UNIT 6 HOMOGENIZATION

Structure

6.0 OBJECTIVES

After reading this unit we should be able to:

- define homogenization;
- explain the theories governing the homogenization process;
- describe the homogenizer design and operations;
- comprehend the innovations in homogenization technology;
- specify factors that affect homogenization efficiency;
- state the effect of homogenization on various physico-chemical properties of milk;
- enumcrate various problems associated with the homogenized milk.

6.1 INTRODUCTION

Milk is an oil-in-water emulsion. Fat globules in the milk are dispersed in a continuous water phase (skim milk) and normally vary in sizes ranging from 1 mm to 22 mm, with a mean size of approximately 3-4 mm. As the density of milk fat is less than that of skim milk, the fat globules tend to rise to the surface during storage and form a cream layer. The rise of fat globules follows Stoke's law where the velocity of rising fat globules is expressed as:

$$V \ a \ \frac{d^2 (r_s - r_f)}{18 \ h}$$

Where, d = diameter of the fat globule, r_s = density of the serum phase, r_f = density of milk fat and n = viscosity of milk serum.

Very small fat globules (<1 mm) remain suspended in the serum phase due to brownian motion and adversely affect the creaming phenomenon. The presence of cryoglobulins in the raw milk causes agglomeration of fat globules, which subsequently have increased tendency to rise to the surface.

Homogenization is a mechanical process in which milk is forced through a homogenization valve under very high pressure. The milk is thus deflected at right angles through a narrow opening of about 0.1 nm (100mm). As the milk comes out of this valve opening, there is sudden drop in pressure and the milk is subjected to impact against an impact ring. This complete process results in disruption of fat globules leading to decrease in the average diameter (typically from 0.2 to 2 mm) and an increase in the number and surface area of fat globules.

Homogenization with reference to milk/ dairy applications thus refers to a mechanical process that is used to reduce the size of fat globules such that milk fat does not rise to form a cream layer during storage of milk. Although homogenization renders fat globules uniformly distributed in the body of the milk, upon prolonged storage it does not remain completely dispersed.

6.2 HOMOGENIZATION: THEORIES AND PROCESS DESCRIPTION

i. Definition of Homogenized Milk

United State Public Health Service has proposed one of the most comprehensive definitions for homogenized milk. This has been the most widely accepted and referred definition. It states that "Homogenized milk is milk which has been treated in such manner as to ensure break-up of the fat globules to such an extent that after 48 hours of quiescent 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 (946ml), or of the proportionate volumes in containers of other sizes, does not differ by more than 10 per cent of itself from the fat percentage of the remaining milk as determined after thorough mixing.

ii. Theories of Homogenization

The principle underlying the process of homogenization is to subject the fat globule to enough severe conditions, which disrupts it into smaller globules. The newly formed fat globules are maintained in dispersion for sufficient time to allow milk fat globule membrane (MFGM) to be formed at the fat-serum interface. The following theories have been proposed to be responsible for the entire phenomenon.

Shearing or Grinding: As milk is passed at high pressure (velocity ~ 200-300 m s^{-1}) through the homogenizer valve (~ 100 mm gap), fat globules undergo shearing action. The shear between fat globules and the surface of the homogenizer wall coupled with wire drawing effect results in elongation of the fat globules which progressively becomes unstable. These phenomenon result in subdivision of the fat globules. Furthermore, the difference in velocity of the faster moving serum phase at the centre of the liquid stream as compared to the liquid near the edge of the stream causes the fat globules to grind against each other. The turbulence created by the difference in velocity and eddy currents of the liquid add to the shear effects and thus enhance the process of disruption of the fat globules.

Exploding: This theory suggests that during homogenization, there is build up of tremendous pressure. When this pressure is suddenly released, the internal pressures within the fat globules pull the globule apart with exploding effect. This results in disintegration or subdivision of fat globules into smaller globules.

Splashing/Shattering: As the high homogenizing pressure is attained in the homogenizer, the homogenizing valve releases the highly compressed milk at very high velocity. The liquid suddenly strikes a retaining wall/ perpendicular surface. This causes splashing or shattering effect on the fat globules resulting in break down of globules into smaller sizes.

Acceleration and Deceleration: This theory relates sudden change in velocity of milk as it passes through homogenizer to the homogenization effect. When milk enters the homogenizer valve, velocity of milk changes from almost static to very high velocity. As it comes out of the valve, there is sudden deceleration at a rate at which it was accelerated. This sudden change in velocity results in shattering effect leading to division of fat globules.

