UNIT 9 PHYSICO-CHEMICAL PROPERTIES OF MILK

Structure

9.0 OBJECTIVES

After studying the unit we shall be able to:

- enumerate important physico-chemical properties of milk;
- specify their role in the processing of milk and milk products;
- describe the methods used to measure the important physico-chemical properties;
- indicate their impact on quality of milk and milk products; and
- test the purity and quality of milk and milk products.

9.1 INTRODUCTION

Certain physical and physico-chemical properties of milk like density, viscosity, acidity, pH etc., are important characteristics of milk with a very narrow range of variation in these properties. Knowledge of physico-chemical properties of milk is essential for identification and effective quality control of milk. In many cases processing parameters can be selected or modified depending upon the nature of the physico-chemical properties of fluid milk for manufacturing purposes e.g. in the processing of milk for ice cream, condensed milk, dried milk, butter, whey protein concentrate, etc. The selected physico- chemical parameters result in the production of the final product with desirable properties and characteristics. Important physico-chemical properties of milk are described here.

9.2 DENSITY

We know that density is defined as mass per unit volume. It is expressed in gm/ml at a given temperature.

Density = weight/volume

Density is a characteristic property of milk. Though the composition of milk is variable but the density of milk remain within a very short range. Same is true for various constituents of milk e.g. milk fat. Density is an absolute value i.e. absolute density. When density is related with a standard material e.g. water it is termed as specific gravity (sp.gr).

Specific gravity=density of substance/density of water

Generally density of water at 4^0C is used as the standard for specific gravity for liquid and solids. Since the absolute value of water at 4^0C is unity, the numerical values for absolute density and sp.gr. are identical. The density of any substance including water varies with temperature, it is therefore necessary to specify the temperature when reporting density or specific gravity.

Determination of Density of Fluid milk: Density of milk is determined by the following methods:

i) **Pycnometer/ Specific gravity bottle:** Pycnometer is a simplified form of specific gravity bottle. Density is determined by weighing milk in the pycnometer with a specific volume generally at 20^0C.

ii) **Lactometer**: Lactometer is used as an instrument for rapid determination of density of milk. The density is determined with a glass instrument called lactometer. It is based on the principle of floatation which displaces specific volume of milk on floatation. The lactometer is graduated in such a manner where each graduation is called as lactometer reading of the scale. Each division is graduated as lactometer degree. The average lactometer reading for normal cow whole milk is between 26-30. For buffalo milk the range is between 28-32. The lactometer reading can be changed to sp. gr. by prefexing 1.0. Thus a reading of 32 indicates a sp.gr. of 1.032. The specific gravity of cow milk ranges from 1.028 to 1.032 and that of buffalo milk from 1.030 to 1.034. Skim milk ranges from 1.034 to 1.036.

Check Your Progress 1

1. Give the normal range of lactometer reading of cow and buffalo milk.

   .....

   .....

   .....

   .....

   .....

2. Convert the lactometer reading 28 to its specific gravity.

   .....

   .....

   .....

   .....

   .....

3. Define density. Write the unit in which it is expressed.

   .....

   .....

   .....

   .....

   .....

9.3 VISCOSITY

Viscosity of a fluid (liquid or gas) is a measure of its resistance towards flow. This resistance is due to internal friction within a liquid as they slide each other. The unit of expression of viscosity is poise (named after Poiseuille). A poise is the force of one dyne acting on area of one square centimeter between two parallel planes one centimeter apart, to produce a difference in flow rate between the planes of one centimeter per second.

In milk centipoise is commonly used to express viscosity, which is one hundreth of a poise.

