aseptic processing methods

CONVENTIONAL CANNING/ IN-BOTTLE STERILIZATION

The in-bottle sterilization method can be further categorized as batch or continuous types. The basic flow chart to explain the in-bottle sterilization is given in Fig. 6.2.

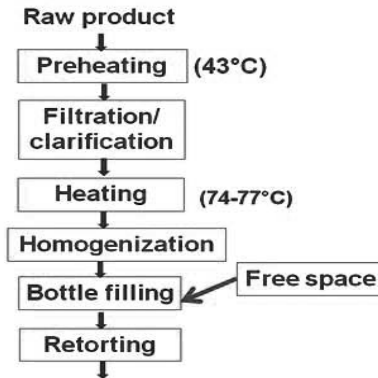


Fig. 6.2 In-bottle sterilization process

Batch sterilization

The equipment which is used for the sterilization process is called a retort and the processing is often called retorting. The batch retorts can be either horizontal or vertical type. The retort has a lid or door with good fastening. It has necessary controls for temperature, pressure and safety devices. They can also be of circular or rectangular cross section.



Fig. 6.3 A horizontal retort

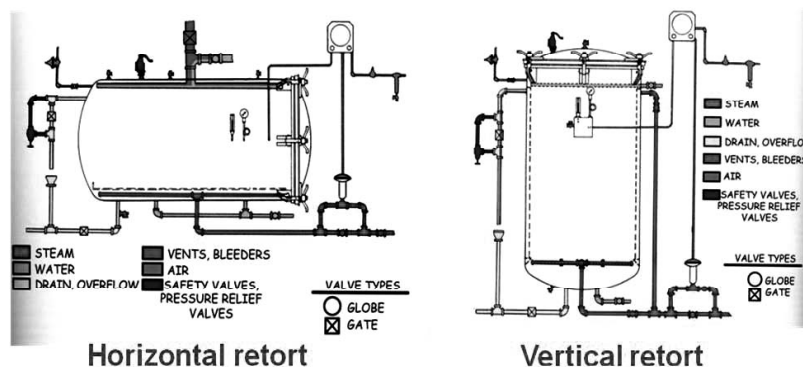


Fig. 6.4 Basic parts of retort

The batch retorting process can be explained as follows.

- The bottles are loaded onto crates and then the crates are travelled into sterilizer with the help of a trolley/truck.
- After the commodity is packed, the door is closed, the vessel is supplied with steam at required pressure.
- The processing time and pressure are properly maintained by controls.
- After desired processing time, steam is vented to atmosphere.
- After this the crates (bottles/cans) are immediately cooled by air (fans) to avoid further cooking of the product.

Water spray or cascading water retort

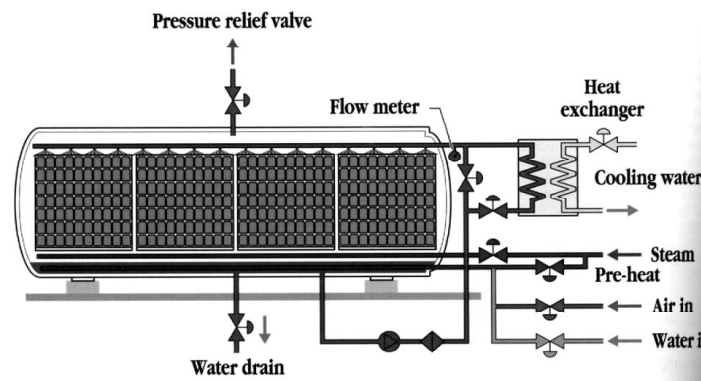


Fig. 6.5 Water spray or cascading water retort

The characteristics of water spray or cascading water retort are as follows.

- It uses a low volume of water.
- Water does not completely cover the containers during processing, but instead sprays or cascades (showers) on the containers.
- The system collects (draws) water from the bottom and reintroduces through sprays from the top and mid-section of the vessel to heat or cool.
- Heating of water is done internally by steam spreaders.
- Air is the source of overpressure.

Rotary batch sterilizer

This sterilizer agitates milk during heating by rotating the load of bottles about a horizontal axis.

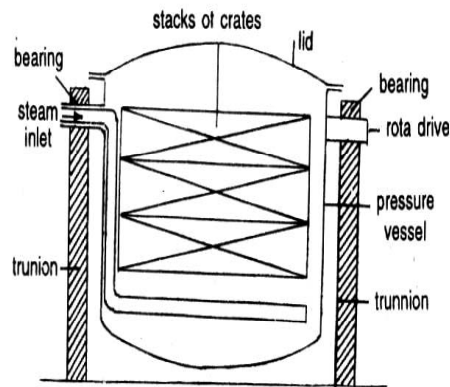


Fig. 6.6 Rotary batch sterilizer

Hydrostatic retort

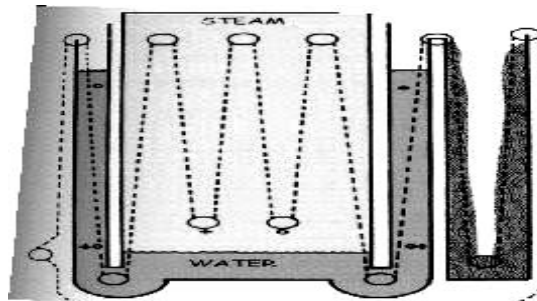


Fig. 6.7 Hydrostatic retort

The characteristics of hydrostatic retort are as follows.

- It operates with steam as the processing medium.
- The processing chamber (also known as steam dome) is maintained at constant temperature.
- It has a continuous conveyor chain that transports containers at a constant rate.
- There is minimal container agitation during processing.

(However, some use cascading water with over pressure as the processing medium and some provide container rotation or rocking during processing.)

- Two, four, six or eight pass hydrostatic retorts are common.
- Pressure within the chamber is maintained and counterbalanced by the weight of water in the feed and discharge gates.
- To increase the temperature, the pressure must increase and thus height of water column must increase.
- For the processing chamber temperature as 121°C, we require 103.4 kPa pressure in the chamber, i.e. the height of water column in the feed and discharge legs must be 11.3m above the steam-water interface.

Continuous sterilizer

In the continuous sterilizers, the cans enter and exit the sterilizer in a continuous manner.

Continuous rotary retort

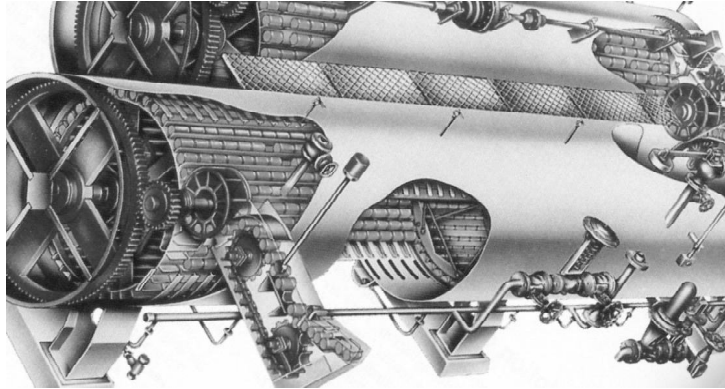


Fig. 6.8 Continuous rotary retort

The characteristics of continuous rotary retort are as follows.

- There is continuous container handling and intermittent product agitation.
- The retort system is constructed of a series of cylindrical vessels called shells (typically 1.5 m diameter).
- Processing and cooling in separate shells connected by transfer valves.
- To maintain pressure in the shells, containers enter and exit through self-sealing inlet and discharge valves.
- Agitation occurs when the containers roll on the bottom of a shell.
- Product agitation increases rate of heat penetration, allows use of higher processing temperature (up to 138°C), and improves product uniformity and quality.
- Large initial investment and additional critical factors to monitor and control.
- Retorts will accommodate a limited range of both length and diameter of cylindrical container sizes due to the physical restrictions imposed by reel steps, spacing of the spiral and other factors.

General problems in in-bottle sterilization

There are two kinds of problems in heat treatment

1. Heat has to pass through the container first before it goes into the milk.
2. Use of glass as container material may cause some auxiliary problems.

While processing milk in bottles, a ring of white solids is found on wall of the bottle at edges of milk surface. It could be due to excessive foam formed during bottle filling operation. It can be avoided by rotation or violent shaking of the bottle during heating and cooling cycle.

Important accessories in retorts

The following are the important accessories in a retort.

- Air vent
- Temperature recorder/ thermometer
- Pressure gauge

They should perform accurately so that damage to the product and to the people and machines are avoided.

Steam requirement for retorting

Assuming that milk bottles are loaded at 70°C and sterilised at 113°C by steam with a heat capacity of 2320 kJ/kg, the steam requirement is about 0.1 kg steam for each litre of milk. However, in practice, the steam capacity ranges between 0.2-0.6 kg of steam per litre of milk according to the plant characteristics.

Bottle cooling by natural air

As it has been mentioned earlier, the bottles have to be immediately cooled after processing so that the product is not overcooked and the quality is not impaired. However, it is essential that any type of thermal shock is avoided during the cooling process. First the steam is vented outside to reduce the pressure and temperature inside the retort. Then cooling of the containers is done either by air or water.

Controlled water cooling within the sterilizer is practised in commercial canning for metal cans, but not for glass bottles, as they may break.

ULTRA HIGH TEMPERATURE STERILIZATION

The main features of Ultra High Temperature (UHT) or aseptic processing are as follows.

- Temperature of 135-150°C is maintained for a few seconds.
- So the product is treated in a continuous heat exchanger.
- Causes much less chemical change than the conventional sterilization process.

The classification of UHT sterilization processes as regards to different types of heating medium and methods are given in Fig. 6.9.

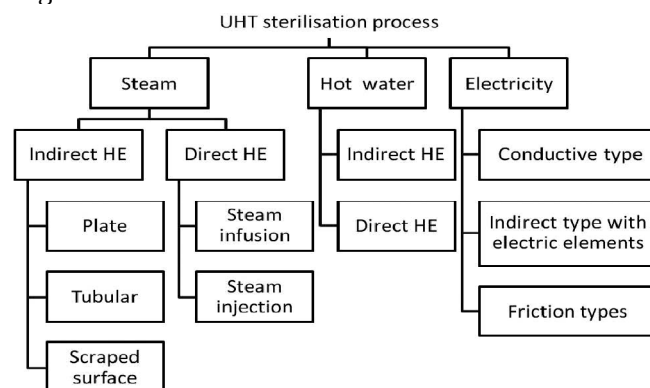


Fig. 6.9 Classification of UHT sterilization process

The flow chart of a UHT sterilization process is shown in Fig. 6.10. We have already discussed about the functions of different parts in the pasteurization section. In this case, the temperature is increased to 135-150°C and the holding time is less. Hence the length of holding tube is much smaller than the HTST pasteurization methods.

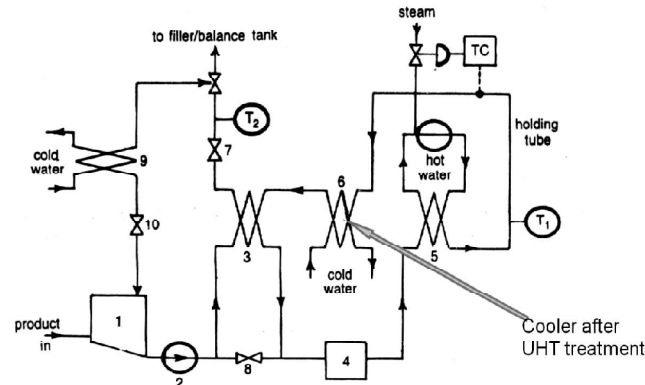


Fig. 6.10 UHT sterilization process (indirect heating type)

(1) level-controlled balance tank (2) centrifugal pump (3) plate heat exchanger (4) homogenizer (5) heat exchanger (6) cooling section (7) restriction (8) by-pass valve (9) cooler (10) back-pressure valve

In the heating chambers, a high pressure is maintained on the milk side. Fig. 6.11 gives a cause-effect diagram to explain why high pressure is required in the chambers.

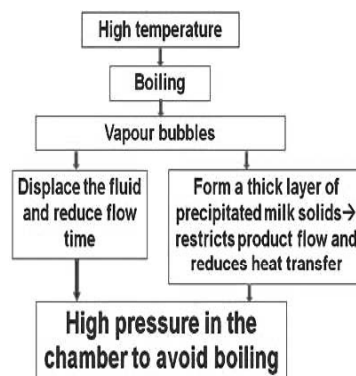


Fig. 6.11 Why high pressure is required in chambers ?