Cavitation: It is postulated that as the milk passes through the homogenization valve, the initial homogenization pressure decreases sharply due to sudden increase in the velocity of milk. Depending on the back pressure that exists outside the homogenizer valve, the pressure can drop to as low as the saturated vapour pressure of liquid. This leads to formation of vapour bubbles due to cavitation. Cavitation generates shock waves, which could be in excess of 1600 kg/cm^2 in intensity. Due to overlapping of these shock waves, disintegration of the fat globules may occur.

iii. Advantages and Disadvantages of Homogenized Milk

Advantages

- Prevents removal of fat/cream from milk
- Homogenized milk results in softer curd and therefore easily digested by infants
- Churning of fat does not occur during bulk transportation
- Fat is uniformly distributed and therefore gives uniform consistency
- Homogenized milk is comparatively resistant to development of oxidized flavour defect

Disadvantages

- Homogenization offers possibility of incorporation of foreign fat into milk
- Homogenized milk is prone to development of ‘sunlight’ or ‘activated’ flavour defect
- Homogenized milk if returned unsold from the market is difficult to salvage as centrifugal separation of fat is not possible

iv. Viscolised Milk

Viscolised milk refers to a product, which has unusually deep cream/fat layer resulting from admixing of homogenized cream, skim milk and/or whole milk. The homogenized fat forms very loose clumps with the unhomogenized fat globules and rise to the surface giving an appearance of deep cream layer. The unfair traders who first separate the cream, homogenize it and then remix with the skim milk sometimes practice it. This gives the remixed milk a very rich and creamy surface appearance and thus deceives the consumers.

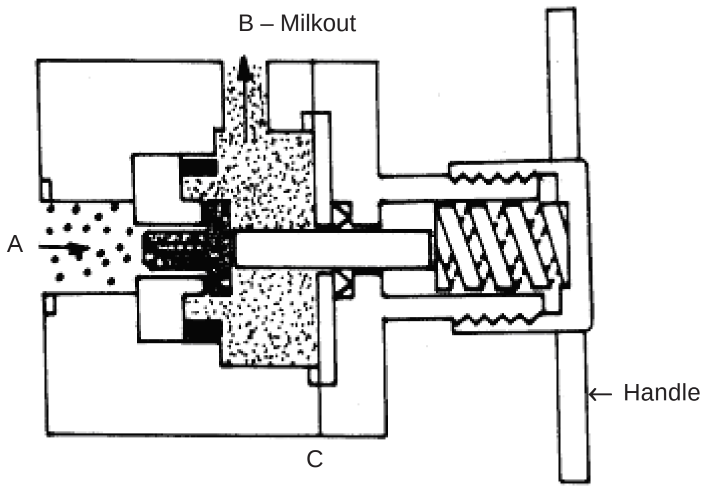
v. Design and Operation of Homogenizers

There are several types of homogenizer valves and therefore designs of homogenizers vary depending on the manufacturers. However, many homogenizers used in the dairy industry have been developed based on the principles introduced by Gaulin. Homogenizers essentially consist of two components – a piston pump to generate high pressure and a homogenizing valve.

The homogenizer pump is generally a positive displacement pump with at least three and sometimes five or seven pistons, which operate consecutively to generate steady pressure. Single piston pumps generate pulsating output with fluctuating pressure thereby resulting in poor homogenization. The pump block is generally made of stainless steel but the piston seal rings are of a soft composite material.

Homogenizer valves, used for milk may be either a 'poppet type' or 'ball type'. A poppet design has relatively large contact surfaces and provides close fitting seal. If maintained properly, 'poppet' valves give better performance with low viscosity liquids like milk. 'Ball' valves can exert greater pressure on the much small seal area and are therefore, suitable for high viscosity liquids or suspensions with smaller particles.

Milk from high pressure manifold enters into the centre of the valve seat. The internal diameter of the valve seat is smaller than the manifold. As it passes into the narrow gap between the fixed and the adjustable faces of this valve, milk velocity gets accelerated. The gap is maintained against the feed pressure by a counter force exerted by an adjustable heavy duty spring. Shear effects result from the high velocity gradients between the liquid and the surface of the homogenizing valve. Turbulence also results from the high velocity of the liquid in the valve, causing eddy currents within the flow. Liquid which passes across the valve at about 200-300 m s^{-1} suddenly drops in pressure to below saturation vapour pressure. This permits microscopic bubbles to form for a few microseconds before collapsing. The high velocity jet of milk then impinges on a perpendicular impact ring. These effects contribute to the disruption of the fat globules. Homogenizer valves are made of very tough corrosion resisting alloys such as stellite. Better resistance to corrosion can be achieved by using tungsten carbide and ceramic valves, which are used by many manufacturers in modern homogenizers.



