UNIT 4 CLARIFICATION, SEPARATION, BACTOFUGATION AND STANDARDIZATION

Structure

4.0 OBJECTIVES

After reading this unit, we should be able to:

- state the purpose of some of the basic milk processing operations.
- differentiate between filtration and clarification of milk.
- define what ‘separation of milk’ means and what factors affect the same.
- enumerate other centrifugal processes viz. bactofugation and clarifixation.
- specify ‘standardization’ means and how to carry our the same.

4.1 INTRODUCTION

As we have studied earlier, that it is essential to keep the milk cool soon after milking till it reaches the processing plant. At the milk plant it may be (i) processed for distribution in fluid form as market milk, or (ii) converted into various products. In either case, it is required to be subjected to certain basic treatments before further processing.

The treatments that milk is required to undergo at a dairy plant include filtration or clarification, separation and standardization. These are aimed at purification and compositional modification of the milk. In the present unit we shall discuss the objectives of such treatments, and ways and means of carrying out the same. Clarification and separation of milk are, in practice, achieved by centrifugation of milk (in specially designed centrifugal machines.certain other centrifugation-based processes such as 'bactofugation' and 'clarifixation' relevant to milk processing will also be briefly discussed in this unit.

4.2 FILTRATION AND CLARIFICATION OF MILK

i. Purpose

Raw milk as produced on the farm and transported to the collection centre or a dairy plant generally contains varying amounts of visible, invisible impurities. This foreign matter includes straw and hair pieces, dust particles, leukocytes (somatic cells or white blood cells), insects, etc. If not effectively removed, such extraneous insoluble matter can result in deposits in milk handling equipment such as cooler, etc., and, more importantly, cause unsightly appearance.

Relatively large pieces of such material e.g. straw, hair and insects, are usually removed by 'straining' (passing the milk through a fine metal–gauge strainer or metallic sieve on the farm, at the collection centre or at the processing plant. Tubular sieves located in the milk inlet pipe to the processing unit (e.g. pasteurizer) are also used.

However, finer foreign matter to be eliminated requires clarification using a special filter or a centrifuged clarifier. These steps of aesthetic improvement of product are particularly useful for overcoming the problem of sediments in fluid milk and liquid milk products in general, and homogenized milk in particular.

ii. Filtration

Filtration (or, clarification using a filter-bag) refers to making the milk pass through a filter-cloth or filter-pad. The filtering medium has a pore size (25-100 mm) that permits most of the foreign matter to be retained on it. The milk filter consists of a nylon filter-bag or a filter-pad supported on a perforated stainless steel (SS) support held in an SS enclosure with a tight-fitting lid, milk distributor, and inlet- and outlet- connections. Milk usually passes from top to bottom. In case of twin filters, three way valves in the inlet and outlet lines enable switching from one filter to the other when the first is to be cleaned. Sometimes, filters may be provided in the form of cylindrical bags or 'stockings' fitted over perforated SS tubes as in the modern continuous pasteurizing plants (high-temperature short-time, or HTST pasteurizers

Filtration can be carried out either on cold milk (about 10^{o}C) or warm milk (40-45^{o}C). Since warm milk filtration is more rapid due to lower viscosity of warm milk, it is universally used. For cold filtration, the filter is located in the line connecting the milk receiving tank or holding tank and the pasteurizer. Since warm filtration requires preheating, the filter of this type is placed between the regenerator and the final heating section of the HTST pasteurizer.

The filter-bag must periodically be cleaned. Accordingly, the operation run may vary from 2 to 10 hours depending on the level of foreign matter and the filter pore size. Generally, twin filters located in parallel are employed to permit cleaning of one filter while the other is in use. This enables continuous process run.

We should be able to realize that filtration removes only the gross impurities, and does not remove bacteria from milk. Accordingly, it does not improve the keeping quality of the milk. In fact, bacteria may grow in the filters if they are used for unusually long times before cleaning.

iii. Clarification

Definition and objective : As an alternative to filtration, clarification can also be employed to remove insoluble impurities especially the finer ones. It involves the use of a centrifugal machine called 'clarifier'. Thus, clarification is a process of subjecting milk to a centrifugal force in order to eliminate the finer but heavier particles from milk, somatic cells, dust particles, etc. Although part of bacteria are also removed along with the extraneous matter, clarification cannot be considered an effective means of bacteria removal. Hence, one should be aware that it cannot be a substitute for a suitable heat treatment in order to ensure safety against pathogenic (disease-causing) microorganisms.

Principle of clarification : As we have studied, when milk is introduced between two adjacent rotating conical discs (in a stack of several discs) of a centrifuge bowl, it is subjected to a centrifugal force. This force causes the heavier dirt particles to be thrown out into the sludge space surrounding the discs where it is collected during the run, while the comparatively lighter milk continuously flows inward and upward to the outlet. There is no separation of fat globules (cream) and skim milk in a clarifier.