- As can be seen from Fig. 6.11, high temperature maintained in the chambers cause boiling of milk and it forms vapour bubbles. The vapour bubbles have two effects, i.e., they displace the fluid and reduce the flow time; and they also form a thick layer precipitation of milk solids which restricts product flow and reduces heat transfer. Therefore, high pressure is required in the chamber to avoid boiling.
- At a temperature of 135°C and 150°C, a back pressure of about 2 bar and 3.75 bar are needed respectively. However, to prevent the separation of air at high temperature and formation of bubbles by the dissolved air, a back pressure over and above this is required, i.e. internal pressures of about 4 bar is required, where the temperature may be above 140°C.
- Because of hydrodynamic pressure drop resulting from the product being pumped through the heat exchanger, higher pressure may be reached in other parts. This highest internal pressure may reach 6-8 bar.

UHT Sterilization in plate heat exchanger

The plate heat exchangers are most commonly used in indirect type UHT heat sterilization. The plate heat exchanger must be able to withstand the high pressure.

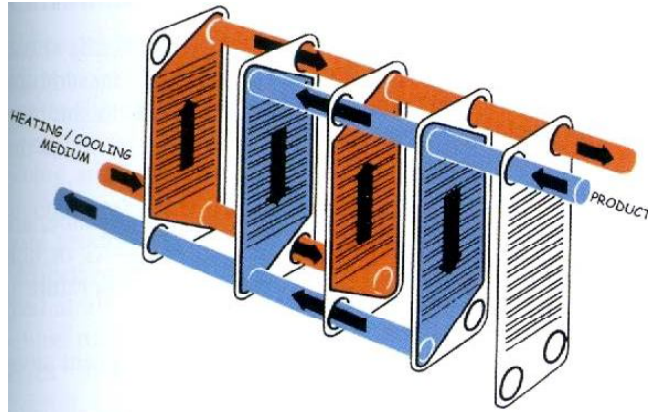


Fig. 6.12 Schematic diagram of a plate heat exchanger

To withstand these severe conditions of temperature and pressure, the gasket materials used with plates must be more sophisticated and expensive. Medium nitrile rubber is suitable for temperatures up to about 138°C. For higher temperatures (i.e. up to 155-160°C) resin-cured butyl rubber is suitable.

UHT sterilization with direct type heat exchanger

Fig. 6.13 shows the flow pattern in a UHT sterilization with direct steam injection type heat exchanger.

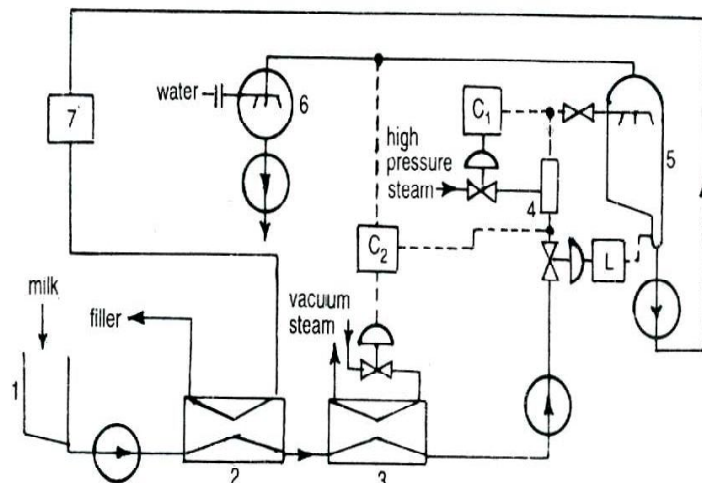
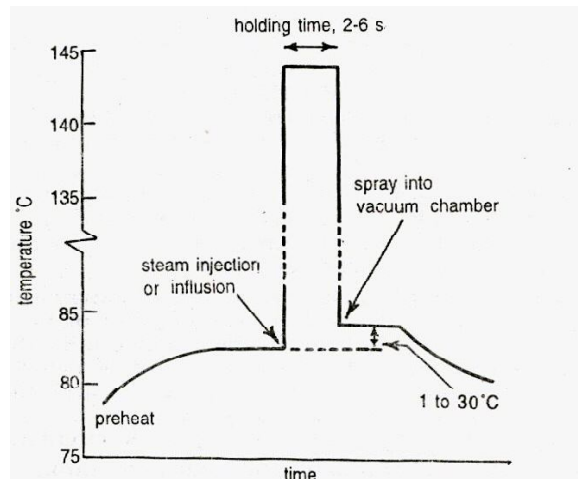


Fig. 6.13 UHT sterilization process (direct heating type)

(1) level-controlled balance tank (2) pre-heater (regenerator) (3) heat exchanger (4) steam injector (5) expansion cooling vessel (6) water jet/ surface condenser (7) homogeniser (L) controller (C) temperature controller



Direct heating injection type system

- The direct steam injection can increase the temperature of milk within fraction of a second and the holding time required is very less.
- The amount of steam to be condensed per kg product is about 0.11 kg or 11 per cent of the product.
- If all this added volume is to be removed in cooling vessel, a small error in the balance will have a considerable practical and commercial effect on the total product volume leaving the plant.
- For accurate compensation, the temperature of vapour leaving the flash vessel should be slightly higher than that of the product before mixing with steam.

Ways to reduce fouling

- A high surface finish of the heat exchangers is required as rough surface provides more surface to which material can stick on.
- The higher the liquid flow velocity, the less is the amount of fouling.
- A lower temperature differential between the heating medium and the product leads to less fouling (a lower differential lowers the temperature at the heating surface-product interface).
- Preheating: The amount of deposit is less if the product is first heated to 75°C or above and held at that temperature for 10 min or more. (There will be reduced deposit due to denaturation of serum proteins and insolubilization of the milk salts by preheating at temperatures between 85°C and 110°C.)

Back-pressure to reduce fouling: It is necessary to maintain a sufficient back-pressure on the product not only to prevent boiling at the highest temperature within the heat exchangers but also to prevent the separation of dissolved gases which are normally present in the product. Thus ultimately it helps to minimize fouling. *The use of a high back pressure to reduce fouling is now standard practice in the UHT heat exchangers.*

- A back pressure of at least 1 bar above that corresponding to the highest temperature in the heat exchanger is required.
- The use of pressurized hot water tends to induce less fouling than steam heating and high product velocities also help to reduce deposits.
- This later approach is limited to holding time and pressure drop considerations.

CHECK YOUR PROGRESS

1. Explain the difference between the conventional canning and aseptic processing.
2. What are the specific time and temperature requirements for sterilization of milk ?
3. Describe the process of batch sterilization.
4. Differentiate between a normal retort and rotary batch sterilizer.
5. Name the important accessories in a batch sterilizer and explain their functions.
6. What are the different types of sterilizers used in UHT sterilization ?
7. Why is it required to maintain high pressure in the sterilization chamber in UHT sterilization ? What is the normal range of pressure maintained ?
8. What specific care should we take if we are sterilizing milk with plate heat exchangers ?
9. Draw the flow chart of a continuous UHT sterilization process.
10. How do we remove the extra moisture added to milk during direct type heat exchangers ?
11. What are the problems caused by fouling in heat exchangers during sterilization of milk ?
12. Explain the different means to reduce fouling in heat exchangers.

Chapter 7

HOMOGENIZATION

(What is homogenization, Homogenizer and its parts, Operational parameters during homogenization)

What is homogenization

Homogenized milk is that which has been treated in such a manner as to ensure break up of the fat globules to such an extent that after 48 hours of storage, no visible cream separation occurs on the milk in a quart bottle, or, proportionate volumes in containers of other sizes does not differ by more than 10% from the fat percentage of the remaining milk as determined after through mixing.

To achieve this, we should have the fat globules in small and uniform sizes.

The process of breaking up the fat globules to very small sizes in order to prevent cream formation is known as homogenization. The equipment used for the same is known as homogeniser.

The fat globules present in normal milk vary from 0.1 to 3 or 4 microns depending upon the breed of cows and various other factors. By homogenization, we break up the fat globules to below 2 micron sizes.

Homogenization of milk also serves the following purposes.

- Prevents cream formation.
- Increases milk viscosity, it gives richer appearance to tea or coffee.
- Fat globules do not rise readily and there is no necessity for agitating the milk before serving.
- Prevents churning of fat during rough handling or excessive agitation.
- Reduces curd tension, i.e. forms a soft curd when homogenized milk is coagulated, i.e. milk becomes more palatable due to brighter appearance, heavier body and richer flavor.
- Milk becomes more digestible partly because of the smaller fat globules and partly because of the lower curd tension. The homogenized milk can be recommended for infants.
- Reduces the chances of separation of fat during the manufacture of evaporated milk and ice-cream, it gives a smoother texture of the product.
- Homogenizer can be used to prepare reconstituted milk by mixing butter oil or butter with skim milk.
- The milk becomes less susceptible to oxidized flavor development.

However, if we are interested in recovery of fat, then homogenized milk should not be taken. Fat recovery from homogenized milk is difficult.

Four different forms of fat globules in milk

- Single globules unattached.
- Clusters, consisting of two or more globules loosely attached.
- Clumps, consisting of two or more globules tightly clumped together so that the individual appearance of the globules is almost lost.
- Churned or butter particles in which the individual globules have lost their identity.

A homogenizer should break up all the clusters, clumps and butter particles present in un-homogenized milk.

THE HOMOGENIZER

The homogeniser consists of a high pressure pump fitted with a minute orifice having an adjustable opening through which fluids are forced at a very high pressure. Thus the fat globules are reduced in size.

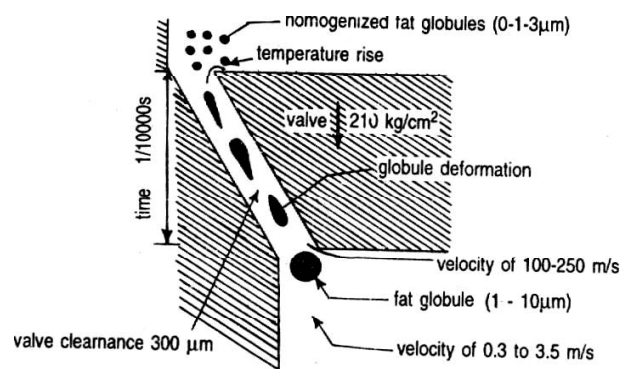


Fig. 7.1 Working principle of a homogenizer

In actual practice most valves employ a combination of three principles (Fig. 7.2). The homogenization can occur due to shear or due to disruption. The shearing action occurs among the fat globules and in the narrow opening through which the milk is forced to pass. The disruption occurs at the breaker ring and also due to sudden pressure drop as the fluid leaves the valve.

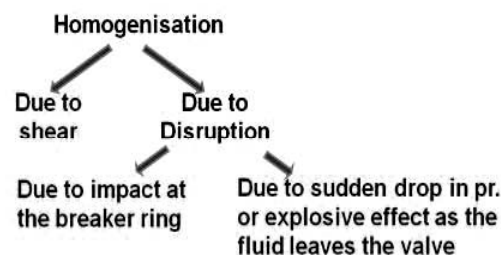


Fig. 7.2 Types of forces acting during homogenization

Proper dispersion is equally important.

- Some homogenizers may give excellent break up, but the dispersion is very poor, resulting in excessive clustering and clumping and even churning.

- This cause the development of excessive viscosity, which sometimes makes the product very difficult to pump or cool.

In addition to other factors, the size and shape of the orifices are also affected by the volume of milk to be handled per unit time and by the viscosity of product.

Main components of a homogenizer

The main parts of a homogenizer are shown in Figs. 7.3 and 7.4.

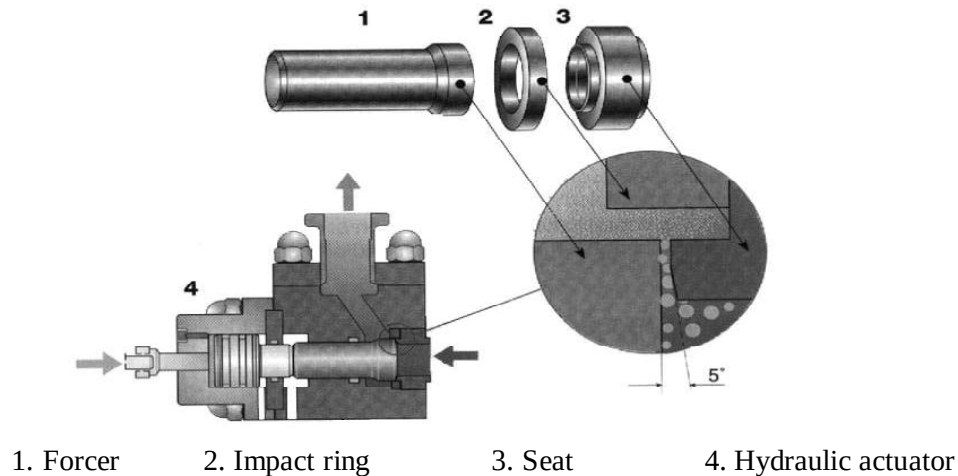


Fig. 7.3 Components of a single-stage homogenization device

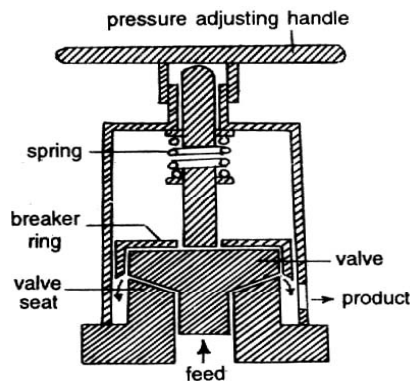


Fig. 7.4 Main components of a homogenizer

As can be seen from the above figures, the main components of a homogenizer are: pump, homogenizing valve, breaker ring, tension spring and the valve sheet.