A – Milk enters into the centre of the valve seat
B – Milk out
C – Heavy Duty Spring

Sectional view of single-stage Gaulin type homogenizing valve

As the fat globules are subdivided into smaller globules, there is increased surface area of the newly homogenized fat globules. The original milk fat globule membrane (MFGM) material is not sufficient to cover this. Proteins, particularly casein micelles migrate from serum phase to form new membrane material with the existing MFGM. This may result in sharing of the casein micelles and therefore some aggregation of fat globules could take place thus defeating the purpose of homogenization. A second stage homogenization therefore, becomes essential at reduced pressure (almost 20% of the first stage pressure (175 kg/cm^2) or upto 35 kg/cm^2). This enables aggregated fat globules to be disrupted for formation of stable emulsion of finely dispersed fat globules.

vi. High Pressure Homogenization Technology

With significant improvement in understanding of machine design, material strength and fluid mechanical knowledge, homogenizers with higher pressure capabilities have been developed. Such high pressure homogenizers could be operating based on two principles: (1) Conventional valve type homogenizer operating at a far higher pressure; (ii) Micro-fluidization based on the principle of collisions between high speed liquid jets.

Conventional Valve Type High Pressure Homogenizers (HPH): Such high pressure homogenizers work on the principle of conventional ball-and-seat type homogenizer valve. Highly abrasive resistant and durable components of high pressure homogenizers are made from best quality stainless steel, high alloy compositions and new ceramic materials. This allows these systems to operate at pressures upto 2550 kg/cm^2 or more. Besides the regular use in emulsion formation, these high pressure homogenizers find applications in inactivation of enzymes and bacteriophages and also in destruction of micro-organisms. Destruction of bacterial cells by HPH is due to several physical phenomenon viz., pressure drop, cavitation, shearing, turbulance and collision. These systems can be therefore, used as a combined process for pasteurization and homogenization.

Microfluidization Technology: The microfluidizer operates under a different principle as in this case the liquid being processed is divided into micro streams that are so projected that these collide with each other. The essential design features of micro-fluidizers include a double acting intensifier pump and an interaction chamber. The intensifier pump, which is either air-driven or electric-hydraulic driven, forces milk/product at high pressure through the interaction chamber. The interaction chamber has fixed-geometry micro-channels, which divides the product into streams. These streams, which accelerate to a very high velocity, are made to collide against each other. Shear and impact that occur lead to homogenization effect. These micro-fluidizers are capable of generating pressures upto 2800kg/cm^2. As in case of conventional valve homogenizers, microfluidizers too bring about changes in the fat and protein fractions of milk thereby altering some physico-chemical properties of milk.

vii. Vacuum Homogenization

This innovation in the homogenization technology is based on the discrete pulse energy input theory. In vacuum homogenization, energy is introduced discretely into the liquid (milk) through powerful short-time impulses. The homogenizer unit, placed in the HTST pasteurization line has two condensing chambers. The chilled milk is first pumped to condenser-I where it is heated to 20^{o}C and subsequently to 30^{o}C in condenser-II. Milk then enters regeneration section of the pasteurizer where it is heated to 65^{o}C. It is then delivered to 1st stage vacuum (homogenization) chamber through a special nozzle. As a result of flashing effect, bubbles are formed in the milk as it falls in the vacuum chamber maintained at 0.15 to 0.2 kg/cm^2. Due to the pressure changes taking place, the bubbles either show high frequency pulsation and release energy or collapse producing shockwave effect in the product. The bubbles therefore burst into smaller units and the fat globules are divided into smaller globules. As the milk enters 2nd stage homogenization chamber, further breakdown of fat globules takes place. The outgoing milk passes through regeneration section followed by chilling section to finally attain 5^{o}C temperature. Besides the generally accepted homogenization effect, the other major advantages offered by this vacuum homogenizer are deodourization, reduced acidity and partial suppression of microbial activity. These systems also claim to be economical as it consumes almost 2.5 times less power than the valve type high pressure homogenizer.

viii. Checking the Efficiency of Homogenization

The method recommended by the United States Public Health Service has been the most widely used for checking the homogenization efficiency. It is performed by subjecting a specified volume (one quart) of milk to quiescent storage for 48 hours and then testing the fat in upper 100 ml and the remainder of milk. For properly homogenized milk, the percent difference in both the top 100 ml and the remainder milk should not be more than 10 per cent.