Operation of a clarifier : Raw milk is made to pass usually under a pump pressure, down a central pipe of a rotating bowl and led to the outer edge of the clarifier discs through a distributor in the bottom and then onto the spinning discs, where milk and dirt are separated. The milk is led to the discharge port at the top of the bowl whereas the dirt is accumulated in the sediment space. The accumulated sludge is removed from the bowl by dismantling the clarifier at regular intervals. The interval may range from 1 to 8 hours depending on size of the clarifier and the amount of impurities in the milk. However, most large-size modern clarifiers are self-desludging or 'partial desludging' type in which periodical sludge removal takes place during the clarification process, without interruption of the clarifier operation. Such desludging results in about 0.05-0.10% of milk being lost and the sludge being liquid rather than solid as in the non-self-desludging machines.

As for the milk filter, clarifier may be located in the raw milk line between the raw milk tank and pasteurizer. Alternatively, milk may be clarified warm/hot by placing the clarifier at a suitable point in the regeneration section of the HTST unit or between the regeneration and heating sections.

The clarifier sludge or clarifier 'slime' consists primarily of dust and dirt particles, blood cells, microorganisms and milk protein. Its composition will depend on whether it is liquid (82-86% water, 6-8 % protein), or solid (65-69% water, 24-28% protein).

Check Your Progress I

1. What type of impurities are removed from milk by filtration?

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2. What will happen if milk is not clarified?

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3. State about the milk filter.

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4. What is the purpose of twin filters?

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5. What is clarification?

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6. How does a clarifier remove milk impurities?

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7. What is the main operational advantage and limitation of a self desludging clarifier?

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8. Where should a clarifier are located?

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9. What is 'clarifier sludge'?

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4.3 SEPARATION OF MILK

We have studied that milk contains fat and non-fat constituents, also called solids-not-fat (SNF). Fat is present as globules whereas the SNF form an ionic solution (e.g. certain salts), true solution (e.g. lactose and whey proteins), or a colloidal solution (e.g. casein micelles) in the water part of milk. Thus, milk represents an emulsion in which the relatively large fat globules are dispersed in the continuous aqueous phase (serum). Since fat globules are lighter as compared to other solids, they tend to readily separate out from the serum (or skim milk), as can be seen in the formation of a 'cream' layer on the top of milk held undisturbed in a container for a few hours. Cream is that portion of milk, which is rich in milk fat, but poorer in SNF. This suggests that much of the fat can be easily separated in the form of cream from milk, leaving behind the skim milk containing very little fat.

Cream separation enables the processor to manufacture a variety of fat-rich dairy products such as cream of various types, butter, ghee, etc. Cream separation also makes it possible to adjust the composition of milk with respect to its fat and SNF contents. Such compositional modification (vide Sec. 4.5) may be desired for products manufacture as also for meeting the legal requirements of different types of fluid milk

i. Methods of Separation

Two methods of separation of cream from milk are commonly used: (i) gravity separation and (ii) centrifugal separation. Both these methods rely on the basic principle of separation of two immiscible liquids having different densities, under the influence of gravitational or centrifugal force.

Gravity Separation: As mentioned above, when milk is allowed to stand undisturbed for some time, a layer of cream (or 'malai') forms on the top due to rising of the fat globules which are initially dispersed throughout the bulk of milk. The upward movement of the lighter fat globules (density, 0.93 g/cc at 20^{o}C) in the heavier serum (density, 1.035 g/cc) takes place owing to gravity. Creaming may become evident in as short time as half an hour.

The rate of cream separation is directly proportional to the difference between the densities of fat and serum and to the square of fat globule diameter, and inversely proportional to the viscosity of serum. Thus, for a given sample of milk, the creaming rate will be maximum when the density difference is maximum and viscosity is minimum. Both these factors are, in turn, affected by temperature of milk. As the temperature rises, the ratio of the density difference and the serum viscosity increases favouring the separation process. This increase is particularly prominent between 10^{o} and 30^{o}C and much less above 50^{o}C.

Cream separation by gravity is, however, a very slow and inefficient process. It is of little practical value for commercial purposes. Hence, mechanized cream separation employing a centrifugal machine is most commonly used in the dairy industry. Even for a very small scale separation involving, say 10-20 litres of milk, a centrifugal separator is used, be it hand-driven or motor-driven.