Principle of Viscosity: Viscosity can be measured both in absolute or relative terms. Absolute viscosity is the viscosity in poise or centipoise. Relative viscosity is the rate of flow of liquid. It is either volume flow during a fixed period of time or time for a fixed volume under specified conditions. The absolute viscosity of water is 1.005 centipoise at 20^0C. Thus centipoise is the viscosity exhibited by water at 20^0C**.**

Viscosity can be measured by the following methods

i) **Ostwald pipette** which is based on the principle of time of flow under a fixed pressure

ii) **MacMichael Viscometer**-Measuring the force required to move two layers of liquid past each other.

iii) **Falling Ball Viscometer**-by measuring the fall of a ball through a column of liquid e.g. Hoeppler viscometer.

Viscosity of Milk: Viscosity of milk ranges between 1.5 to 2.0 centipoise at 20^0C. Due to fat emulsion and colloidal particles milk is viscous than water. Any alternation in the physical nature of fat or protein hydrolysis, cooling or heating of milk affects proteins and fat and thus the viscosity. Clustering of fat globules affects viscosity e.g. cream where viscosity increases due to clustering of fat globules. Likewise homogenization of milk results in the state of sub-division of dispersed constituents e.g. fat. Thus homogenization of milk increases the viscosity. Viscosity increases also due to heating and concentration e.g. condensed milk due to increased total solids and changes in milk constituents.

Check Your Progress 2

1. Define viscosity.

   .....

   .....

   .....

   .....

2. Explain why homogenized milk is more viscous than unhomogenized milk.

   .....

   .....

   .....

   .....

3. Name the methods employed for measuring viscosity.

   .....

   .....

   .....

   .....

9.4 SURFACE TENSION

A molecule in the interior of a liquid is attracted in all directions because it is surrounded by molecules equally in all directions. However, the molecules at the surface of the liquid are attracted sideways and downwards but not upwards. The cohesion or tension of molecules at the surface, resulting from imbalance of forces acting on them, convert the surface to act as though covered with a film or skin. This, phenomenon is known as surface tension. Surface tension can be demonstrated by carefully horizontally placing needle at the surface of the water where it will float due to the forces of surface tension.

Surface tension is expressed is dynes per centimeter (dynes/cm). In simple words surface tension is defined as the force in dynes acting at right angles to any line, 1 cm of length on the surface of a liquid.

Surface tension in milk can be measured any of the two methods:

i) **Ring Detachment or Tensiometer method:** This is based upon the principle of force required to pull a metal ring free from the surface of a liquid.

ii) **Drop Weight method:** Here the number of drops formed when a given amount of liquid is allowed to fall from a pipette is measured. The instrument used to measure drop weight is known as stalagmometer. It consists of a glass tube with a uniform diameter of 1-3 mm with a small bulb which is sharply grounded so that the liquid drops from the tube in an almost spherical form. The tip of the tube can be enclosed in a circulating water bath to control the temperature. Droplets falling from the tube are collected and weighed.

The Surface tension of milk: Surface tension of milk falls in the range of 40 to 60 dynes/cm. A value of 50 dynes is commonly taken as surface tension of milk at 20^0C. Water has a surface tension of 72.75 dynes/cm at 20^0C. The lower value of milk compared to water is due to substances which lowers the surface tension of milk. Notably, these include fat and protein. Fat significantly lowers the surface tension of milk as cream has a surface tension value of 39-40 dynes/cm. Lipolysis also lowers down the surface tension of milk.

Check Your Progress 3

1. Define surface tension along with its unit of expression.

   .....

   .....

   .....

   .....

2. Name the two methods commonly used to measure surface tension.

   .....

   .....

   .....

   .....

3. Explain why the surface tension of milk is lower than that of water?

   .....

   .....

   .....

   .....