Homogenizing valve

- The homogenizing valve is the heart of the homogenizer.
- This may be of different shapes and sizes.
- Most valves are of poppet type, which have a breaker ring so that the fluid strikes the inner surface of the breaker ring perpendicularly as it leaves the orifice formed by the conical shaped valve and seat.

- The valve is held by a heavy spring having adjustable tension. As the fluid pressure comes against it, the valve rises few thousandth of an inch to form a narrow annular opening (orifice).

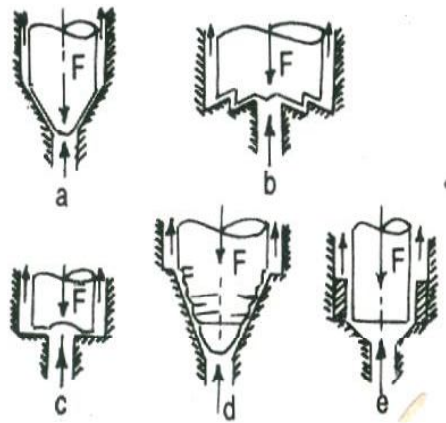


Fig. 7.5 Types of homogenizing valves

- The valve parts are subjected to extreme abrasion because of the high velocity and pressure of the fluid as it passes through the valve. So they must be constructed of extremely tough and wear resistant hard metals such as stellite.
- The valve size must be suited to the capacity of the machine. Larger valves cause excessive clustering and too small valves may not give proper break up.
- Any slight grooving due to wear and tear may reduce the effectiveness. Hence, two valves are used in series, which is called a two stage homogeniser. A two stage homogenizer is shown in Fig. 7.6.
- The principal advantage of the two stage method is that it improves dispersion of fat globules and is useful in controlling viscosity of cream and ice cream mix.

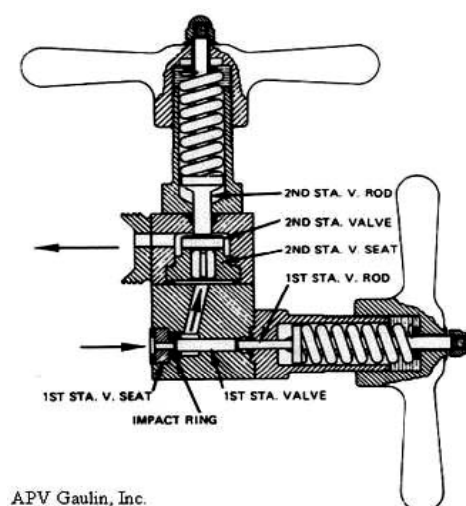


Fig. 7.6 A two stage homogenizer

Homogenizing pump

The homogenizing pump imparts the desired pressure required for homogenization. Table 7.1 gives an understanding on the effect of homogenization pressure on fat globules break up.

Table 7.1 Effect of homogenization pressure on fat globules break up

Pressure (psi)	Range of size of fat globules micron	Average size of fat globules in micron
500	1 to 14	2.39
1,000	1 to 7	1.68
1,500	1 to 4	1.40
2,000	1 to 3	1.08
2,500	1 to 2.5	0.99
3,000	0.5 to 2	0.76

- As can be seen from the table, the homogenization of milk should be carried at 2000 to 3000 psi (136-204 kg/cm²) pressure.
- For milk with up to 6% fat content, usually 136-170 kg/cm² (2000-2500 psi) in a single stage is sufficient.
- Higher pressure may increase the tendency for the milk to curdle when cooked, due to the increased destabilizing effect on the milk proteins.
- For products with more than 6% fat, 2-stage homogenization is needed to prevent fat clumping: 136-170 kg/cm² at the first stage and 34 kg/cm² at the second.
- New modern valves use low pressure, even 1/3rd less than that of conventional valves and furthermore they maintain efficiency without frequent valve grinding, since the wearing out (the wire valve) is replaced every day.

The homogenizer is always required to maintain steady pressure because

- The shearing effect of the valve changes with the velocity of the fluid and, for a certain valve, shearing effect can be acceptable only at a given velocity.
- With fluctuating pressure, the velocity will fluctuate, thus causing irregular results, non-uniform products and thereby decreasing the efficiency.
- A single plunger pump will develop pulsating pressure, and hence it is very common to have 3-plunger positive displacement pump, or, triplex pump for the purpose.

- The overlapping of strokes tends to give a reasonably uniform pressure (there is about 20% pressure variation).

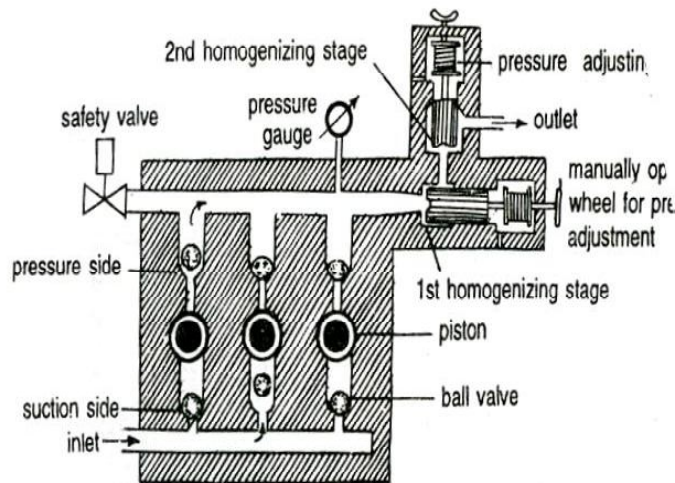


Fig. 7.7 Typical two stage homogenizer with 3-plunger pump

Temperature during homogenization

The following points are important in this context.

- The melting point of fat is 33°C.
- For inactivation of lipase, we require 55°C.
- The viscosity of milk during homogenization should also be optimum.
- Therefore, to inactivate the enzyme lipase and to reduce the tension between globules, the milk is heated to 65-70°C for homogenization.

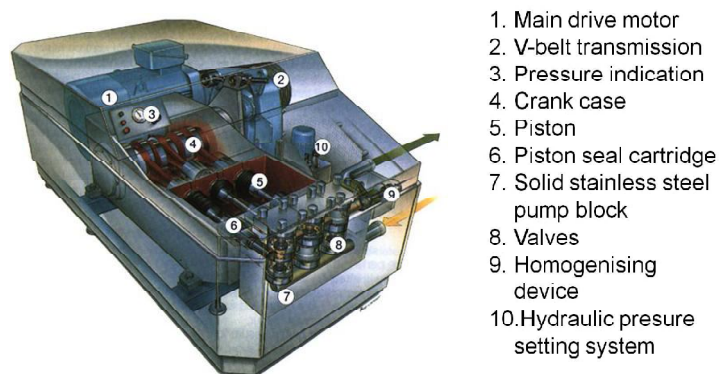


Fig. 7. A homogenizer showing different components

Effect of different operational parameters during homogenization

- High temperature homogenization causes reduced clustering, reduced viscosity, and better break up of fat globules.
- Low temp (50-55°C) homogenization reduces break up and offers more resistance to flow.

- Increase in pressure causes finer break up of fat globules, increases tendency to form clusters or clumps.
- Irregular pulsating pressure reduces efficiency.
- High temperature and pressure cause excessive casein destabilization.
- High acidity causes more viscosity, and tends to form clusters or clumps.
- Homogenization efficiency may be reduced if the produce is not held at proper temperature for 30 min.
- Minute imperfections in the homogenizing valve allow large globules to slip through and thereby prevent effective homogenization.
- The fat globules are surrounded by a membrane of about 10 µm thick consisting of approximate 48% protein, 33 % phospholipids and 19% water.
- When the fat globules are reduced to smaller sizes in a homogenizer, new membranes are automatically formed, provided the membrane material does not become limiting.
- The requirement of membrane material becomes high when the fat globules are reduced to very small sizes.
- In certain situations, e.g. for the preparation of the reconstitution of milk from skim milk powder and butter oil, some amount of fresh milk is required. The fresh milk supplies the desired amount of phospholipids to the new membranes, which are formed during the homogenization of butter oil.

Judging the efficiency of homogenization

- One of the best methods is to examine a sample under a high power microscope and to note and analyze the size of the fat globules.
- The product is accepted as homogenized if 85% of the fat globules are less than 2 µm size.

Care and maintenance of homogenizers

- The suction and discharge pipes need to be kept in good condition otherwise the homogenizer will pulsate badly, yielding an inferior product.
- The homogenizing valve, being the heart of the machine, must be kept smooth. When the valve or the seat shows grooves on the wearing surface, they should be returned to the factory for resurfacing of the valve and seat.
- Care should be exercised to keep the suction line as short as possible.
- All joints should be carefully finished to eliminate any possibility of air leakage.
- In installations where suction lines are longer than 5 m, it is recommended that a feeding pump be installed.

CHECK YOUR PROGRESS

1. Define homogenized milk.
2. State the advantages of homogenization of milk.
3. What are the four different forms of fat globules in milk?
4. Explain the different parts of the homogenizer with suitable figures and also state their functions.
5. What are the pressure and temperature maintained during homogenization of milk? Why only those values?
6. Explain the effect of different operational parameters during homogenization.

Chapter 8

CREAM SEPARATION

(Centrifugation, Tubular bowl centrifuge, Disc bowl centrifuge, Domestic cream separator)

The cream separation is a very important unit operation in dairy industry. The cream or fat is taken out of milk for standardisation purpose. Besides, cream is also required to prepare some value added products as ghee, butter, etc. Cream is usually separated from milk by the centrifugation process.

Principle of centrifugation

Sometimes gravity separation may be too slow because of the closeness of densities of the particle and the fluid, or because of the association forces holding components together, as in emulsions like whole milk. In that case centrifugation helps in separation of the components on the basis of differences in their densities.

- The centrifuge increases the forces on particles many fold.
- Thus the particles that do not settle readily or at all in gravity settlers can often be separated from fluids by centrifugal force.
- The relative settling velocities of small particles are not changed, but the disturbing effects of Brownian motion and free convection currents are overcome.

The equipment using this principle of separation is known as a centrifuge. The centrifuges are used for:

- separation of immiscible liquids,
- clarification of liquids by removal of small amounts of solids, and
- for removal of solids from liquids.

Centrifuges are also used for *centrifugal filtration*, where the centrifugal force is used (not the pressure difference) to separate the solids through a filter medium. The major applications of the centrifuges are shown in Fig. 8.1.

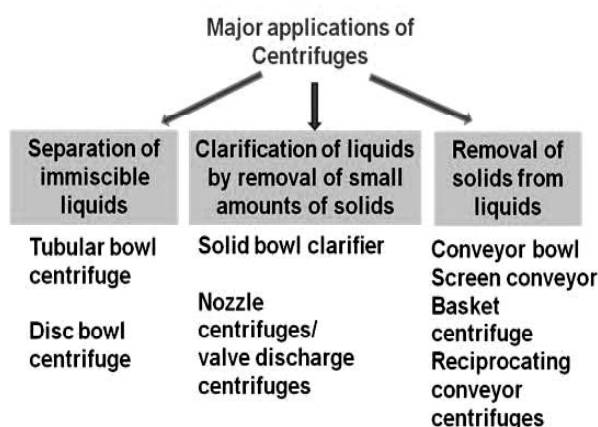


Fig. 8.1 Major applications of the centrifuges

As can be observed from Fig. 8.1, for cream separation, two types of centrifuges are used, namely, the tubular bowl centrifuge, and the disc bowl centrifuge.

Tubular bowl centrifuge

The basic characteristic features of a tubular bowl centrifuge are as follows.