Centrifugal Separation: In principle, this method of cream separation is similar to gravity separation but gravity as the driving force is replaced by the centrifugal force for which a rotational machine is used. Since the latter force is much larger than the gravitational force, separation is greatly accelerated. The centrifugal separator is similar to the clarifier discussed in the earlier section, but milk entering through the bottom of the separator bowl holding a stack of conical discs rises up through holes located somewhere in the middle of the inner and outer edges of the discs. The milk between discs is subjected to a centrifugal force in the rotating bowl and thereby tends to fly out from the centre. The skim milk fraction, being heavier, moves away and forms a layer on the outer edge of the discs, whereas the fat globules gather on the inside edge. The incoming un-separated milk forces the separating layers further and upward out at the top of the bowl. Thus, there are two outlets in a cream separator, one for skim milk and the other for cream, the cream outlet being nearer to the centre.

The rate of cream separation in ease of a centrifugal separator is influenced by the same factors affecting gravity separation, but the speed of the separator bowl and the disc diameter are also very important here. The higher the speed of the bowl or larger the diameter of discs, the greater will be the separation rate.

ii. Factors affecting Skimming Efficiency

Since fat removal from milk is the principal function of a cream separator, the efficiency of the process, also called skimming efficiency, is determined by the effectiveness with which the fat content of the out-coming skim milk is reduced. The residual fat content of skim milk is usually in the range of 0.01 – 0.05% in the modern machines. A fat content higher than 0.06% represents poorer separation efficiency. The skim milk fat content is inversely related to fat recovery in the cream. Hence, the *skimming efficiency* is often defined as the percentage of total fat in whole milk recovered in the cream separated from it. For a given fat content of whole milk, the higher the fat content of skim milk, the lower the skimming efficiency. The factors that affect the skimming efficiency are related to either the milk being separated or the separator.

Intense agitation of milk prior to separation, air incorporation (or foaming) and high acidity of milk adversely affect the separation efficiency. Further, if the proportion of smaller fat globules (especially below 2 mm in diameter) is greater, the skimming efficiency will go down. It should, therefore, be obvious that homogenized milk with its very small globules (please see Unit 3) cannot be separated. Gravity or centrifugal separation of fat globules from skim milk is faster at a higher temperature. Thus skimming efficiency increases with increasing temperature of milk up to about 80°C, beyond which increasing viscosity of milk tends to make the separation process less efficient. Depending upon location of the cream separator in the milk processing line (particularly with respect to HTST pasteurization), the separation temperature may range usually from 35-75°C, optimum being 50-55°C (‘warm milk’ separation). However, cold milk separators’ may operate at 5-10°C giving an advantage of less foaming, but partial churning of fat, bowl clogging and reduced flow rate (separator capacity) are the associated disadvantages.

Adjustment of the ‘cream screw’ for high-fat cream (above 55%), or excessive flow rates of feed milk reduce the skimming efficiency. However, feeding rates below the normal separator capacity does not enhance the skimming performance, but it may lead to undesirable air incorporation. A higher bowl speed gives higher skimming efficiency but, since increased speed requires greater energy input, normal range of 4000-7000 rpm (sometimes as low as about 2000 rpm) giving efficient separation is normally not exceeded in the separator design. Poor disc condition (e.g. deshaped, dirty or scratched one), vibrations of the separators, and defective gaskets in the cream section could cause unacceptable skimming efficiency. Excessive slime getting collected in the sludge space of the bowl would also have an adverse impact on the separator performance.

iii. Factors affecting Yield and Fat Content of Cream

The yield of cream and skim milk can be given by the following formulae:

i) Yield of cream (% of feed milk) =

$$\frac{f_m - f_s}{f_c - f_s} \times 100 \text{ .....} \qquad \text{(Eq.1)}$$

ii) Yield of skim milk (% of feed milk) =

$$\frac{f_c - f_m}{f_c - f_s} \times 100 \text{ ....} \qquad \text{(Eq. 2)}$$

where,

f_m = fat in milk, %

f_s = fat in skim milk, %

f_c = fat in cream, %.

All those factors which affect the skimming efficiency can be expected to influence the cream yield too. Conditions leading to a higher skimming efficiency would give a better yield. However, the fat content of cream is obviously the major factor influencing the yield of cream. Accordingly, the adjustment of the cream screw or skim-milk screw is critical with regard to cream yield.

The position of the cream screw i.e. a valve provided in the cream outlet controls the flow rate of the cream being discharged. Turning the screw 'inward' reduces the cream discharge rate thereby increasing the fat content of cream. Adjusting the valve by 'outward' movement has the opposite effect. Similarly, manipulation of the skim milk screw so as to decrease the flow rate of the exiting skim milk will decrease the fat concentration of cream, and vice-versa. Thus, changing the position of the cream screw or skim-milk screw alters the ratio of cream to skim milk; an increased ratio decreases the fat content of cream and a decreased one raises it.

Further, a lower separation temperature and a higher fat content of milk lead to an increased fat content of cream, whereas an increased feed rate causes a decreased richness of cream, and vice-versa.