Check Your Progress 1

1. What is stock's law and how it is related to creaming phenomenon?

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2. How would you define homogenized milk?

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3. How would you relate shearing or grinding action with homogenization?

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4. What is the theory of cavitation?

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5. List out the different theories of homogenization

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6. What is viscolised milk ?

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7. How would you describe the homogenizer pump?

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8. Name the types of homogenizer valves and explain their suitability for milk processing

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9. What are the materials of construction of homogenizer pumps and valves?

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10. Why is a two stage homogenization often recommended for milk?

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11. Describe the special features and applications of conventional valve type high pressure homogenizers.

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12. Describe the working of a micro-fluidizer.

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13. Describe the working of a vacuum homogenization system.

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14. How would you check the homogenization efficiency?

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6.3 INFLUENCE OF PROCESS VARIABLES ON THE PROCESSING EFFICIENCY AND PRODUCT QUALITY

i. Factors Affecting Homogenization Efficiency

Type of Homogenizing Valves: Design of homogenizer valve affects homogenization efficiency. Grooved valves require less homogenization pressure to attain same degree of homogenization pressures as compared to either simple valve with flat seat or needle valve.

Homogenization Pressure: The recommended pressure ranges for homogenization of milk is 140-175 kg/cm^2. If the homogenizer is in perfect working condition i.e. the homogenizer valves are not worn out and are well seated, a homogenizer pressure of 175 kg/cm^2 should give good homogenization efficiency. Some modern valves may, however, give satisfactory performance at lower homogenization pressure as well. Higher pressure of homogenization however does not improve the efficiency any further.

Single or Two Stage Homogenization: Two stage homogenization is often recommended because broken fat globules after first stage homogenization (175 kg/cm^2) may have a tendency to agglomerate. In order to re-disperse them, homogenization at reduced pressure (35 kg/cm^2) may be thus necessary in the second stage. A homogenization process of two or more stages does not however affect the mean particle size of the fat globules in any significant way. Modern homogenizer designs permit two stage homogenization with a single machine.

Effect of Fat Content in Milk: Homogenization becomes less effective with increasing fat content. When high fat milk is homogenized, the newly created total fat globule surface becomes so large that materials required to form new membranes for all the fat globules is not sufficiently availably in the serum phase. Thus the newly formed fat globules may have a tendency to agglomerate and rise to the surface during storage.

Effect of Temperature of Homogenization: Milk can be homogenized over a wide range of temperature provided the homogenization temperature is above the melting point of milk fat (32^{O}C). However, a temperature in excess of 50^{O}C is often recommended which is necessary to inactive nature lipases. It lipase is not inactivated; it acts as a surface active agent and becomes incorporated into the newly formed membranes thereby causing hydrolytic rancidity in the product. Raw milk is therefore not to be homogenized. The recommended temperatures for attaining high degree of homogenization (80-90%) are therefore between 60 and 70^{O}C. Higher homogenization temperatures are also recommended for high fat milk. This is so because at higher temperatures, less protein is adsorbed during the formation of a new fat globule membrane. Furthermore, the membranes are formed more rapidly and thus the tendency of the fat globules to agglomerate is significantly reduced.

ii. Effect of Homogenization on Physico-Chemical Properties of Milk

Effect on Fat: Homogenized milk drains more freely out of the glass container leaving less milk sticking to the sides. This lack of adhesion is attributed to the reduction in size of the fat globules and the protection provided to these globules by the adsorption of higher proportion of casein. Homogenized milk with normal fat content does not have marked clustering of fat globules. This lack of clustering is attributed to:

- destruction of natural agglutinin of milk during homogenization.
- resurfacing of the fat globules.
- increased brownian movement resulting from greatly increased number of fat globules.

Proper homogenization however, does not cause any change in important fat constants or physico-chemical properties.