- It consists of a vertical cylinder (or bowl), typically 0.1-0.15 m in diameter and 0.75 m long.
- Rotates inside a stationary casing (15000-50000 rev/min depending on the diameter).
- Tubular bowl centrifuges, which develop about 13000xg force, are also known as super centrifuges.
- Feed liquor is introduced continuously at the base of the bowl and the two liquids are separated and discharged through a circular weir system into stationary outlets.
- Some narrow centrifuges known as ultra centrifuges have a diameter of 75 mm and very high speeds of about 60000 rev/min.

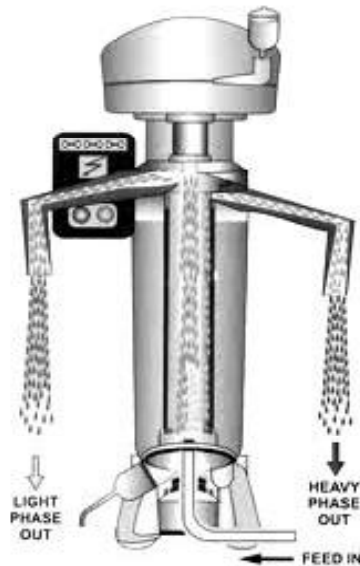


Fig. 8.2 A tubular bowl centrifuge

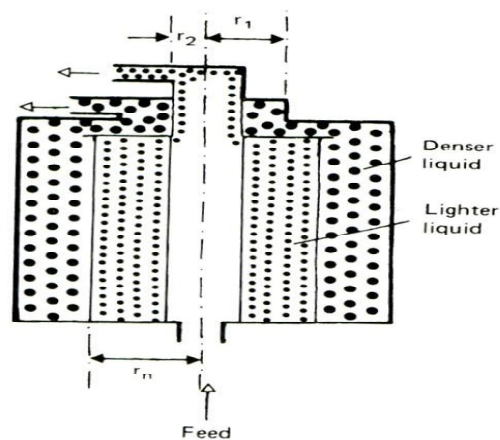


Fig. 8.3 Working principle of a tubular bowl centrifuge

Disc bowl centrifuge

The characteristic features of a disc bowl centrifuge are as follows.

- It consists of a conical bowl (0.2-1.2 m diameter), which contains a stack of inverted metal cones.
- The cones rotate at 2000--7000 rev/min.
- There is a fixed clearance between cones: 0.5-1.27 mm; and they have matching holes which form flow channels for liquid movement.
- Feed is introduced at the base of the disc stack.
- Due to the centrifugal force, the denser fraction moves towards the wall of the bowl, along the underside of the discs. The lighter fraction moves towards the centre along the upper surfaces.
- Both liquid streams are removed continuously by a weir system at the top in a similar way to the tubular bowl system.

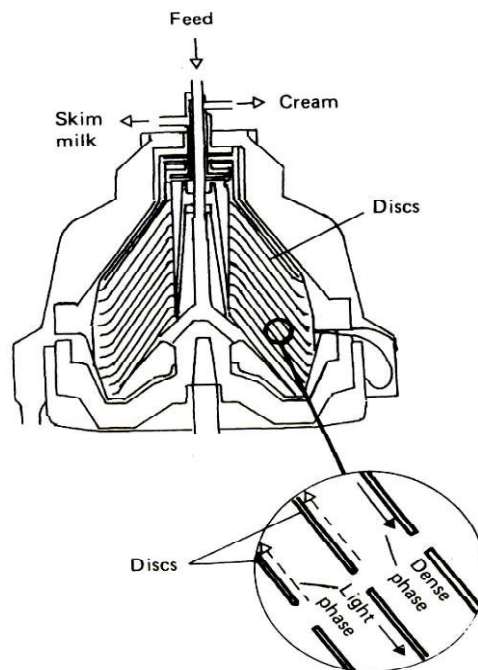


Fig. 8.4 Working principle of a disc bowl centrifuge

- Disc bowl and tubular centrifuges can have capacities even up to 150000 l/h.
- Better separation is obtained by the disc bowl centrifuge due to the formation of thinner layers of liquid.
- Periodic cleaning of deposited solids is required.
- The disc bowl centrifuge, in addition to being widely used for separation of cream from whole milk, is also used for clarification of oils, coffee extracts and juices, and separation of starch-gluten.



Fig. 8.5 A disc bowl centrifuge

Domestic cream separator

Small capacity domestic cream separators working on the principle of disc bowl centrifuges are also available. Fig. 8.6 shows such a domestic cream separator with its basic component parts. The separator is operated by hand with the help of a handle fixed to it.

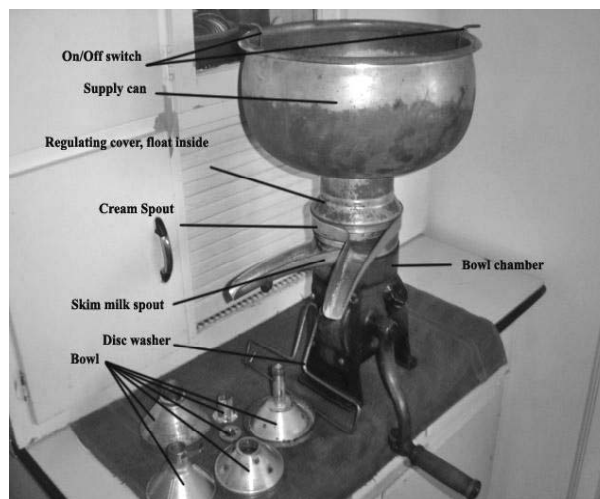


Fig. 8.6 Domestic cream separator

CHECK YOUR PROGRESS

1. What is a centrifuge ? What are its main applications?
2. Explain the working principle of a tubular bowl centrifuge with a neat sketch.
3. Explain the working principle of a disc bowl centrifuge with a neat sketch.
4. Explain the different parts of a domestic cream separator.

Chapter 9

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.

Butter fat. 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.

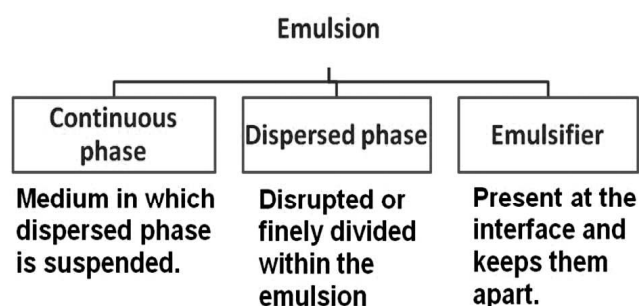


Fig. 9.2 Different phases (constituents) of an emulsion.

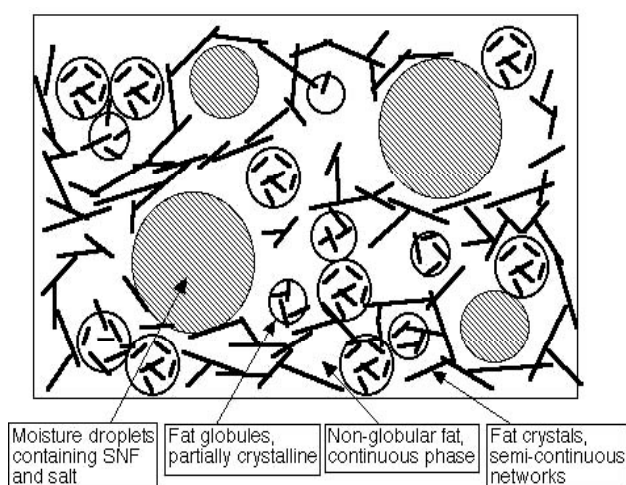


Fig. 9.3 Butter structure

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 19th century, the continuous churn was commercialized by the middle of the 20th 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 ($\text{pH} > 6.6$, $\text{TA} = 0.10\text{-}0.12\%$), 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.

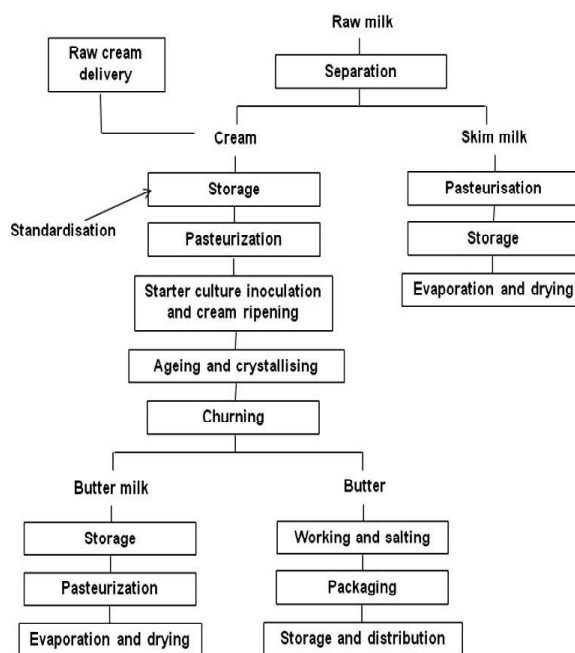


Fig. 9.5 Butter making process

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.

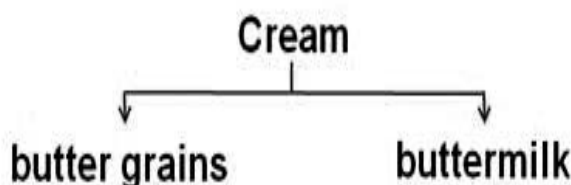


Fig. 9.6 Cream is separated to butter grains and butter milk

- 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.

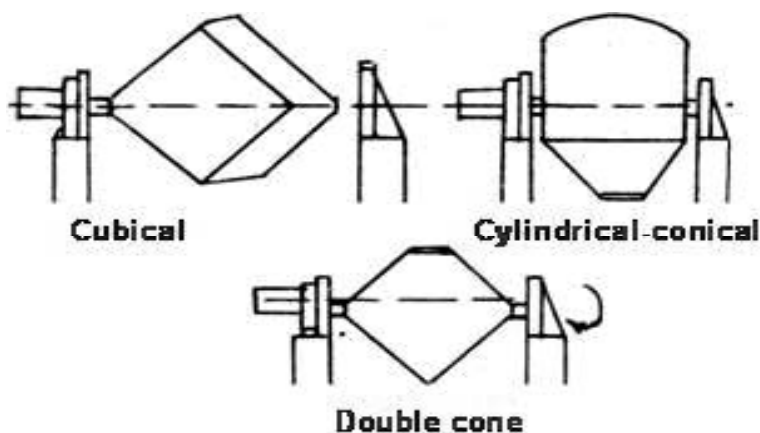


Fig. 9.7 Different configurations of butter churns



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 CHURNS

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

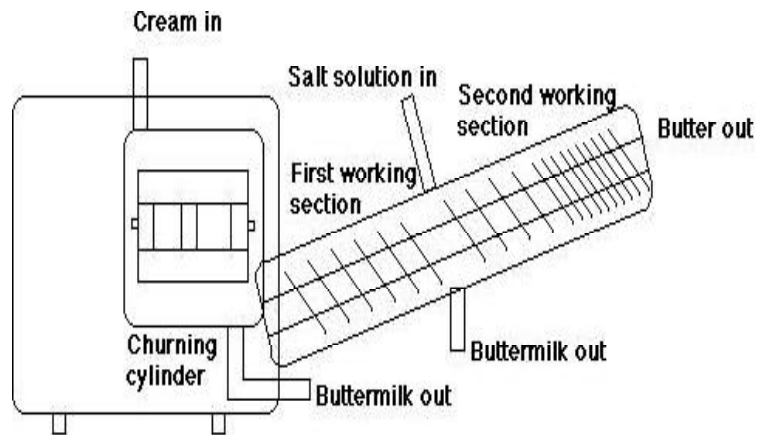


Fig. 9.9 Schematic diagram of a continuous Butter Churn



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.

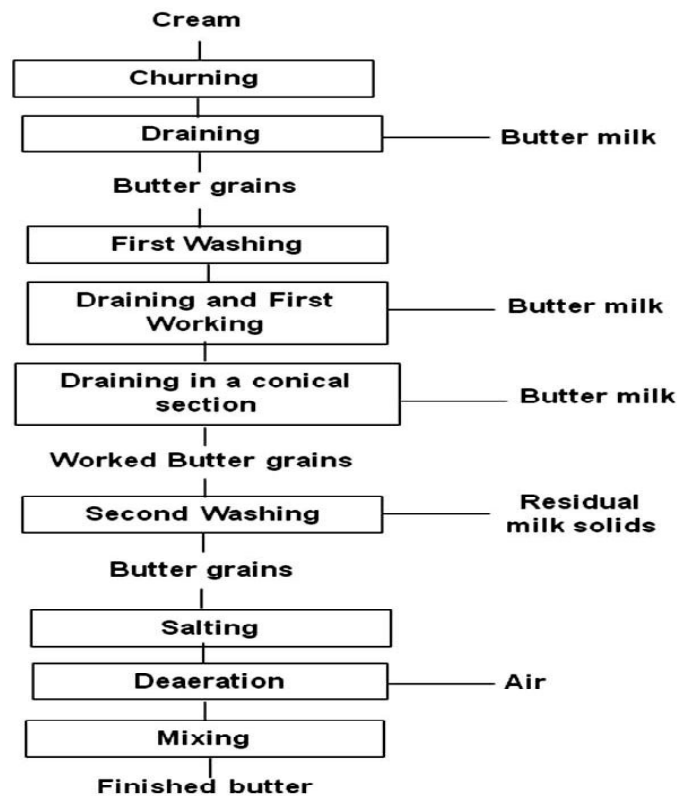


Fig. 9.11 Continuous Butter Churn

- 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 $\pm 0.1\%$)

- 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).

$$E_s = 1 - \frac{f_s}{f_m}$$

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).

$$E_c = 1 - \frac{f_{bm}}{f_c}$$

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.