Check Your Progress 2

1. What are the objectives of cream separation?

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2. What are the methods of separation of milk?

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3. What is creaming?

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4. What are the factors affecting the creaming rate?

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5. What is the effect of temperature on the rate of creaming?

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6. What is the major drawback of gravity separation as compared to centrifugal separation?

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7. How is fat separated from skim milk in a centrifugal separator?

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8. How do the machine parameters affect the rate of fat separation in a centrifugal separator?

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9. What do you understand by 'skimming efficiency'?

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10. List the factors affecting the skimming efficiency.

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11. How is the fat content of cream exiting the separation adjusted?

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12. How does the fat content of feed milk influence the richness of cream?

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13. What is the effect of temperature of separation on the fat content of cream?

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4.4 OTHER CENTRIFUGAL PROCESSES FOR MILK

The principle of differential movement of heavy and light components of milk subjected to a centrifugal force has been utilized in a few applications other than clarification and cream separation. These include bactofugation and clarifixation.

i. Bactofugation

We may recall clarification of milk wherein it was stated that the centrifugal removal of heavy dirt particles etc. results in elimination of a part of bacteria as well. Such bacteria removal is made more effective using a special high-speed disc-bowl centrifuge called ‘bactofuge’. This process known as ‘bactofugation’ is particularly applicable to removal of bacterial spores from milk, which are not only difficult to inactivate by heat treatment but also heavier (or denser) than vegetative cells.

The bactofuge is kind of high-speed (up to 20,000 rpm) clarifier provided with discharge nozzles in the bowl wall. The centrifugal force generated in it is upto 10,000 g (g = gravitational acceleration). The bacteria in milk being bactofuged are collected in the form of ‘bactofugate’ in the sludge space. The bactofugate is approx. 3% of the feed volume and contains primarily bacterial spores and milk proteins. Anaerobic spores are removed to an extent of 98-99%. A double-bactofuge treatment at 73°C yields more than 99.9% reduction in bacterial spore count of milk. However, since bactofugation does not effectively eliminate all microorganisms, pathogens in particular, the milk must ordinarily be pasteurized so as to ensure safety of consumption.

The main application of this expensive process is in the field of cheese making where removal of anaerobic (clostridial) spores from milk is useful in avoiding the problem known as ‘late blowing’ in hard and semi-hard cheeses. Bactofugation has also been employed to extend the shelf life of milk under refrigeration.

In order to destroy the bacteria contained in the bactofugate and improve the economy of the process by utilizing the milk protein in it, a process called ‘Bactotherm’ has been evolved. Clarified and standardized milk is bactofuged at 60-75°C followed by pasteurization employing the HTST process. The bactofugate is deaerated in a vacuum chamber and sterilized at 130-140°C for 3-4 sec using steam injection, and finally mixed with chilled bactofuged milk for further processing.

ii. Clarifixation

A clarifixator is a machine working on the same principle as that of the centrifugal separator but has an additional provision to effect reduction of the size of fat globules in the cream fraction before it is remixed with the outgoing skim milk. The resulting milk, sometimes called ‘stabilized’ milk has a reduced tendency to creaming upon undisturbed storage because of small-size fat globules.

The break-down of fat globules is brought about by the peripheral spikes or protrusions on the ‘paring disc’ provided in the cream passage at the top of the centrifuge. A paring disc is a fixed circular structure acting as a stationary centripetal pump. The cream separated from milk strikes the protruding obstacles before entering the paring disc. The fat globules thus experiencing an intense turbulence or shearing action are broken down to a smaller size (less than 2 mm). The cream is then mixed with the incoming milk to be recycled through the bowl. The fat globules of sufficiently reduced size will not get re-separated when the cream passes through the bowl discs again and will therefore, exit the separator through the skim milk outlet which thus discharges ‘homogenized’ whole milk. However, because of its lower effectiveness as compared to pressure homogenization, clarifixation has not been used to any significant extent in the dairy industry.

Check Your Progress 3

1. What is the function of a bactofuge?

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2. How is a bactofuge different from a clarifier?

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3. Whether bactofugation can be a substitute for pasteurization.

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4. Give the major applications of bactofugation.

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5. What is the 'Bactotherm' process?

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6. What is the difference between a cream separator and a clarifixator?

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7. What is a 'paring disc'?

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8. How is clarifixated milk different from homogenized milk?

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4.5 STANDARDIZATION OF MILK

i. Purpose and Definition

We know that liquid milk sold in the market is of different types with regard to its composition. Since the milk available to the processor may not necessarily be of the same composition as desired in the milk to be marketed, it is a very common practice to adjust the composition as per the requirement. Also, compositional modification (or adjustment) is necessary if the milk is to be converted into a certain product. A product must conform to the legal standards prescribed for it, or the quality standards set by the manufacturer. Product manufacture without appropriate compositional manipulation of milk may lead to poor quality product, or a product that does not meet legal requirements, or it may be an economical loss to the processor.