Effect on Protein: The fat globule membrane is composed of approximately 1/3 phospholipids and 2/3 protein. The membrane acts as an emulsifier to keep the emulsion stable. During homogenization, the original membrane is destroyed and the surface active agents in the serum phase get adsorbed on the fat globules to form a new membrane. The new membrane consists mainly of casein as well as serum proteins. While only 2% casein in milk is adsorbed on the fat globules in un-homogenized milk, in homogenized milk almost 25% of casein is adsorbed as part of fat globule membrane. Homogenization is often associated with destabilization of proteins. This destabilization effect is reflected in reduced alcohol stability, increased feathering of cream in coffee and in coagulation during the manufacture of evaporated milk. This destabilization effect is partly attributed to adsorption of citrates and phosphates on the newly formed fat globule membrane, which lowers their concentration in the serum phase thereby adversely affecting the protein stability.

Colour of Milk: Homogenization results in more uniform, opaque and whiter milk which make the product more acceptable to the consumers. The increased whitening is due to the increase in number and total surface area of fat globules, which reflect and scatter more light.

Emulsion Stability: It is practically not possible to churn homogenized milk. However, with increasing fat content, the emulsion stability decreases.

Curd Tension: Homogenized milk has greater tendency to form coagulum and requires less coagulating agent. The resultant coagulum has lower curd tension and a soft, spongy body. Homogenization at recommended pressure of 175 kg/cm^2 causes the curd tension to be lowered by more than 50%. The possible reason for this effect of homogenization on curd tension is attributed to the increase in the number of fat globules, which serve as the points of weakness in the coagulum. Further, nearly 25% of the casein get adsorbed on the fat globules during the formation of new fat globule membranes as against only 2% of the total casein adsorbed on the surface of the fat globules in un-homogenized milk. This results in lower casein concentration in the serum phase thereby lowering the curd tension. Fat losses in the cheese whey are however low as the finely divided fat globules are retained in the curd due to adsorption of casein micelles on their surface.

Viscosity: Single stage homogenization causes increase in viscosity. This is brought about by formation of fat clusters, which results from membranes of newly formed fat globules joining together although fat itself is not in contact. When the milk is subjected to second stage homogenization, the fat globule clusters are disintegrated/ broken down resulting in decrease in viscosity. The degree of clustering of the fat globules is directly proportional to the viscosity. A high fat content, a high homogenization pressure and a low homogenization temperature can significantly increase the fat clustering and hence the viscosity of milk. Preheating of milk at temperatures that promote whey protein denaturation also reduces membrane formation and hence increases agglomeration of fat globules.

iii. Problems/ Defects Associated with Homogenized Milk

Curdling During Cooking/Sterilization: Homogenized milk is some times more susceptible to curdling when it is used in certain food preparations requiring cooking. This is in part related to reduced protein stability of homogenized milk as also to the seasoning salts added as an ingredient in the new food formulation.

Recovery of Fat During Centrifugal Separation: Milk fat is difficult to separate from the homogenized milk. If the milk has been homogenized at the generally accepted homogenization pressure of 175 kg/cm^2, a significant portion (50-90%) of the fat remain in the skim milk after centrifugal separation. Even addition of homogenized milk with un-homogenized milk and then centrifugal separation does not yield a satisfactory result. The recovery of fat from homogenized milk is a serious problem for commercial dairies which receive significant quantities of processed milk as ‘returns’ from the market and need to salvage fat for economic operation of the plant.

Formation of Cream Plug: Appearance of scum or buttery particles on the surface of the homogenized milk is objectionable. Sometimes, fat rising in homogenized milk is to such an extent that a compact ring of creamy material is visible under the container closure often referred as cream plug. Several factors such as worn out or poorly maintained homogenizer valve, improper homogenization pressure, excessive foaming, improper cleaning of processing lines and failure to recycle the first few liters of milk coming out of the homogenizer lead to such defects in the product.

Sedimentation: Appearance of sediments in homogenized milk upon storage could be a serious problem. This defect is often ascribed to settling of the extraneous matters such as body cells and dirt as also to destabilization of proteins during homogenization. However, clarification of milk before homogenization reduces the amount of deposits significantly whereas clarification after homogenization prevents this defect entirely.

Foaming: Though not a serious problem, excessive foaming in homogenized milk poses handling difficulties. The two possible reasons for this could be inclusion of air as a result of splashing or excessive agitation of the homogenized milk or homogenizing the air into the milk during processing. However, improving the handling procedure during homogenization can largely eliminate this problem.