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

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

$$\% \text{churn over run} = - \frac{(\text{Kg butter made} - \text{kg fat churned})}{\text{kg fat churned}} \times 100$$

Package fill control

$$\text{Package fill control} = \frac{(\text{Actual weight} - \text{no min al weight})}{\text{no min al weight}} \times 100\%$$

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.

$$E_s = 1 - \frac{0.05}{3.9} = 98.7\%$$

$$E_c = 1 - \frac{0.2}{45} = 99.55\%$$

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

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 = $(4.72 - 3.9)/3.9 = 21.02\%$

CHECK YOUR PROGRESS

1. Define (a) Butterfat (b) AMF (c) Butter oil (d) Butter.
2. Draw the flow chart for butter manufacture and state the principal equipment used.
3. What are the different types of butter making process ?
4. Briefly describe (a) continuous floatation churns (b) ripening of cream (c) working of butter (d) main constituents of butter.
5. State the different expressions for butter yield calculations.

Chapter 10

DRYING OF MILK

(Objectives of milk drying, Spray drying, Drum drying)

Objectives of milk drying

- To preserve for long period by reducing moisture content and as well by reducing water activity.
- To reduce the cost and difficulty of packaging, handling, transportation and storage by converting the material into a dry solid, thus reducing its weight and in most cases volume.
- To add value to the commodity and give a new form.

We all know that different types of dryers can be classified on the basis of type of commodities being handled as follows.

- Dryers for solids and pastes, and
- Dryers for liquid materials.

We also know that the drum dryer and the spray dryer are the two common types of dryers used for drying liquid foods. Thus, they are used also for drying of milk.

SPRAY DRYING

The different parts of a spray dryer are shown in Fig. 10.1

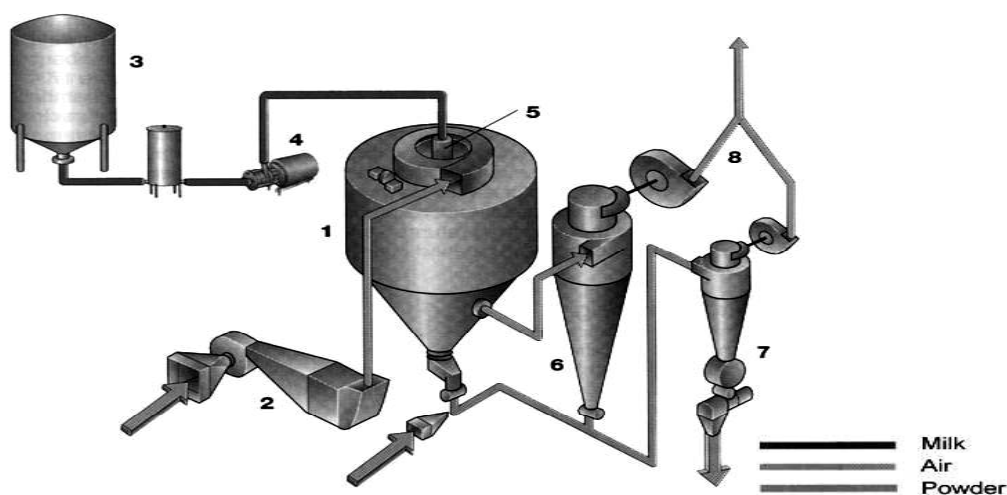


Fig. 10.1 A spray dryer

(1)Drying chamber, (2) Air heater, (3) Milk concentrate tank, (4) High pressure pump, (5) Atomiser, (6) Main cyclone, (7) Transport system cyclone, (8) Air suction fans and filters

The main characteristics of a spray dryer are as follows.

- The liquid food dispersed in to a stream of hot gas
- Rapid vaporization of moisture
- Cylindrical drying chamber with a short conical bottom
- Other major parts: atomization system, air handling system, powder separation system

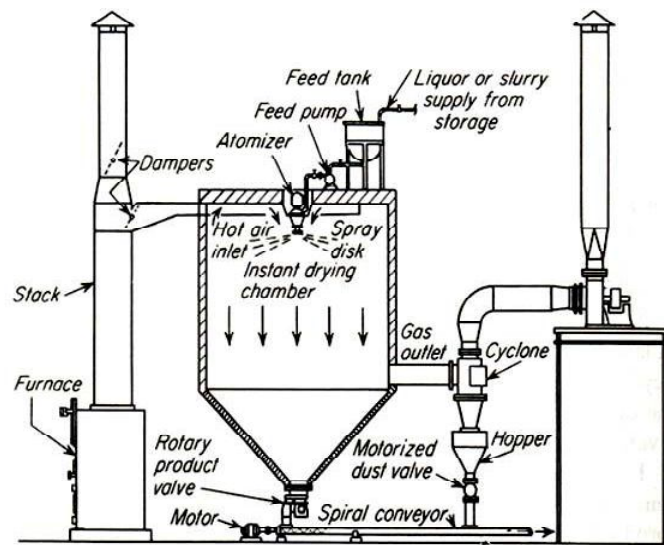


Fig. 10.2 Components of a spray drying system

- Air temperature of 150 to 300°C. Air flow may be concurrent, counter current or a combination of both.
- Dryer chamber: few meters to 25-30 m long, diameters of 2.5-9 m, horizontal/ vertical
- Droplets exit the atomizer at about 50 m/s, but quickly decelerate to terminal velocity (0.2 to 2 m/s).
- Separation of powder is done first by gravitational settling, subsequently by a cyclone separator and then by a textile or bag filter.
- The food is usually fed in a pre-concentrated form to the drying chamber.
- Drying time is usually 5 to 100 seconds.
- The outlet air temperature varies between 50 and 100°C (drying temp-product temp-thermal stability)
- Can be of very high capacity (10000 kg dried milk/h)

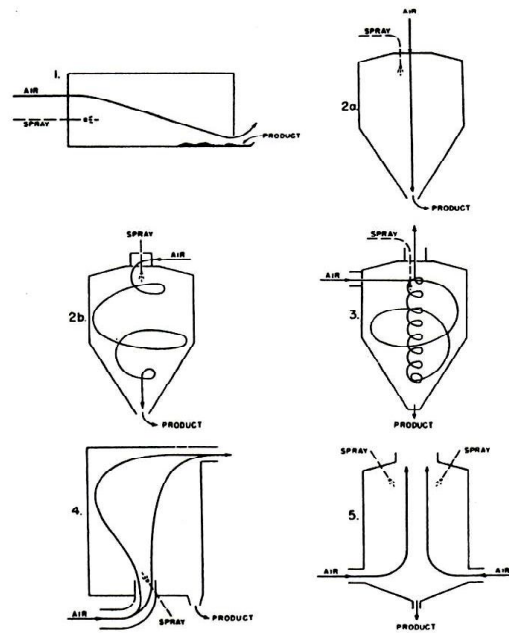


Fig. 10.3 Air and fluid flow patterns in a spray dryer

The atomization is caused by

- High pressure (700 to 2000 kPa) nozzle- It yields the droplets at 100 to 300 μm .
- Centrifugal atomization (disc usually about 300 mm in diameter and rotates at 5000-10000 rev/min, peripheral velocity 90-200 m/s): droplet size is 50-60 μm
- By compressed air.
- Ultrasonic nozzle atomizer (first atomized by a nozzle atomizer and then by using ultrasonic energy to induce further cavitation)



Fig. 10.4 A laboratory spray dryer

Main advantages of spray drying

- Very short drying time
- Large scale continuous production
- Low labor costs
- Relatively simple operation and maintenance.

Disadvantages

- Much heat is lost in discharge gates
- High capital cost (due to atomization)
- Requirement for a relatively high feed moisture content
- Higher volatile losses.

The spray dryers are specifically used for:

- Highly heat sensitive materials, e.g. instant coffee and tea, milk powders, soymilk powder, enzymes, cocoa, potato, ice cream mix, butter, cream, yoghurt, cheese, fruit juices, meat and yeast extracts, encapsulated flavors, wheat and corn starch products, egg powders, etc.

DRUM DRYING

It consists of drying of a slurry on a heated drum. The drum dryers can be of many types as shown in Fig. 10.5.

Classification of drum dryers

<u>Number of drums</u>	<u>Feeding device</u>	<u>Pressure or vacuum operation</u>
Single drum	Dip feed	Atmospheric type
Double drum	Splash feed	Vacuum type
Twin drum	Nip feed	
	Roller feed	

Fig. 10.5 Classification of drum dryers

The main characteristics of a drum drying system are as follows.

- Slowly revolving drum(s) 0.6-3 m in diameter, 0.6 to 4 m long. (revolving at 1 to 10 rev/min)
- Steam is supplied to heat the surface of the drum
- Single drum, double drum or twin drum
- Dip feed / spraying / spreading or by auxiliary feed rollers
- Scraper or doctor blade to collect the product

- Drums may be enclosed in a vacuum chamber
- Drying capacity depends on drum area (Usually between 5 and 50 kg/m² of drying surface).
- High temperature drying (over 100°C)
- Rapid drying (Residence time 30 to 60 seconds)
- Exposure to high temperatures may cause browning or burnt flavour, protein denaturation
- Because of low thermal conductivity of food, thin layers of food are needed to conduct heat rapidly without causing heat damage.



Fig. 10.6 A laboratory scale double drum dryer

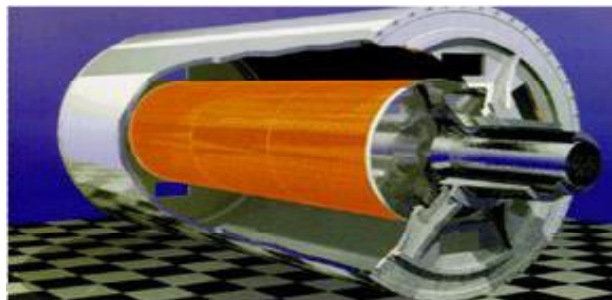


Fig. 10.7 A single drum dryer showing the drum in the drying chamber

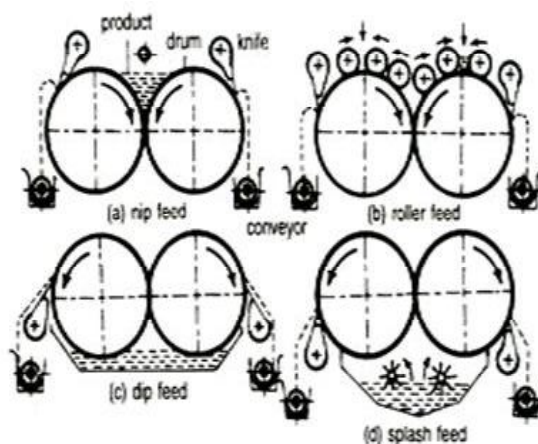


Fig. 10.8 Feeding arrangements in a spray dryer

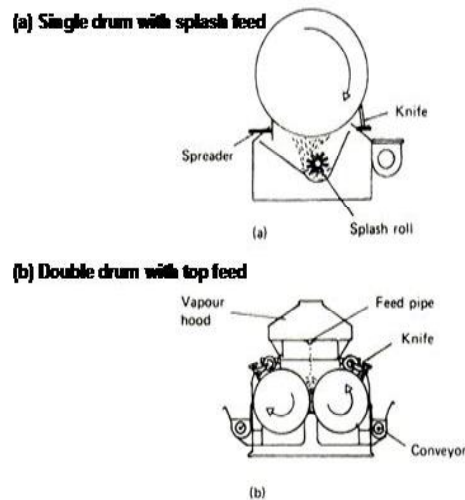


Fig. 10.9 Two common configurations of drum dryers

The drum dryers are applied also to:

- Dilute/concentrated solutions, moderately heavy slurries.
- Not suitable for solutions of salts with limited solubility or for slurries of abrasive solids that settle down and create excessive pressure between drums.
- Earlier used for drying of milk.
- In conduction dryers, typical heat consumption is 2000-3000 kJ/kg of water evaporated compared with 4000-10000 kJ/kg of water evaporated in hot air dryers.