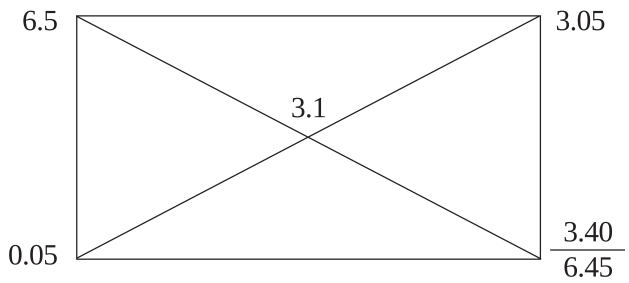
Standardization thus refers to the process by which the milk composition is adjusted to the desired level. The most commonly considered compositional parameters are fat and SNF for market milk, although sometimes fat alone may be taken into account for standardization. For certain specific, product,-manufacturing applications even protein content may be adjusted. Accordingly, the process of standardization involves lowering or raising the level of a particular constituent(s) to the desired value specially fat.

ii. Standardization of Milk for Fat

Often milk may be standardized to a certain value of a single component i.e. fat or SNF alone. This can be achieved by adding to the milk, a calculated quantity of a fat-rich product such as cream if the fat level is to be raised, or a low-fat or fat-free component e.g. skim milk, if the milk has excess fat. The fat content of milk can be reduced also by separating a calculated amount of cream of known fat percentage.

The calculation of the quantity of cream or skim milk to be added to milk, or cream or skim milk to be separated from it can be made by a simple method known as the Pearson's square method. It consists in drawing an arbitrary square (or, a rectangle), placing at the left concerns of the square, the values of fat content of the two products to be mixed and at the centre of the square, the desired fat percentage. Then, subtractions are made diagonally across the square, the smaller value being deducted from the larger one, and the differences are entered at the correspondingly opposite corners on the right- hand side. These two new values at the right corners are summed to obtain a third value. All the three values placed at the right represent the proportions or relative amounts of the given products to be mixed (top right figure for the amount of the product to the top left, bottom right figure for the product to the bottom left, and the sum for the final product). The following is an example of such a calculation:

500 kg of milk testing 6.5% fat to be standardized to 3.1% fat using skim milk containing 0.05% fat.



Thus mixing of 3.05 kg of 6.5% fat milk with 3.40 kg of the skim milk will yield 6.45 kg of milk containing the desired fat level i.e. 3.1%. Therefore, the quantity of skim milk required to be added to 500 kg whole milk will be

$$\frac{3.4 \times 500}{3.05} = 557.38 \text{ kg}$$

Accordingly, 557.38 kg of 0.05% skim milk mixed with 500 kg of 6.5% fat whole milk will yield 1057.38 kg of milk having 3.1% fat.

The single-component (fat-based) standardization is commonly used for cream meant for butter-making. It generally involves adjusting the fat percentage of a high-fat cream to the desired level by mixing it with the calculated quantity of skim milk (or, whole milk). Blending of the two components i.e. cream and skim milk or whole milk can be carried out by transferring the calculated quantities of the two (one after the other), to a tank (or, silo) with a provision for adequate mixing.

Continuous, on-line blending is much more desirable in a large-scale operation. This can be achieved on the cream separator itself by allowing sufficient cream to remix with the skim milk so that the mixture is a milk with the desired fat content; the balance cream flows through the cream line into the cream tank. This requires that the separator is fitted with a standardizing device.

iii. Standardization of Milk for Fat and SNF

When milk is required to be standardized for both fat and SNF, the basis of calculation of the quantity of skim milk or cream to be added is the *ratio of fat to SNF*, and the total solids (TS) content. If the desired fat-to-SNF ratio is higher than the actual ratio in the available milk, then skim milk will be required to be added. On the other hand, when the desired ratio is lower, cream needs to be blended into the milk. It is, therefore, necessary that both the fat and SNF contents of the milk to be standardized, and those of cream or skim milk to be used are known. If the fat content of cream or skim milk (separated from a milk of known fat and SNF contents) is known, the SNF content can be estimated as under

i) SNF in cream, % $= SNF_m \times \frac{100 - f_c}{100 - f_m}$ .... (Eq. 3)

ii) SNF in skim milk $= SNF_m \times \frac{100 - f_s}{100 - f_m}$ .... (Eq. 4)

where,

SNF_m = SNF percentage in milk

f_c = fat percentage in cream

f_m = fat percentage in milk

f_s = fat percentage in skim milk.