9.5 REFRACTIVE INDEX

Definition

The velocity of light varies with density of the medium through which it passes. Thus when light passes from a less denser medium such as air into a more dense medium water it is bent or refracted. The magnitude of this bending when expressed as a ratio of sines of the angles of incidence and refraction of the light, is the refractive index. It is designated by the letter *n*.

$$n = \frac{\sin i}{\sin r}$$

Where i = angle of incidence

r = angle of refraction

n=refractive index constant

Refractive index of milk and ghee: Refractive index of milk has a range between 1.3440 to 1.3480. The refractive index of water at 20^0C with the D line of sodium spectrum (589.3 mm) is n_D^{20} = 1.33299. The refractive index of material such as milk is higher than water due to dissolved material in milk. The dissolved material includes salts, lactose, etc. The refrecture index is used to measure the concentration of dissolved solids like sugar in food industry e.g. jams, jellies, syrups, etc., to estimate sugar. A butyro refractometer (B.R. Index) reading between 40-42.5 is the index of purity of ghee. Ghee exhibiting a refractive index of 1.4545 corresponds to a B.R. index of 43 at 40^0C.

Measurement of Refractive Index

i) **Immersion refractometer:** It is used for measuring refractive index of milk. Milk serum is prepared with the help of copper sulphate. The proteins are removed by filtration. A drop or two is placed on the prism of refractometer and the refraction is measured

ii) **Abbe's refractometer:** Abbe's refractometer is a modified version of refractometer. It is provided with a narrower range for measuring RI for fats and oils. There is an arrangement for circulation of water so that fat remains in a melted state and temperature can also be controlled. The scale is usually graduated in numbers (e.g. 43 which corresponds to *n* = 1.4545). Abbe's refractometer is used to measure purity of ghee. A drop or two of ghee drop -lets are placed on the surface of Abbe's refractometer prism, which is heated at 40^0 C through water circulation. The refractometer reading called as butyro refractometer reading (B.R) is recorded on the scale. A B.R reading between 40-42.5 is taken as the criteria for purity of ghee. This is commonly known as the B.R. index of ghee. An increase in B.R. shows the adulteration of ghee with vegetable oil/animal body fat.

Refractive index is used to measure

- Total solids in milk and condensed milk
- Sugar content
- Purity of ghee
- Adulteration of milk with water

Check Your Progress 4

1. Define refractive index

   .....

   .....

.....

.....

2. Name the instruments used to measure R.I.

.....

.....

.....

.....

3. Name the applications where R.I. can be applied

.....

.....

.....

.....

9.6 FREEZING POINT OF MILK

Freezing point of water is a constitutive property i.e. it depends upon the nature of the molecules of the liquid i.e. water. But the freezing point of a solution or a liquid such as milk is a colligative property which depends on the total number of solute particles. If the solvent content is the same any variation in the solute concentration will affect freezing point of the solutions. The solvent of milk is water while solute consists of molecules like sugars, minerals, proteins, milk fat in suspension, etc. When ice and water are in equilibrium with one another that is called freezing. At this temperature they have the same vapour pressure. The addition of solute to water lower the vapour pressure. The reason is that it delays the escape of the vapours from the surface. Thus the freezing of a given solution is always lower than that of water. The amount of depression of the freezing point is proportional to the fraction of the total number of solute particles, which are solute molecules. Also freezing point depression is a function of the osmotic pressure of the solution. The osmotic pressure of milk is believed to be the same as that of blood physiologically.

Freezing point of milk: Freezing point of milk ranges from $– 0.530^0$ to $- 0.550^0$C. In order to obviate negative sign the term freezing point depression is used. Thus 0.540 refers to the freezing point depression of milk. This eliminates the negative sign. Addition of water lowers this value. Values below 0.530 indicate the addition of water. Since skim milk also has the same freezing point as milk adulteration of skim milk cannot be detected by this method.

Souring of milk lowers the freezing point as the number of molecules increases due to breakdown of lactose, which affect the osmotic pressure of milk. This results in an increase in freezing point depression

Determination of freezing point depression of milk: Freezing point is a fairly sensitive and constant property of milk. It is principally used to detect adulteration of milk with water. Since the freezing point depression of milk differs from water with only 0.5^0C, highly sensitive and accurate thermometers are required for its measurement, which can read up to 0.001^0C. Two methods are used to determine freezing point of milk

1. **Hortvet Cryoscope method:** It was one of the earliest method to determine freezing point of milk by an instrument called Hortvet cryoscope. It was developed and used as early as 1923. This instrument has a number of drawbacks. Major difficulty being the cumbersome of the operation of cryoscope and limitations in getting reproducibility of results. This instrument uses ordinary thermometer called freezing point thermometer.