CHECK YOUR PROGRESS

1. Explain the different parts of a spray dryer along with their functions
2. What are the different powder recovery systems in a spray dryer ?
3. What are the different configurations of a drum dryer ?
4. Give a comparison between the advantages and disadvantages of spray dryer and drum dryer for milk.

Chapter 11

JUICE EXTRACTION AND FILTRATION

(Juice extraction methods and equipment, Filtration, Plate and frame filter press, Shell and leaf filter)

Juice extraction methods and equipment

The juice extraction from fruits and vegetables can be done by size reduction methods as crushing, chopping and comminuting. This is usually employed for fruits that are fully ripened and too soft for whole or diced or sliced packs.

The following points must be remembered in such situations.

- Crushing of products by chopping them into small pieces (0.025-0.075 inch) prior to heating speeds enzyme activity. Hence it is required to remove the air at the time of crushing and immediately after comminuting.
- Therefore, direct super heated steam introduction into the chopper or crusher is applied.
- Super heated steam aids in creating a partial vacuum. So superheated steam preferably under a vacuum will eliminate the air and aid immensely in creating a better consistency in the final product.

The equipment used for separation of the pulp is known as a pulper, where mainly the compression force is used. Basket press is a common equipment for taking out juice from soft fruits as oranges.



Fig. 11.1 Hand operated pulp extractor



Fig. 11.2 Motor operated pulper

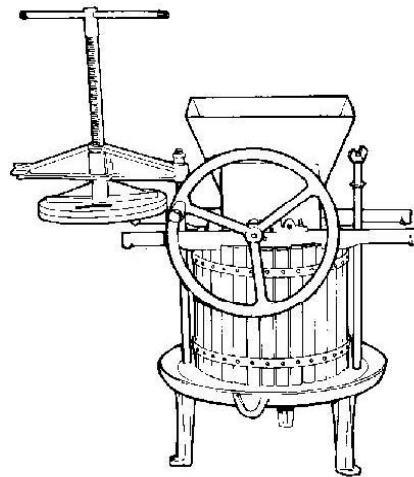


Fig. 11.3 Basket press

FILTRATION

Filtration is the removal of solid particles from a fluid by passing the fluid through a filtering medium (or septum) on which the solids are deposited. The fluid may be a liquid or a gas. The feed is usually modified to increase the filtration rate (by heating, recrystallizing, or adding a filter aid). Because of enormous variety of materials to be filtered and the widely differing process conditions, many types of filters are used.

Filters can be classified broadly as cake filters, clarifying filters and cross flow filters.

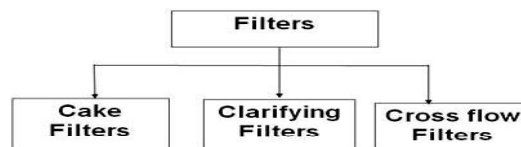


Fig. 11.4 Classification of filters

Cake filters separate large amounts of solids in the form of cake or crystals or sludge. Here the filter medium is relatively thin compared with that of a clarifying filter. At the start of the filtration, some solid particles enter the pores of the medium and are immobilized, but soon they begin to collect on the septum surface. After this initial period, the cake of solids does the filtration, not the septum. As the cake builds up to an appreciable thickness on the surface, it has to be removed periodically.

Further categorization of cake filters are shown in the Fig. 11.5. The filters may be continuous or discontinuous types depending on whether the discharge of filtered solids is steady or intermittent. During much of the operating cycle of a discontinuous filter, the flow of fluids through the device is continuous, but it must be interrupted periodically to permit discharging the accumulated solids. In a continuous filter, the discharge of both solids and fluids is not interrupted as long as the equipment is in operation.

Pressure filters are usually discontinuous; vacuum filters are usually continuous. Pressure filters can be either gravity filters or centrifugal filters depending on whether a pump or blower or centrifugal force is used to develop pressure on the upstream side. In vacuum filters the vacuum is maintained on the downstream side.

The clarifying filters remove small amounts of solids to produce a clean gas or sparkling clear liquid such as beverages. These are also known as deep bed filters, because the particles of solids are trapped inside the filter medium and usually no layer of solid can be seen on surface of the medium. The examples are cartridge filter and ultra filter.

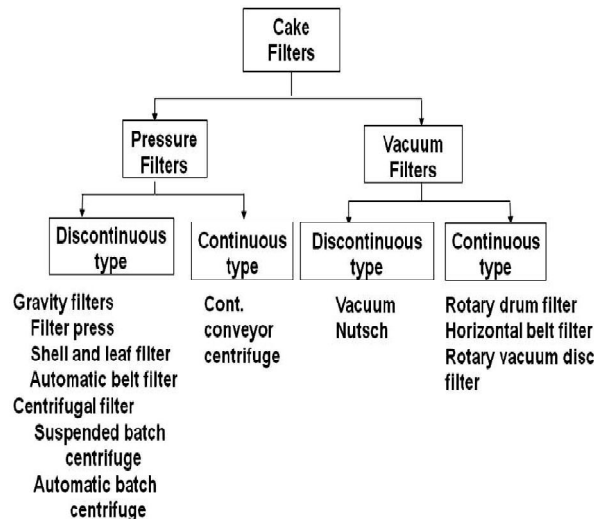


Fig. 11.5 Classification of cake filters

In case of cross flow filters, the feed suspension flows under pressure at a fairly high velocity across the filter medium. A thin layer of solids may form on the surface of the medium, but the high velocity keeps the layer from building up.

Plate and frame filter press

The characteristic features are as follows.

Construction and operation

- It consists of plates and frames arranged alternatively and supported on a pair of rails. The plates have ribbed surfaces and the hollow frames are separated from the plates by filter clothes, i.e. the set of plates are designed to provide a series of chambers in which solids are collected.
- The plates may be square or circular, vertical or horizontal, and may be 6 to 50 mm thick. Usually square plates are used and the size may be 0.15 m to 2 m on a side. In many cases, the compartments for solids are formed by recesses in the faces of molded polypropylene plates.
- The press is closed by means of a hand screw or a hydraulic press.
- The feed channel is formed by a hole in each plate and frame, these holes registering together. Slurry enters through this channel running length wise through one corner of the assembly.
- In each frame there is an opening from this channel that admits feed into the frame and at the bottom of each plate there is an outlet for the filtrate. Liquor passes through the cloth, down grooves or corrugations in each faces, and out of the press.

- During filtration, the solids quickly form a thick cake at low pressure (1.5-3.2 kg/cm² gauge pressure) on the cloth covered faces of the plates.
- The filtration is continued until the frames are completely filled, i.e. when the filtrate ceases to flow from the drain cock at the bottom. This is known as solid filling or the press is said to be jammed.
- Filling may be followed by blowing of air to expel solution before wash is applied. At that time no displacement of cake occurs as the cell is completely filled with solids.
- Then washing is carried out by admitting wash solution or water under pressure behind the filter cloth of each alternate plate.
- An air blow may be given again to remove the wash and obtain as dry cake as possible.
- The press is then opened, cake removed and dropped onto a conveyor or storage bin. Slurry is admitted to each compartment under pressure; liquor passes through the canvas and out a discharge pipe, leaving the wet cake of solids behind.

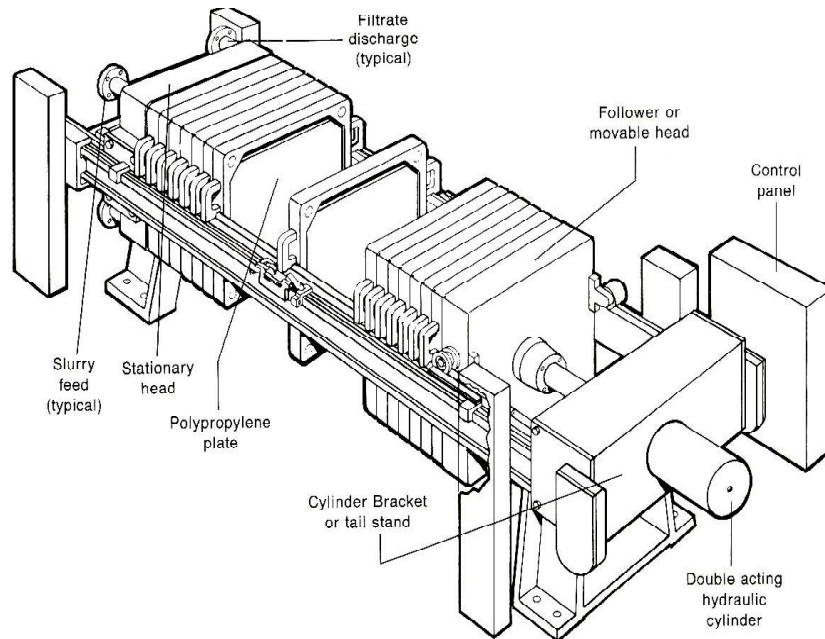


Fig. 11.6 Plate and frame filter press

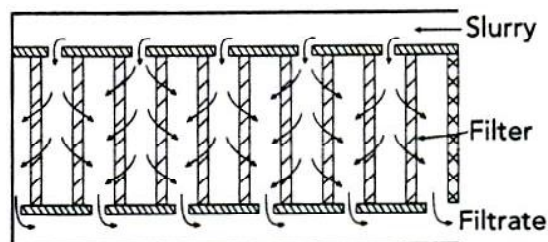


Fig. 11.7 Flow pattern in a Plate and frame filter press

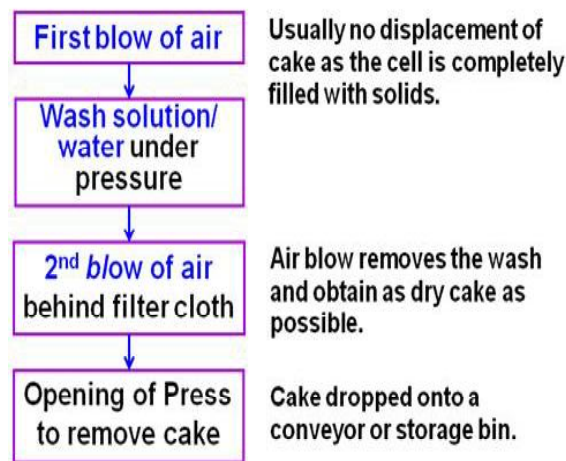


Fig. 11.8 Removal of solid filling in a plate and frame filter press

Salient features

- It involves low capital cost, high flexibility for different types of products, and can be easily maintained.
- The dryness of the cake is one major advantage with the plate and frame press.
- The disadvantage associated with this system is the intermittent operation since the presses must be taken away and cleaned by hand at the end of each cycle.

Applications: This is widely used for production of apple juice and cider, other juices, and filtration of oil.

Shell and leaf filter

Construction and operation

- It consists of a set of vertical mesh leaves held on a retractable tract.
- The leaves are coated in filter medium and supported on a hollow frame which forms the outlet channel for the filtrate.
- The leaves are stacked vertically or horizontally inside a pressure vessel.
- During operation, the leaves are inside the closed tank; feed enters through the side of the tank; feed liquor is pumped into the shell at a pressure of approx. 400×10^3 Pa. and filtrate passes through the leaves into a discharge manifold.
- The cake is blown or washed from the leaves after completion of the filtration operation.
- In some designs the set of leaves rotate at 1-2 rev/min to improve the uniformity of cake build up.

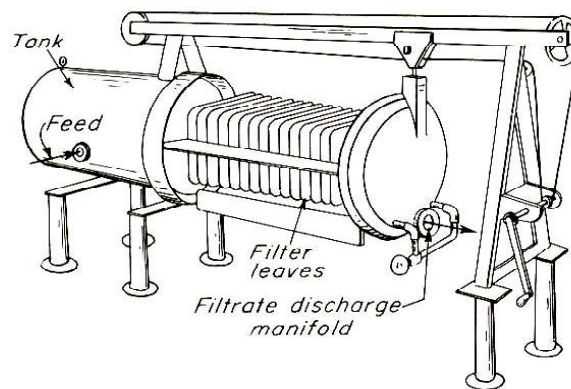


Fig. 11.9 Shell and leaf filter

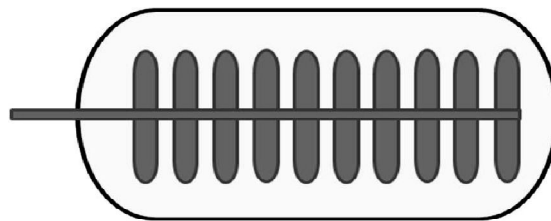


Fig. 11.10 Leaves arranged in the shell

Salient features

- It involves higher cost than the plate filters.