The amount of skim milk or cream required to be added to a given quantity of milk (so as to attain the desired levels of fat and SNF in it) can be worked out by using the following formulae:

i) $Q_c = Q_m \times \frac{(R \times SNF_m) - F_m}{f_c - (R \times SNF_c)}$ .... (Eq. 5)

ii) $Q_s = Q_m \times \frac{(f_m/R) - SNF_m}{SNF_s - (f_s/R)}$ .... (Eq. 6)

where,

Q_m = Quantity of milk to be standardized

Q_c = Quantity of cream required

Q_s = Quantity of skim milk required

R = Fat/ SNF ratio desired.

f_m = Fat percentage in milk

f_c = Fat percentage in cream

f_s = Fat percentage in skim milk

SNF_m = SNF percentage in milk

SNF_c = SNF percentage in cream

SNF_s = SNF percentage in skim milk.

Alternatively, an algebraic method can be used taking '*x*' quantity of cream or skim milk of known fat and SNF contents required to be added to the given quantity of milk with certain fat and SNF levels, and then solving. (for *x*) an equation of the desired fat-SNF ratio:

$$R = \frac{f_c \text{ (or } f_s) \times \frac{x}{100} + f_m \left(\frac{Q_m}{100}\right)}{SNF_c \text{ (or } SNF_s) \times \frac{x}{100} + SNF_m \left(\frac{Q_m}{100}\right)} \quad .... \quad \text{(Eq.7)}$$

where all values except that of *x* are known.

Check Your Progress 4

1. What is 'standardization of milk'?

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2. The Pearson's Square method is used for standardizing milk for fat and SNF. True or False?

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3. Single component standardization is applicable to cream for butter-making. True or False?

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4. How can an in-line cream separator be used for standardization of milk?

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5. When standardizing milk for both fat and SNF, how is it determined as to whether cream should be added or skim milk?

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4.6 LET US SUM UP

There are certain basic operations in relation to processing of raw milk into market milk (or, fluid milk) or dairy products. These are primarily aimed at removing the physical impurities (insoluble foreign matter) from the milk and ensuring the desired composition of the finished product.

The processes that are supposed to 'clean' the milk include straining through a metallic sieve to remove coarse particles, filtration using a filter-bag which eliminates small particles and body cells, and centrifugal clarification meant for removal of very fine dust, dirt and cells. While in-line straining and filtration are most common milk treatments followed in a dairy plant, clarification (using a centrifugal machine) is employed only to a limited extent, usually when filtration is not practiced.

A centrifugal separator helps fractionate milk into a fat-rich component i.e. cream, and an essentially fat-free component i.e. skim milk. Several milk- and machine-related factors affect the efficiency of the separation process, also known as 'skimming efficiency'. Similarly, the yield of cream and its fat content are governed by several variables, which must be controlled by the operator in order to obtain the desired quality and quantity of cream.

Besides cream separation, clarifixation and bactofugation are other centrifugal dairy processes. Intended to make milk resistant to fat separation, clarifixation causes break-down of the fat globules, whereas bactofugation eliminates microorganisms (especially bacterial spores) from milk.

In order to meet quality and legal requirements milk meant for market purpose or product manufacture may be adjusted to a prefixed level of certain compositional parameters such as fat or non-fat solids (SNF) alone, or both. Such standardization is usually practiced on batch milks in tanks and silos by blending of the milk with cream or skim milk. Alternatively, standardization can, more conveniently, be carried out on a separator in a continuous manner.

4.7 KEY WORDS

Bactofugation : It is a process of removing microorganisms, particularly bacterial spores, from milk by means of a centrifugal machine called 'bactofuge', which is essentially a high-speed clarifier.

Bactotherm : It is a process in which the 'bactofugate' (the bacterial mass entrained in milk protein getting collected in the sludge space of a bactofuge) is subjected to a high heat treatment (130-140^{o}C for 3- 4 sec) and then remixed with the milk.

Clarification : It is a process of removing insoluble extraneous matter such as dirt particles, somatic cells (or, blood cells), etc. from milk by using a clarifier', which is a centrifugal machine similar to a cream separator but having only one outlet i.e. the one for the clarified milk.

Clarifier sludge : It is the semi-solid impurities separating from milk and getting collected in the sludge space of a clarifier bowl. It primarily comprises dust particles, leucocytes, microorganisms and milk protein.

Clarifixation : It is a process of reducing the size of fat globules in milk (and making it stable against fat separation) by using a specialized centrifugal machine called clarifixator in which fat globules are separated and broken down before being remixed with the milk.

Cream : It is the fat-rich fraction of milk obtained upon separation of fat globules from milk under a gravitational or centrifugal force (the latter using a disc-bowl centrifuge).