2. **Thermistor Cryoscope method**: Due to the development of special type of thermometers called thermistor probes, thermistor cryoscope has been developed which has replaced Hortvet cryoscope in determining freezing point of milk. Thermistor probes are special type of thermometers based on the measurement of changes in electrical resistance with variation in temperatures. Thermistor cryoscope are vary popular in determining freezing point depression of milk. "Fiske Cryoscope" and "Advanced Milk Cryoscope" are the important cryoscope instruments which are used for determining freezing point of milk. Official methods of Analysis of the Association of Official Analytical Chemists (AOAC) has recommended the method for determining freezing point depression of milk using thermistor probes.

   In order to determine percentage of water added it can be calculated by the formula -

   Minimum percentage of added water by mass = $\text{F.P.} = \frac{0.530 - \Delta T}{0.530} \times (100 - \text{SNF})$

   Where WT is the freezing point of sample

   F.P = Freezing point

   SNF = % Solids- not-fat of milk sample

   (0.530^0 is the freezing point depression of genuine milk)

Check Your Progress 5

1. Name the methods used for freezing point determination of milk

   .....

   .....

   .....

   .....

2. Give the freezing point range of pure milk.

   .....

   .....

   .....

   .....

3. Give the formula for detecting water by F.P. method

   .....

   .....

   .....

   .....

4. Explain why freezing point of milk is lower than that of water?

   .....

   .....

   .....

   .....

5. Name the two instruments to measure freezing point of milk

   .....

   .....

   .....

   .....

9.7 BOILING POINT

A solution always boils at a higher temperature compared to a pure solvent. This depends on the concentration of the dissolved substances or the solute concentration. Milk contain several constituents such as protein, fat, minerals, etc. These constituents are responsible for elevating the boiling point above 100^0C. Value of 100.15^0C is taken as the boiling point of milk but actual boiling points is 100. 45^0C. The reason for this discrepancy is an alteration of the normal ionic and molecular colloidal equilibrium as a result of heating.

Milk boils more quickly than water. The reason is not that milk boils at a lower temperature but it requires less heat to raise its temperature than water does. The boiling point of milk, in fact, is slightly higher than that of water. Milk contains a number of easily heated solids. Therefore, if the same amount of heat is applied to equal quantities of milk and water the temperature of the milk will be raised more than that of water.

As a conductor of heat milk is poorer than water. Addition of water lowers the concentration of the dissolved substances responsible for elevating the boiling point of milk. Though boiling point is lowered by addition of water it can be used as a method of water adulteration in milk. However, there are practical difficulties in determining the boiling point of milk.

Check Your Progress 6

1. Explain why the boiling point of milk is higher than that of water?

   .....

   .....

   .....

   .....

2. Give the boiling point of the milk.

   .....

   .....

   .....

   .....

9.8 SPECIFIC HEAT OF MILK

The specific heat of a substance is the amount of heat required to raise the temperature of a given mass of the substance one degree centigrade, compared with the amount of heat required to raise an equal mass of some standard substance one degree centigrade. Water is taken as a standard and its specific heat is 1. Compared to water specific heat of milk is 0.9454 which is lower than that of water. Thus it requires less heat to raise the temperature compared to same quantity of water. It also takes less ice to cool a certain volume of milk one degree than it does to cool the same quantity of water through one degree.

The specific heat of skim milk is lower than milk. This is due to the absence of fat from skim milk. Skim milk has a value of 0.933 to 0.954 cal $g^{-1}C^{-1}$. Fat has a higher specific heat of about 0.52 cal $g^{-1}C^{-1}$. The specific heat of milk and cream depend strongly upon the fat content.