Applications

The shell and leaf filter is widely used for filtration involving the filter aids. Besides, the shell and leaf filter is used under following conditions:

- For filtration under higher pressures than are possible in a plate and frame filter.
- To economize on labor.
- When more effective washing of the cake is necessary.

Besides there are also other common types of filters as automatic belt filter, suspended batch centrifuges, automatic batch centrifuges, continuous filtering centrifuges, rotary drum filter, horizontal belt filter and clarifying filters, etc. which have been explained in the “Manual of Food Engineering Equipment” by the same author and his colleagues.

CHECK YOUR PROGRESS

- 1) Explain the working principles of different types of commercial juicers.
- 2) Explain the working principle of a plate and frame filter press with suitable sketches.
- 3) Explain the working principle of a shell and leaf filter with suitable sketches.

Chapter 12

MEMBRANE SEPARATION

(Membrane processing methods and equipment, RO, NF,UF,MF, Applications of membrane separation, Membrane techniques, Membrane materials, Membrane modules)

Membrane separation is a process of separating food components by using semi-permeable membranes, basing on the molecular size and molecular weight of the components. The driving forces of the separation process is, for example, differences in concentration or pressure between the two sides of the membrane.

Membrane separation processes can remove much smaller substances, such as viruses and dissolved ions, from the water.

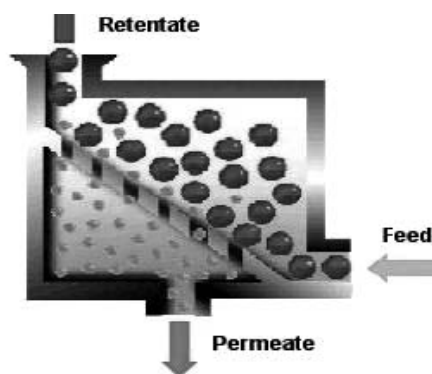


Fig. 12.1 Principle of operation in membrane separation

MEMBRANE PROCESSING METHODS

The different membrane processing methods are as follows.

Reverse osmosis (RO). Concentration of solution by removal of water

Nanofiltration (NF). Concentration of organic components by removal of part of monovalent ions like sodium and chlorine (partial demineralization).

Ultrafiltration (UF). Concentration of large and macro molecules

Microfiltration (MF). Removal of bacteria, separation of macromolecules

The difference in application of these technologies is shown in Fig. 12.2.

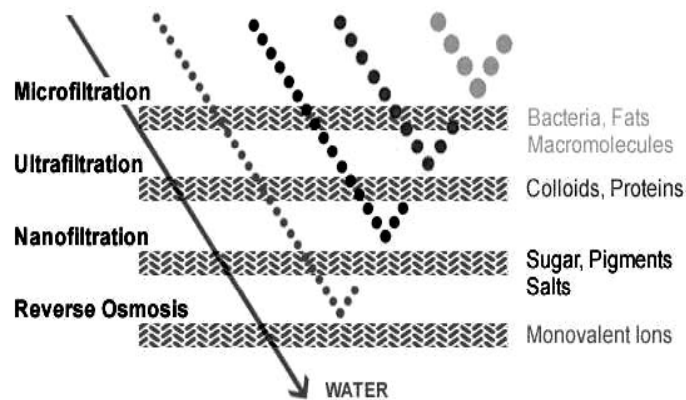


Fig. 12.2 Application of different membrane processing technologies

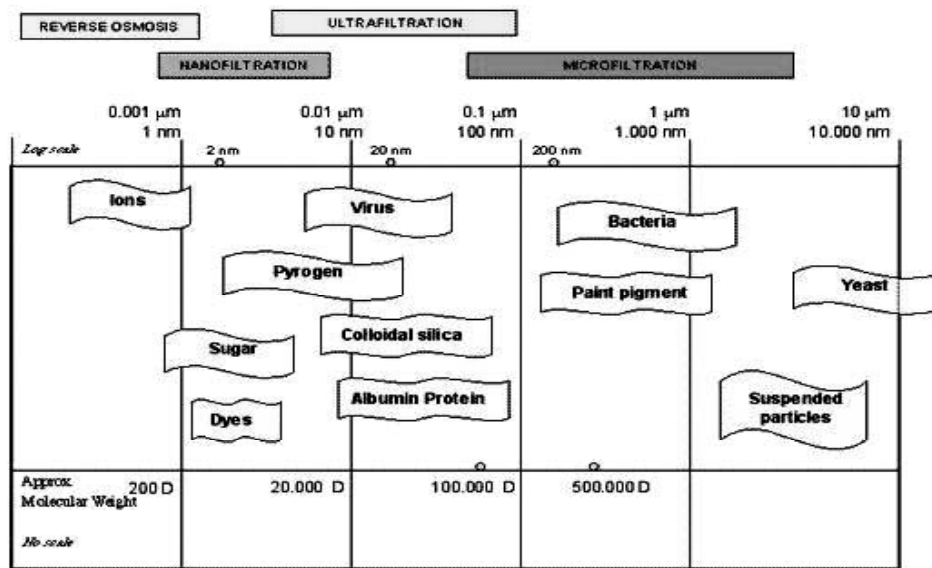


Fig. 12.3 Range of concentration in various filtration systems

There are also other methods for selective separation as follows.

- Pervaporation
- Ion exchange
- Electro-dialysis

REVERSE OSMOSIS

It is a membrane separation process, driven by a pressure gradient, in which the membrane separates the solvent (generally water) from other components of a solution. The solvent flow is opposite to the normal osmotic flow.

The membrane pore size is very small allowing only small amounts of very low molecular weight solutes to pass through the membranes.

Applications

Broadly used to separate water from low molecular weight solutes (salts, aroma compounds etc.), which have high osmotic pressure.

- Concentrate and purify fruit juices, enzymes, fermentation liquors and vegetable oils; pre-concentrate juices and dairy products before evaporation.
- Concentrate wheat starch, citric acid, egg white, milk, coffee, syrup, natural extracts and flavors.
- To clarify wine and beer (De-alcoholization for low alcohol wines and beers)
- To determine and purify water from boreholes or rivers or desalination of sea water.
- Water and waste water purification.
- Concentration of whey during cheese manufacture.

RO materials and equipments

- Polymer having high permeability for water, high rejection for soluble salts and durability.
- Cellulose acetate is outstanding being inexpensive.
- Polyacrylonitrile, polyamides, polyurethanes are also used, but they have low temperature resistance and low pH range.
- Polysulphones and ceramic materials can withstand high temperature and wider pH range.
- Operating pressure ranging from 40 to 80 bar @ 450 to 2400 lit/h of flux.

NANOFILTRATION (NF)

- New class of pressure-driven membrane processes that lies between RO and UF.
- Pressure range: 10-50 bar (lower pressure than RO).
- Rejects ions with more than one negative charge (such as SO_4^{2-} , CO_3^{2-}).
- Also known as loose reverse osmosis.

Applications

- Removes materials having molecular weight between 300 to 1000 Da.
- Employed for pre concentration for RO.
- Removal of inorganic salts Na, K, Cl, urea, lactic acid.
- Partial demineralization
- Membranes that leak particle species with a radius in the nanometer range.
- Reduction of salty taste
- Reduction of salt during cheese making
- Pretreatment for electro dialysis, ion exchange.
- Acid removal
- Separation of dispersed particles such as colloids, fat globules, etc.

ULTRAFILTRATION

Ultra-filtration is similar to reverse osmosis with low pressure of operation. In UF, the membrane pore size is larger allowing some components to pass through the pores with the water. It is a separation/fractionation process.

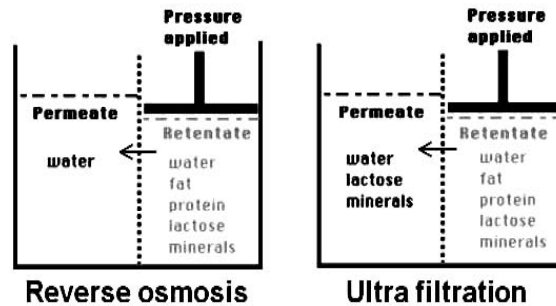


Fig. 12.4 Difference between RO and UF

Dia-filtration is a specialized type of ultra-filtration process in which the retentate is diluted with water and re-ultra filtered, to reduce the concentration of soluble permeate components and increase further the concentration of retained components.

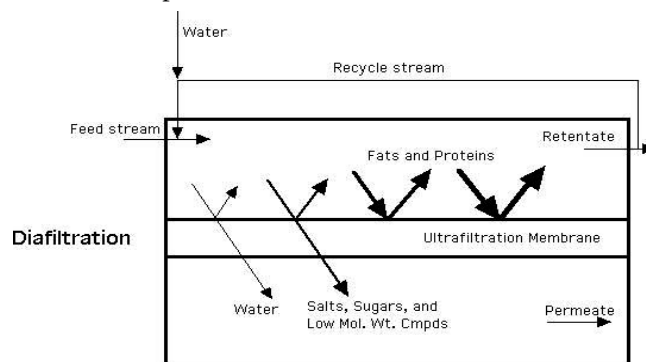


Fig. 12.5 Diafiltration process

Equipment

- U.F. membranes have higher porosity.
- They operate under low pressure (0.05 to 10 bar @ 2400 lit/hr of flux).
- Polymers like polysulphones, polyamides, PVC, polystyrene, polycarbonates and polyethers are normally used.

Applications

- Most commonly used to pre concentrate milk prior to preparation of other range of dairy products
- Concentration of sucrose and tomato paste.
- Separation and concentration of enzymes, other proteins or pectin.

- Treatment of water to remove bacteria and contaminants greater than 0.003 μ dia.
- To selectively remove lactose and salts from the whey.
- Removal of protein hazes from honey & syrups.
- Pretreatment for RO to prevent fouling by organic and colloidal material.



Fig. 12.6 Integrated membrane filtration system comprising UF plant for WPC & RO plant for lactose concentration



Fig. 12.7 Module filters for food and beverages



Fig. 12.8 Filter to remove microbiological impurities from cheese brine

MICROFILTRATION

- Microfiltration (MF) designates a membrane separation process similar to UF but with even larger membrane pore size allowing particles in the range of 0.2 to 2 micrometers to pass through.
- The pressure used is generally lower than that of UF process.
- MF is used in the dairy industry for making low-heat sterile milk.

Table 12.1 Applications of membrane filtration

		Permeate	Concentrate
RO	dyeing effluent	clean water	BOD, salt, chemicals, waste products
	water	low salinity water	salty water
	whey	low BOD permeate	whey concentrate
NF	antibiotics	salty waste product	desalted, concentrated antibiotics
	dyeing effluent	clean, salty water	BOD/COD, color
	water	softened water	water product
	whey	salty waste water	desalted whey concentrate
UF	antibiotics	clarified fermented broth	waste product
	bio gas waste	clarified liquid for discharge	microbes to be recycled
	carrageenan	waste product	concentrated carrageenan
	enzymes	waste product	high value product
	milk	lactose solution	protein concentrate for cheese production
	oil emulsion	oil free water (<10 ppm)	highly concentrated oil emulsion
	washing effluent	clarified water	dirty water (waste product)
	water	clarified water	waste product
	whey	lactose solution	whey protein concentrate
	xantan	waste product	concentrated xantan

Membrane techniques

- Counter diffusion
- Osmotic distillation
- Electro dialysis
- Ion-exchange

Counter diffusion

- Separate small ions from large molecules.
- Hollow fiber cellulose diffusion tubes.
- Counter diffusion can produce 50 per cent demineralization.
- which may represent 70 per cent removal of monovalents.

Osmotic distillation

- Low pressure and low temperature separation.
- Hollow fiber or spiral wound hydrophobic membrane.

Electrodialysis

- Similar to ion exchange separation.
- Used to separate electrolytes from non-electrolytes and to exchange ions between solutions.
- Direct current is passed through a solution having number of ion exchange plates/membranes.
- The ion selective membranes act as barriers to either cations or anions.
- Anions and cations are attracted towards anodes and cathodes, respectively.
- The membranes are arranged alternatively to form ion diluting cells and ion concentrating cells.
- Electro dialysis is used for demineralization of milk products.
- It is also used for desalination of water.
- Also used to de-mineralize whey, to remove potassium and tartaric acid from wines and to de acidify fruit juices.