Flavour Defects of Homogenized Milk: The most important flavour defect associated with homogenized milk is 'sunlight flavour', sometimes referred as 'tallowiness", 'burnt like' or 'activated flavour'. This develops due to oxidation of free methionine and formation of free SH compounds from sulfur containing amino acids. Development of 'sunlight flavour' also requires riboflavin. Probably, all of these compounds are together responsible for 'sunlight flavour'. The possible reasons for sensitivity of homogenized milk for development of these flavour defects could be the effect of the light upon the increased protein surface following homogenization. Homogenized milk is however resistant to development of oxidized flavour defect. This could be attributed to the formation of new fat globule membranes resulting in 'dilution' of catalytic metals viz., copper and iron, which are concentrated in the native MFGM, thereby minimizing direct contact between the fat and the metal ions.

Check Your Progress 2

1. Why does high fat content in milk affect homogenization efficiency adversely?

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2. Why raw milk is not homogenized?

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3. Why relatively high heating temperatures are recommended for homogenization of high fat milk?

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4. Why is homogenized milk sometimes less stable?

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5. Why homogenized milk is whiter?

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6. Why homogenized milk forms softer curd?

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7. What factors are responsible for increase in viscosity of homogenized milk?

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8. How does fat recovery from homogenized milk affect economic efficiency of liquid milk processing plants?

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9. What factors contribute to formation of cream plug in homogenized milk?

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10. Describe the most common flavour defect associated with homogenized milk.

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6.4 LET US SUM UP

Milk is an oil-in-water emulsion, in which fat globules are dispersed in a continuous skim milk phase. As milk fat has less density than the plasma phase, it has a natural tendency to rise to the surface and form cream layer. To overcome this problem, milk is subjected to a mechanical treatment referred as homogenization. During homogenization, milk heated to a temperature of 60-70^{o}C is passed through a tiny orifice under very high pressure such that as a result of shearing, turbulence, cavitation and impact there is decrease in the diameter and increase in the number and surface area of the fat globules. Homogenizer essentially consists of two major components: a piston pump and the homogenizer valve. New generation homogenization technologies such as microfluidization, however work based on a different principle involving collision of thin streams of liquid. Microfluidizers are capable of operating at very high pressures and serve more functions than mere homogenization. Homogenization efficiency is determined by several factors including the valve design, the homogenization pressure, single or double stages of homogenization and the temperature of homogenization. Homogenization affects several physico-chemical properties of milk including the plasma protein, the fat globule membrane composition, colour, curd tension and viscosity. One of the major problems associated with the homogenized milk is it's susceptibility to development of 'sunlight' or 'activated' flavour defect.

6.5 KEY WORDS

Alcohol stability : It refers to stability of milk to definite concentrations of alcohol and is a measure of colloidal stability of milk to heat. The alcohol test is used as the initial classification of milk.

Brownian motion : It is zigzag, irregular motion exhibited by minute particles of matter when suspended in a fluid. It is named after the botanist Robert Brown who observed (1827) the movement of plant spores floating in water. The effect, being independent of all external factors, is ascribed to the thermal motion of the molecules of the fluid. Brownian motion is observed for particles about 0.001 mm in diameter.

Cavitation : Cavitation is the formation of pockets of vapor in a liquid. This process is caused by low pressures in the liquid. When the local ambient pressure at a point in the liquid falls below the liquid's vapor pressure, the liquid undergoes a phase change to a gas, creating "bubbles," or, more accurately, cavities, in the liquid.

Emulsion : It is a colloid in which both phases are liquids. Milk is an "oil-in-water emulsion".

Feathering of cream : It refers to coagulation of cream forming small flakes which is a body and texture defect of fluid dairy products

Homogenizer Valve : It is the heart of homogenizer assembly. It essentially comprises of a narrow opening through which the thin flow of milk passes. This creates conditions of high turbulence and shear, combined with compression, acceleration, pressure drop, and impact thereby resulting in disintegration of particles and dispersion throughout the product.

Lipases : They are the group of enzymes that catalyze the hydrolysis of fats into glycerol and fatty acids. Lipases are naturally present in milk and heat resistant lipases are liberated by psychrotrophs.