Specific heat is measured easily with the help of a calorimeter with an electric heater. With the help of calorimeter energy used to raise the temperature can be easily measured. Specific heat of milk varies with the temperature. Specific heat

of warm milk is the same as that of normal milk. This is due to the fact that fat is in the liquid state. This value is however, lower of milk as milk is cooled below 19^0C. At this temperature some of the heat supplied to the milk system at a temperature near the melting point of the fat is used by the fat for its melting.

Table 9.1: Specific heat of milk and milk products

Milk and milk products	At 60^0F	At 40^0F
Milk	0.94	0.93
Whey	0.98	-
Butter	0.53	-
Cream (30% fat)	0.98	0.85
Cream (60% fat)	1.05	0.72
Cheese	0.64	-

Check Your Progress 7

1. Define specific heat of milk.

   .....

   .....

   .....

   .....

2. Give value for specific heat of milk, skim milk and cream.

   .....

   .....

   .....

   .....

3. Why the specific heat of milk is higher than skim milk?

   .....

   .....

   .....

   .....

9.9 ACIDITY

Natural acidity of milk: Freshly drawn milk is slightly acidic in nature. This is due to the presence of natural constituents of milk. These include various salts such as phosphate, citrate, carbonate, etc. Also milk constituents like casein, albumin, non-protein nitrogenous compounds and various acids which contribute towards the natural acidity.

Developed acidity of milk: During storage of milk acidity develops due to the fermentation of milk lactose to lactic acid and other acidic components, primarily due to microbial effect. Beyond an acidity of 0.18% as lactic acid milk coagulates on boiling.

COB Test for detection of coagulation of milk: The developed acidity along with natural acidity, which is refered as total acidity, gives positive reaction on boiling milk. A platform test named COB test called clot-on-boiling test is used to detect coagulation of milk. Formation of clot on boiling is an index for acidic abnormal milk.

Measurement of acidity: Acidity of milk can be determined against a standard alkali such as 0.09 N NaOH or 0.1N NaOH solution in the presence of phenolphthalein indicator. On complete neutralization of acidity phenolphthalein indicator changes its colour in milk to faint light pink. The following reaction occurs during titration.

$$CH_3CHOHCOOH + NaOH \rightarrow CH_3CHOHCOONa + H_2O$$

Lactic acid **Sodium lactate**

The titratable acidity is expressed as lactic acid per 100 ml of milk.

$$TA = 0.9 \times V_1 \times N_1$$

Where V_1 = Volume in ml of the standard

NaOH solution required for titration

N_1 -= Actual normality of the NaOH solution

TA = Titratable acidity

Note: The calculation becomes simpler when 0.09N $(\frac{N}{9})$ NaOH is used for titration as titre value is direct reading of acidity.

Check Your Progress 8

1. What is the natural and developed acidity of milk? Name the constituents responsible for developed acidity of milk.

   .....

   .....

   .....

   .....

2. What is COB test and its relation to acidity.

   .....

   .....

   .....

   .....

3. Why is it easier to use $\frac{N}{9}$ NaOH to calculate acidity of milk ?

   .....

   .....

   .....

   .....

9.10 pH OF MILK

pH refers to the hydrogen ion concentration (C_H+). Mathematically, pH = -log C_H+

pH is an index of the true acidity or alkalinity of the system. pH is expressed in the form of pH scale which is 1 to 14 pH units. pH of 7.0 is called as neutral pH. pH below 7.0 is acidic while above 7.0 it is basic or alkaline.

pH of normal fresh milk is between 6.6 to 6.8. The slight lower side of pH is due to natural acidity as a function of natural milk constituents contributing towards acidity. During titration of milk with alkali to measure developed acidity induces

shifting of pH through hydrogen ion equilibrium due to the buffering action of milk. Buffer action simply indicates a state of resistance to a change in hydrogen ion concentration of a solution i.e. milk. The buffer compounds present in milk are the acids, proteins, salts of acids such as phosphate, citrate, carbonates and dissolved CO_2.