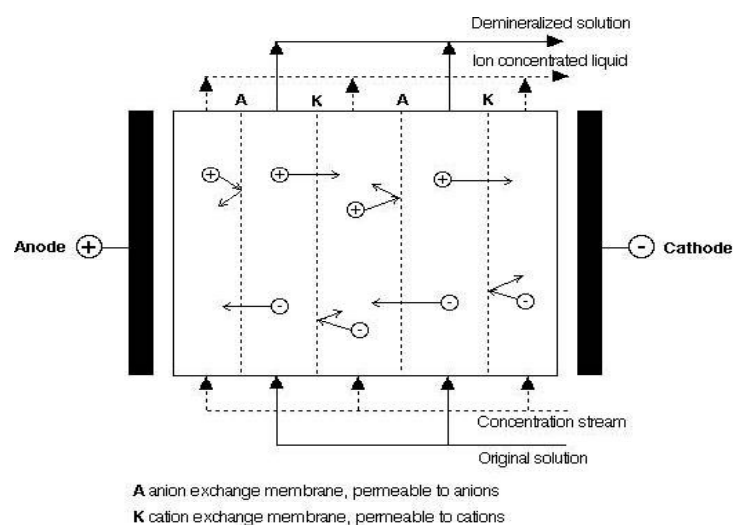


Fig. 12.9 Electrodialysis process

Ion-exchange

- Food components are separated basing on their electrical properties.
- Metal ions, proteins, amino acids and sugar are transferred from the feed and retained on a solid ion exchange material.
- Two types of ion exchangers (having fixed electrical charges) namely cation exchanger that attracts cations and anion exchanger that attracts anions by a process called electro static adsorption.
- The components are then separated by washing off the ion exchangers.
- They are constructed using porous matrix made of polyacrylamides, polystyrenes, dextrans or silica.
- Generally employed for de-colorization of sugar syrup, protein recovery from whey, softening & demineralization of water and separation of enzymes.

Membrane material

- Membranes may be composed of natural (e.g. modified natural cellulose polymers) or synthetic polymers (plastic materials) or inorganic ceramic materials.
- They should be good film formers, manage high permeate flows and have high selectivity.
- They should have good chemical and bacteriological resistance, be resistant to detergents and disinfectants.
- They should be inexpensive.

Table 12. 2 Advantages and limitations of different membranes used in R.O. and U.F.

Type of membrane	Advantages	Limitations
Cellulose acetate	High permeate flux, good salt rejection, easy to manufacture	Operates below 30°C and pH range 3 to 6, broken down by chlorine
Polysulphones, polyamides, PVC, poly styrene, poly carbonates, poly ethers	Better temperature resistance, Better pH resistance, Better chlorine resistance, easy to fabricate	Don't withstand high pressure- restricted to UF, Poly amides are more sensitive to chlorine than cellulose acetate
Composite or ceramic membranes (porous carbon, zirconium oxide, alumina)	Inert, very wide range of operating temp. and pH, resistance to chlorine and easily cleaned	Expensive

MEMBRANE MODULES

The different types of plate modules are as follows.

The tubular type

Hollow fibre

Wide tube design

The flat plate type

Plate and frame type

Spiral wound cartridges

The flat plate type

- Plate and frame design is similar to plate filter press.
- Have membranes stacked together with intermediate spacers and collection plates to remove permeate.
- Either laminar or turbulent flow.
- The feed can be passed in either series or parallel.
- High surface area to be fitted in a compact space.
- Individual plates can be replaced easily, hence less expensive.

Plate and frame design

- Membrane sandwiched between membrane support plates which are arranged in stacks similar to a plate heat exchanger
- Typically polymers (e.g. polyethersulfone) with polypropylene or polyolefin support
- UF (<1 to 1000 kDa MWCO)
- MF (0.1 to 0.16 μm diameter)



Fig. 12.10 Plate and frame module in waste water system

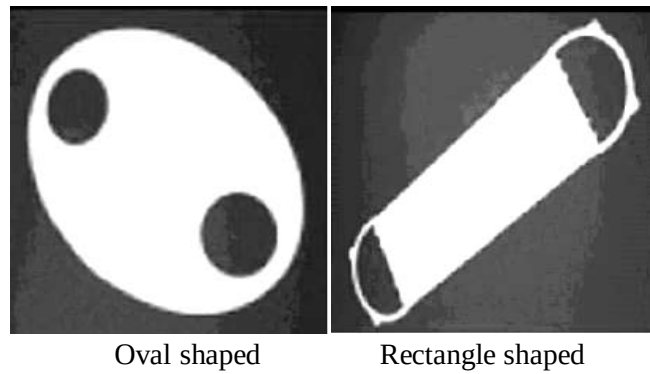


Fig. 12.11 Types of plates

Spiral wound system

- In the spiral wound system, alternating layers of polysulphone membranes with polyethylene supports are wrapped around a hollow central tube, separated by channel spacers and drains.
- The cartridge is about 12cm in diameter and 1m long.
- Feed liquid enters the cartridge and flows tangentially to the membranes.
- The permeate flows into the central tube and the concentrate flows out of the other end of cartridge.
- Separator screens cause turbulent flow and hence more flux.
- Low cost and popularly adopted.

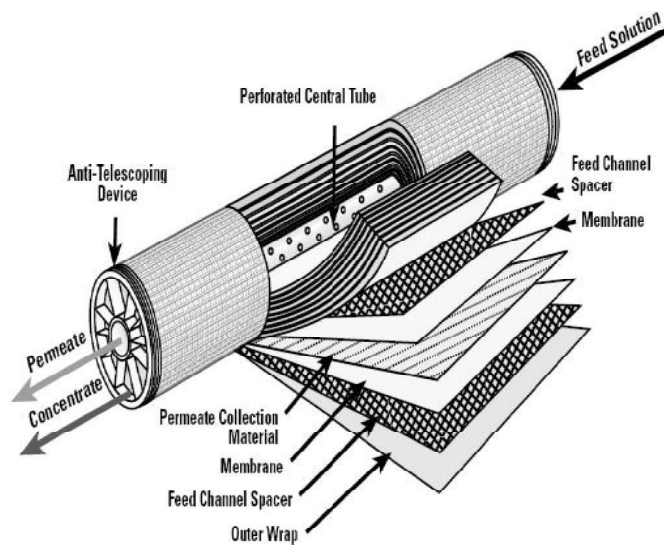


Fig. 12.12 Spiral wound membrane

The tubular type

- *Hollow fibre systems* are usually a narrow tube made of a non-cellulosic polymer, have 50-1000 fibres, 1m long, 0.001-1.2 mm diameter.
- Attached to each end of a tubular sheet.
- Having large surface area, generally employed for RO.
- Comparatively expensive as whole cartridge is changed in case a single fibre is damaged.
- They are easy to clean and don't block easily.
- In *Wide tube design*, a number of stain less steel tubes having lined membranes are fabricated.
- Give rigid support to membranes.
- About 20 tubes, each 1.2-3.6 m long and 12-25 mm diameter are fitted in parallel or series.
- Operate under turbulent flow conditions with higher flux, hence can handle more viscous fluids.



Fig. 12.13 Hollow fibre membrane

Advantages of Membrane separation

- Basically membrane concentrations occur at ambient temperatures.
- Loss of heat sensitive nutrients and characteristics are insignificant.
- Sensory and nutritional qualities of foods remain unaltered.
- Simple installation with low operation costs and labor.
- In contrast to conventional concentration by evaporation, no requirement of steam boilers.

Limitations

- Change in concentration of feed affects the flux.
- Higher capital cost involvement than evaporation,
- Limited to maximum concentration to 30 per cent total solid.
- Fouling of membranes may adversely affect the efficiency and time of operation.

Pervaporation

It is another separation technique which has the following characteristics.

- Liquid feed mixture is separated by partial vaporization through a non porous selectively permeable membrane.
- Produces vapor permeate and liquid retentate.
- Partial vaporization done by decreasing pressure of the permeate side.
- Two types of membranes used.
- Hydrophilic polymers (polyvinyl alcohol or cellulose acetate) permit water permeation.
- Hydrophobic polymers (polydimethyl siloxane or polytrimethyl silylpropyne) permit permeation of organic materials.
- Hydrophilic membranes are used to de-alcoholize wines and beers.
- Hydrophobic membranes are used to concentrate aroma compounds like alcohols, aldehydes and esters.

CHECK YOUR PROGRESS

1. Write short notes on the equipment specifications and applications of reverse osmosis, nanofiltration, ultra filtration and microfiltration.
2. Explain the different membrane techniques.
3. What are the different membrane modules ?
4. Write short notes on pervaporation, electro dialysis, ion exchange methods of separation.

Further reading

- Ahmed T. 1997. *Dairy Plant Engineering and Management*. 4th Ed. Kitab Mahal.
- De S. 1980. *Outlines of dairy technology*. Oxford University Press. Delhi.
- McCabe WL & Smith JC. 1999. *Unit Operations of Chemical Engineering*. McGraw Hill.
- Sahay KM & Singh KK. 1994. *Unit Operations of Agricultural Processing*. Vikas Publ. House.
- Singh RP & Heldman DR. 1993. *Introduction to Food Engineering*. Academic Press.
- Toledo R T. 1997. *Fundamentals of Food Process Engineering*. CBS Publisher.

Course outline-Theory

- Dairy development in India
- Engineering, thermal and chemical properties of milk and milk products
- Unit operation of various dairy and food processing systems
- Process flow charts for product manufacture
- Working principles of equipment for-
 - o Receiving, Pasteurization, Sterilization, Homogenization, Filling & packaging, Butter manufacture
- Dairy plant design and layout
- Composition and proximate analysis of food products
- Deterioration in products and their controls
- Physical, chemical and biological methods of food preservation
- Changes undergone by the food components during processing, evaporation, drying, freezing, juice extraction, filtration, membrane separation, thermal processing
- Plant utilities requirement

Course outline-Practical

- Study of a composite pilot milk processing plant & equipments
- Study of pasteurisers
- Study of sterilizers
- Study of homogenisers
- Study of separators
- Study of butter churners
- Study of evaporators
- Study of milk dryers
- Study of freezers
- Design of food processing plants & preparation of layout
- Visit to multi-product dairy plant
- Determination of physical properties of food products
- Estimation of steam requirements
- Estimation of refrigeration requirements in dairy & food plant
- Visit to Food industry

Concepts in Dairy and Food Engineering

(A guide book for better understanding)

Dr. Sanjaya K Dash

Professor

Dept. of Agricultural Processing and Food Engineering

**College of Agricultural Engineering and Technology
Orissa University of Agriculture and Technology
Bhubaneswar- 751 003**

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by

Sanjaya K Dash

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P R E F A C E

With the revision of the courses and with higher expectations of the ICAR, the contents to be covered in the “Dairy and Food Engineering” course have increased a lot. Thus, the responsibility of a teacher has increased and he has to cover virtually two courses “Dairy Engineering” and “Food Engineering” in a single semester in 2+1 credit hours. This has compelled me to mostly stick to power point presentations in the class, even though I personally love to interact with the students with a chalk and black board. And with the slides rolling in the class, as I have always felt, handing over the lecture notes to the students prior to the class, helps them to keep their hands reasonably free and they can spend more time for thinking and interacting with the teachers. The good students also read the topics to be discussed in the class beforehand and come prepared to the class to ask questions to improve the interactions. As I always say, most of the students have doubts, but a few dare to ask them, and when they ask the questions, the whole class is benefited.

Until last year, I used to publish my presentations in the internet (www.sanjayakdash.blogspot.com) and circulate the hard copies of the presentations in the class. However, this manual, which is a compilation of the lecture notes/ power point presentations that I used for the course “Dairy and Food Engineering” during 2011-12, is expected to facilitate more to the students and peers. Though I keep modifying, and the power point presentations that I will be using in the subsequent years may not be exactly the same available on the net, but still this endeavor should serve as a useful reading material beyond the class hours.

This manual is not a substitute for an effective class or a good book, but it is intended to assist the student to check the understanding before and at the end of the class. Some students can not follow the pace of the teacher, and hence they can refer the manual and come back to the teacher at leisure times.

I am grateful to Prof. Md. K. Khan, Dean of the College of Agricultural Engineering and Technology, OUAT, Bhubaneswar for kindly allowing the publication of this manual by the college and for his encouragements. He taught me “Dairy engineering” during my B. Tech. I am also indebted to all faculty members of my department for their support and suggestions during the course of preparation of manuscript. I am also highly thankful to my colleague Sri Sandeep Dawange for helping me in arranging the manuscript to make it press-ready.

I wish the students/ readers all success in future endeavours.

Sanjaya K Dash

CONTENTS

Chapter No.	Topic	Page No.
1	Introduction to dairy and food engineering	1
2	Properties of milk	11
3	Process flow charts and plant layout	25
4	Reception of milk	36
5	Pasteurization	46
6	Sterilization	56
7	Homogenization	66
8	Cream separation	74
9	Butter manufacture	78
10	Drying of milk	89
11	Juice extraction and filtration	95
12	Membrane separation	101