Phospholipids : A class of molecules containing a polar head group that contain phosphorus atom and two non-polar hydrocarbon chains. There are many phospholipids due to the various possible types of head groups and hydrocarbon chains of different lengths. The major lipids in milk fat are trigylcerides, which are composed of three fatty acids covalently bound to a glycerol molecule by ester bonds. The remainder of the lipid fraction (~2% of the total) is phospholipids, diglycerides and cholesterol. Milk fat globule membrane is rich in phospholipids

Suspension : It is a mixture of two substances, one of which is finely divided and dispersed in the other. A suspension is different from a colloid or solution. Particles in a suspension are larger than those in colloids or solutions; they are visible under a microscope, and some can be seen with the naked eye. Particles in a suspension precipitate if the suspension is allowed to stand undisturbed.

Viscosity : It is resistance of a fluid to flow. This resistance acts against the motion of any solid object through the fluid and also against motion of the fluid itself past stationary obstacles. Viscosity also acts internally on the fluid between slower and faster moving adjacent layers. All fluids, i.e., all liquids and gases, exhibit viscosity to some degree.

6.6 SOME USEFUL BOOKS

Trout M. (1950) Homogenized Milk: A Review and Guide, Michigan State College Press, East Lansing, USA

Walstra P, Geurts T.J., Noomen A, Jellema A, Bookel M. A. J. S. van (1999). Dairy Technology: Principles of Milk Properties and Processes, Publisher: Marcel Dekker, Inc., New York, USA.

Kessler, H. G. (1981) Food Engineering and Dairy Chemistry, Publisher: Verlag A, Friesing, Germany.

6.7 ANSWERS TO CHECK YOUR PROGRESS

Your answer should include following points:

Check Your Progress 1

1) i. This equation provides basis for explaining rise of fat globules in the un-homogenized milk. As the density of milk fat is less than that of the skim milk, depending on the diameter/size, the fat globules rise to the surface during storage and form cream layer.

2) i. Homogenized milk is milk which has been treated in such manner as to ensure break-up of the fat globules to such an extent that after 48 hours of quiescent storage no visible cream separation occurs on the milk and the fat percentage of the milk in the top 100 ml of milk in a quart bottle (946ml), or of the proportionate volume in containers of other sizes, does not differ by more than 10 per cent of itself from the fat percentage of the remaining milk as determined after thorough mixing.

3) i. As milk passes through the homogenizing valve at very high pressure, high velocity gradients between the liquid and the surface of the homogenizer valve cause the fat globules to undergo shearing action. There is also wire drawing effect causing elongation and subsequent division of the fat globules. The difference in velocity of the liquid streams at the centre and towards the edge result in grinding action thereby leading to sub-division of fat globules.

4) i. Milk attains very high velocity as it enters the homogenizer valve. As it comes out there is sudden pressure drop and the pressure falls below the vapour pressure of the continuous phase. This leads to formation of small vapour bubbles in the milk due to the cavitation. As the pressure increases again, these vapour bubbles collapse and sets up shock waves. Due to overlapping of these shock waves, fat globules disintegrate.

5) i. The various theories that explain the phenomenon of homogenization primarily are: shearing or grinding, exploding, splashing/shattering, acceleration and deceleration and cavitation.

6) i. Viscolised milk is obtained by admixing homogenized cream with skim milk and/or whole milk. The homogenized fat forms very loose clumps with the unhomogenized fat globules and rise to the surface. The unfair traders use this practice for giving their milk a very rich and creamy surface appearance and thus deceive the consumers.

7) i. The homogenizer pump is a positive displacement type pump with at least three and sometimes five or seven pistons. These pistons are so arranged that they operate consecutively to maintain an uniform feed pressure.

8) i. Commonly used homogenizer valves, for milk may be either a poppet type or ball type. A poppet design has relatively large contact surfaces and provide close fitting seat. This is suitable for milk. Ball valves have a small contact area with the valve face and are particularly advantageous for viscous liquids and also when small particulates are present in the feed.

9) i. The pump block is generally made of stainless steel but the piston seal rings are of a soft composite material. Homogenizer valves are made of very tough corrosion resisting alloys such as stellite. Modern homogenizers also use valves machined from more corrosion resistant materials like tungsten carbide or ceramics.

10) i. During the first stage homogenization, new fat globule membranes are formed. Proteins, particularly casein from the serum phase are utilized for the purpose. Sharing of the casein micelles in the newly created membranes cause fat globules to form large aggregates, which have a tendency to rise to the surface. A second stage homogenization at reduced pressure (20% of the first stage) disrupts these larger aggregates and forms stable emulsion.