Measurement of pH

pH of milk can be determined mainly by the following two methods:

i) **Indicator Paper Strip Method:** With indicator paper strip method pH can be easily determined within few seconds. However, this method gives less accurate results compared to electrometric method. In this method help of pH paper strip is taken. The pH of the strip is so choosen so that it is nearest to the expected pH. On dipping the pH paper strip colour of strip changes. The pH of milk is equal to that of standard pH colour scale to which the dipped paper compares.

ii) **Electrometric method:** Electrometric method is based on the principle of potentiometer, which measures electromotive force (emf) of the system, the difference of emf is measured with the help of two electrodes. One of the electrode is known as reference electrode which has potential independent of the solution,. The other electrode is pH dependent. It generates emf when dipped in a solution. This emf is generated by H^+ ion concentration in the solution, which causes emf generation. It is directly related to pH. Due to emf generation by two electrodes and along with the emf of the reference electrode causes electric current to flow. The magnitude of the electric current flow can be measured accurately and rapidly with modern electromotive devices.

Measuring pH of milk: pH meter is standardized with a standard pH solution e.g pH 4.0, .6.0 or 9.0. After standardization, milk is taken in a beaker and the electrodes are dipped in milk. This results in pH measurement, which can be obtained directly from the pH meter.

Check Your Progress 9

1. Define pH. What is the natural pH of milk?

   .....

   .....

   .....

   .....

2. Give the range of pH scale. Give the neutral value of pH scale.

   .....

   .....

   .....

   .....

3. Name the two methods commonly used to measure pH.

   .....

   .....

   .....

   .....

9.11 BUFFERING ACTION OF MILK

There are several constituents of milk which act as a buffer i.e. they give resistance towards change in pH. These include carbon dioxide, proteins, phosphate, citrate and a number of minor constituents. Due to microbial action additional components

are introduced in milk, which include lactate and many other organic anions. Titration of milk in the pH range of 4.8 to 8.3 has been used to assess the behaviour of milk during titration in the presence of phenolphthalein indicator. When milk is titrated against an alkali maximum buffering occurs at a pH range of 4.8 to 6.8 but at pH 8.0 to 8.3 very little alkali is required resulting in lower buffering. Titration of fresh milk over pH 6.6 to pH 8.3 requires 13 to 20 ml of 0.1 NaoH per 100 ml (1.3 to 2.0 meq. per 100 ml). Most fresh milk samples fall in the range of 1.5 to 1.8 meq. per 100 ml.

Buffering of milk varies between samples and breeds. Some of the constituents responsible for buffering of milk are given here.

i) **Carbon dioxide**: Milk contains 20 mg CO_2 per 100 ml of milk or 10% by volume. CO_2 behave like an acid in the form of carbonic acid. This on titration offers a titration value of 0.5 meq/100 ml between pH 6.6 and 8.3 out of the total value of 1.3 to 2.0

ii) **Proteins:** Milk contain around 2.5% casein and 0.6% whey proteins. Casein contributes to a titration value of 0.8 meq/100 ml and whey proteins 0.1 to 0.2 meq/100ml.

iii) **Phosphate:** Presence of phosphate in milk has three buffering ranges. In the presence of calcium it forms a complex of calcium phosphate. During titration precipitation of calcium phosphate occurs as the pH is raised e.g. pH 6.0 About 0.6 meq of alkali is needed around pH 6.0

$$3Ca^{++} + 2H_2PO_4^- \text{ D } Ca_3 (PO_4)_2 \text{ F } + 4H^-$$

$$4H^+ + 4OH^- \text{ D } 4H_2O$$

iv) **Citrate:** Citric acid as citrate ions has very little buffering capacity of 0.1 meq per 100 ml. However, it complexes with calcium as calcium citrate. This delays the precipitation of calcium phosphate and affect the titration indirectly.

v) **Lactate**: Lactic acid also delays the titration as it also forms a complex with phosphate ion.

$$CH_3 \text{ CHOH COOH } + HPO_4^{--} = \text{ D } H_2PO^-_4 + CH_3 \text{ CHOHCOO}^-$$

Lactic acid **Lactate ions**

Check Your Progress 10

1. Explain buffering.

   .....