Creaming : It is the phenomenon of cream separation in general, but refers particularly to gravity separation of fat globules in the form of cream from whole milk; a fat-rich cream layer forms at the top of undisturbed milk.

Cream separator : It is a centrifugal machine in which milk is subjected to a whirling action resulting in separation of lighter fat globules (cream) from heavier non-fat fraction (skim milk).

Filtration : It refers to removal of extraneous impurities such as hair pieces, dust, dirt, insects, cell debris, etc. from raw milk by passing it through a filler-bag usually placed in-line during milk processing.

Self desludging : It refers to automatic, intermittent removal of clarifier slime (or, separator slime) from the sludge space (without dismantling the bowl) while the process of clarification or cream separation is going on.

Separator slime : It is the semi-solid material (impurities) separating from milk and getting collected in the sludge space of the bowl of a cream separator. It is similar to the clarifier slime.

Serum : The portion of milk excluding fat globules. It comprises water and the non-fat constituents viz., lactose, protein and minerals.

Skim milk : The non-fat component of milk obtained upon separation of cream from it. It contains very little fat, usually less than 0.10%.

Skimming : It refers to the effectiveness with which milk fat can be separated as cream from milk. It is defined as the percentage of the total fat in the whole milk recovered in the cream that has been separated from it.

Solids-not-fat : The solids (or constituents) in milk other than fat are called SNF. These include milk protein, lactose and minerals (or, ash).

Standardization : It is the process whereby the composition of milk (in terms of fat, or both fat and SNF) is adjusted to a predetermined level.

Straining : Refers to removal of coarse impurities such as hair pieces, insects, etc. from milk by passing it through a cloth piece or metallic sieve (called strainer).

Yield (or, out-turn) : It is the amount of a product (e.g. cream), expressed in terms of percentage of milk used (or separated).

4.8 SOME USEFUL BOOKS

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4.9 ANSWERS TO CHECK YOUR PRGRESS

Your answer should include the following points:

Check Your Progress 1

1) i. Insoluble foreign matter such as straw, hair pieces, insects, dust, dirt particles, somatic cells, etc.

2) i. Unfiltered or unclarified milk will tend to cause deposit formation in equipment used in handling of the milk and give rise to unsightly sediment at the bottom of the container.

3) i. A milk filter is made up of a nylon cloth with fine pores (25-110 mm) and it is supported over a perforated stainless steel basket or tube.

4) i. Twin filters permit uninterrupted run of a continuous milk process (e.g. in an HTST pasteurizer): Since at a time one filter is in use, when one filter is required to be cleaned, the other is brought into use merely by turning appropriate valves.

5) i. Clarification is a process of removing milk impurities comprising fine dust and dirt particles, body cells, etc. by means of a centrifugal machine (although ‘filtration’ is also sometimes termed as one of the methods of clarifying milk).

6) i. When milk is subjected to a whirling motion, the centrifugal force acting on throws the heavier dirt particles away into the sludge space while the milk, being higher, moves inward and upward between the conical discs of the clarifier bowl.

7) i. The clarifier slime in a self-desludging clarifier keeps discharging automatically at a definite interval of time so that the machine can work for a long period without the need to stop it for cleaning. The disadvantage however, is that desludging takes place by means of milk jets. Hence, 0.05 – 0.10% of milk is lost with the sludge.

8) i. If cold-milk clarification is desired, the clarifier should be located in the raw milk line to the HTST pasteurizer. For warm-milk clarification, the clarifier may be located within the regeneration section, or between the regeneration and heating sections.

9) i. The clarifier sludge (or clarifier slime) is the liquid or semi-solid (or solid) material separating from milk and gathering in the sludge space of the clarifier bowl. It is the milk impurities consisting of dust particles, body cells, leucocytes and bacteria in addition to milk protein.

Check Your Progress 2

1) i. Separation of milk into cream and skim milk makes it possible to adjust the milk composition with respect to fat and SNF, and also facilitates manufacture of certain products such as cream, ghee, butter, skim milk powder, etc.

2) i. Cream separation (or, separation of milk) can be achieved by either (i) the gravity (quiescent storage) method or (ii) centrifugal separation.

3) i. Creaming is the phenomenon wherein the lighter fat globules in undisturbed milk tend to rise and form a fat-rich layer (of cream) at the top under the influence of gravity.

4) i. The factors affecting the rate of fat separation in milk include the density difference between fat and serum, size of fat globules, and viscosity of serum. All these factors particularly the first and the last ones are in turn, influenced by the temperature of milk.

5) i. As the temperature increases, there is an increase in the ratio of the density difference (between fat and serum) to the viscosity of serum up to about 80^{o}C, the increase being more prominent up to about 50^{o}C. Thus the creaming rate is higher at higher temperatures, up to approx. 80^{o}C, beyond which it goes down.