11) i. Conventional ball-and-seat type valves in high pressure homogenizers are made of high quality steel, special alloy or a range of ceramic materials so that it can withstand high operating pressures which sometimes exceeds 2550 kg/cm^2. Besides in the formation of emulsions, these homogenizers could also have applications in inactivation of enzymes, bacteriophages and destruction of microorganisms. Therefore, much better processing solutions could be sought for liquid milk industry by high pressure homogenizers.

12) i. Microfluidizer is a high pressure homogenizer with a different working principle. The two principal component of this homogenizer is (a) double acting intensifier pump (b) interaction chamber. The interaction chamber has micro channels, which subdivide the liquid into very fine streams. These liquid streams at high velocity are made to collide with each other

so that the shear and impact that is created results in homogenization effect. The micro-fluidizers can also operate at very high operating pressures (upto 2800 kg/cm^2).

13) i. The working of a vacuum homogenizer is based on the discrete pulse energy input theory. In vacuum homogenization, milk is delivered into the vacuum (homogenization) chamber through a special nozzle. Due to flashing effect, bubbles are formed in the milk. As a result of the pressure change, the bubbles either show high frequency pulsation and release energy or collapse producing shockwave effect in the product. The bubbles therefore burst into smaller units and the fat globules are divided into smaller globules.

14) i. A specified volume (one quart) of milk is subjected to quiescent storage for 48 hours and then tested for the fat content in upper 100 ml and the remainder of milk. For properly homogenized milk, the percent difference in fat content of both the top 100 ml and the remainder milk should not be more than 10 per cent.

Check Your Progress 2

1) i. When high fat milk is homogenized, surface area of newly created fat globules becomes so high that there is not enough proteins available in the serum phase for formation of new fat globules membranes. The fat globules therefore form agglomerates and tend to rise to the surface.

2) i. If raw milk is homogenized, the natural lipases present in milk act as surface active agents and become a part of the newly formed membranes. During storage, they hydrolyse fat and cause rancidity in the product.

3) i. At higher homogenization temperature, less of protein from the serum phase is adsorbed during the formation of new fat globule membranes. Also the membranes are formed more rapidly. Therefore, the fat globules remain uniformly dispersed and do not agglomerate.

4) i. When milk is homogenized, original fat globule membranes are destroyed and new membranes are created. This results in nearly 25% of the casein from serum phase getting adsorbed as part of the new membranes, besides the citrates and phosphates. This lowers their concentration in the serum phase and adversely affects the protein stability.

5) i. Homogenization results in increase in the number and surface area of fat globules, which reflect more light. Milk after homogenization therefore becomes whiter

6) i. Homogenization causes large increase in the number of fat globules, which serve as points of weakness in the coagulum when curd is formed. Furthermore, almost 25% of the casein from the serum phase is used up in the formation of new fat globule membranes. This results in lower casein concentration in the serum thereby lowering the curd tension.

7) i. The factors responsible for increase in the viscosity of homogenized milk are: high fat content in milk, single stage homogenization, a high homogenization pressure, a low homogenization temperature and pre-heating of milk at temperatures, which promote whey protein denaturation, agglomeration of fat and therefore viscosity of milk.

8) i. As centrifugal separation of fat from the homogenized milk is very difficult, utilization of processed milk as returns from the market, which is sizeable at times in many dairies is economically challenging.

9) i. The factors responsible for cream plug formation in homogenized milk are: worn out/damaged homogenizer valve, improper homogenization pressure, excessive foaming, improper cleaning of processing lines etc.

10) i. The most common flavour defect associated, with homogenized milk is sunlight flavour also referred as 'tallowy', 'burnt like' or 'activated flavour'. The mechanism for development of this flavour defect involves oxidation of free methionine and formation of free SH compounds from sulfur containing amino acids. Development of 'sunlight flavour' also requires riboflavin. The effect of sun light upon the increased protein surface following homogenization increases the sensitivity of homogenized milk to development of these flavour defects.

6.8 SOME MORE QUESTIONS TO CHECK YOUR PROGRESS

1. Explain the working principle of a valve type homogenizer.
2. Compare the valve-and-seat homogenizer with a microfluidizer.
3. Explain various factors affecting homogenization efficiency.
4. Explain various advantages and disadvantages of homogenized milk.
5. Explain why homogenized milk is resistant to development of oxidized flavour defect.