6) i. Gravity separation being much slower than centrifugal separation, it is of little practical utility in the industry.

7) i. The milk distributed between the discs of the rotating separator bowl is subjected to whirling action. Under the resulting centrifugal impact the heavier serum portion is thrown outward whereas the lighter fat globules move inward and upward through the passage near the central axis to the cream outlet at the top; the skim milk is continuously forced upward over the outer edges of the discs and then to the skim milk outlet.

8) i. The higher the speed of the separator bowl and the larger in diameter of the discs, the greater is the rate of separation of fat in a centrifugal machine.

9) i. Skimming efficiency refers to the effectiveness with which fat can be separated from milk. It is defined as the percentage of total milk fat recovered in cream. Skimming efficiency is often indicated by the fat content of skim milk, which should not be higher than 0.06% for an efficient separation process.

10) i. The factors affecting skimming efficiency include agitation of milk before separation, presence of air in milk, size of fat globules, acidity of milk, temperature of milk, feed rate, position of cream-screw, separator-bowl speed, condition of discs, vibrations of the machine and the condition of gaskets.

11) i. The primary method of controlling the fat content of cream is by adjustment of the cream screw.

12) i. The higher the fat content of the feed milk, the greater with the concentration of fat in the resulting cream if the cream screw setting and other factors are not changed.

13) i. As the temperature of separation decreases, the viscosity of cream increases which causes the cream flow rate to fall. Thus, a colder milk gives richer cream at the same feed rate.

Check Your Progress 3

1) i. A bactofuge achieves removal of bacteria, bacterial spores in particular, from milk by subjecting it to a centrifugal force, the heavier bacteria being thrown away from the axis of rotation and thereby getting collected in the sludge space of the disc bowl.

2) i. The bactofuge has a higher speed (about 20,000 rpm) providing a larger centrifugal force (10,000 g) to effect removal of bacteria to a greater extent than in a clarifier.

3) i. Bactofugation does not necessarily eliminate all pathogenic microorganisms from milk although the bacterial load is greatly reduced in bactofuged milk. Hence, heat treatment of such milk is necessary to make it safe for human consumption.

4) i. Since bactofugation can render the milk nearly free from anaerobic spores, bactofuged milk is particularly suitable in cheese-making where the spores cause defects like 'late blowing'. Also bactofuged milk can be used for products with extended shelf life.

5) i. The Bactotherm process refers to bactofuging clarified milk, subjecting the resulting bactofugate to high heat treatment (130-140^{o}C for 3-4 sec) and then remixing the latter with the pasteurized bactofuged milk for further processing.

6) i. In a cream separator, milk under the influence of a centrifugal force is separated into a fat-rich component (cream) and a low-fat component (skim milk), but the fat globule size remains unchanged. On the other hand, a clarifixator reduces the size of fat globules in the separated cream to below 2 mm before remixing the cream with the feed milk from which small fat globules are not reseparated but pass into the skim milk. Thus it delivers 'homogenized' whole milk.

7) i. A paring disc is a stationary structure in the cream outlet of a cream separator (or a clarifixator). The product enters the disc in a circular path at the periphery whereby the rotational energy is converted into linear kinetic energy providing a pumping effect to the cream.

8) i. Both clarifixated milk and homogenized milk have fat globules of reduced size giving stability against separation, but the mean globule size is larger in the former. Also, the clarifixated milk is also clarified one so that it shows little sediment.

Check Your Progress 4

1) i. Adjustment of the composition of milk with regard to fat alone, or both fat and SNF, so that the milk has predetermined levels of these components. It usually involves mixing of a calculated quantity of cream or skim milk with milk in or der to attain the desired values of the compositional parameters.

2) i. False. The Pearson's Square method is suitable for a single-component standardization, not for both fat and SNF.

3) i. True. In butter-making cream is standardized for the fat content only.

4) i. Special pipeline connections with necessary valves and flow meter provided in the outlets for cream and skim milk on a separator enable mixing of cream into the skim milk at a predetermined rate and thereby allow standardization of milk.

5) i. Comparing the fat-SNF ratio (R_a) of the available milk with the desired ratio (R_d) one can determine if cream is to be added ($R_d > R_a$) or skim milk ($R_a > R_d$).

1.10 SOME MORE QUESTIONS TO CHECK YOUR PROGRESS

1. How does a clarifier deliver unseparated purified milk?
2. What is separator slime?
3. What is the role of temperature in clarification and separation of milk?
4. What is the function of the cream screw?
5. How are paring discs useful in a semi-closed separator?
6. What are the rotational speeds of a cream separator and a bactofuge?
7. Why is clarifixator not used extensively in the dairy industry?
8. What are the requirements of in-line standardization of milk?