   .....

   .....

   .....

2. Name the constituents of milk responsible for buffering of milk.

   .....

   .....

   .....

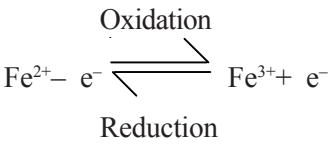
   .....

9.12 OXIDATION-REDUCTION POTENTIAL (Eh)

Definition: Oxidation may be defined as the uptake of oxygen or the loss of hydrogen or the loss of electrons. Likewise reduction is defined as the loss of oxygen or the uptake of hydrogen or the gain of electrons. These process of oxidation and reduction go simultaneously in a system composed of more than one

substance constituting the system which involve exchange of electrons simultaneously in the system.

Theory: Exchange of electrons generates an electromotive force i.e. emf in the system which indicates the direction in which processes proceeds. This is illustrated with the equation



Method of determining oxidation-reduction potential: Method of determining oxidation-reduction potential is based on the principle of oxidation-reduction. Substances giving or taking electrons in a solution creating potential difference can be measured using electrodes. Potential difference can be measured by platinum electrode (e.g., donating or accepting electrons) and a reference calomel electrode in the presence of a potentiometer. The voltage measured under these conditions gives the oxidizing or reducing capacity of the system. This is simply called as oxidation-reduction potential and is designated by the symbol E_h. A positive potential involving loss of electrons from the platinum electrode is indicative of oxidizing properties, whereas a negative potential, which involves gain of electrons at the platinum electrode, gives reducing capacity.

The Oxidation-Reduction Potential of milk: Milk has a positive oxidation-reduction potential. It ranges between +0.2 and +0.3 volt for cow milk with an average value falling between +0.23 and +0.25 volt. This is primarily due to the presence of dissolved oxygen in milk. Flushing of oxygen of milk with nitrogen decreases the oxidation - reduction potential of milk. Heating of milk such as HTST Pasturization milk or preheating prior to making milk powder produces reducing substances in milk. This lowers E_h values in heated milk or dried milk. Thus superior quality with higher storage capacity milk powders can be prepared by increasing reducing substances in it.

Bacterial contamination of milk affects E_h of milk. A lowering of E_h occurs due to consumption of oxygen by microorganisms. Also reducing substances are formed during the course of bacterial **metabolism.** Methytane blue reaction is based on E_h. A negative E_h is obtained when the dye becomes colourless.

Presence of copper in milk also influences E_h. Copper acts as an oxidizing agent with very strong electron acceptance. Presence of copper raises E_h of milk.

Check Your Progress 11

1. Define oxidation-reduction potential.

   .....

   .....

   .....

   .....

2. Briefly describe the E_h

   .....

   .....

   .....

   .....

3. Give two application of E_h in relation to milk and milk products

.....

.....

.....

.....

9.13 ELECTRICAL CONDUCTIVITY

Solutions of electrolytes can conduct electric current due to the presence of electrolytes under the influence of an electric field.

Definition: Electrical conductivity may be defined as a measure of the ability of a solution to carry electric current. This conductance is obeyed by ohm's law and is measured by specific resistance.

Theory: Specific resistance is defined as resistance in ohms of a column of solution 1 cm long and 1sq cm in cross-section. The conductivity or specific conductance is the reciprocal of specific resistance. It is expressed as reciprocal ohms (i.e., $ohms^{-1}$ or mhos)

Measurement of Electrical Conductivity: The electrical conductivity is measured in terms of specific conductance which is reciprocal of specific resistance. The specific conductance is estimated from the resistance obtained from the filled solution in the cell. The electric resistance of milk is measured by placing milk in a cell, between two platinum electrodes fixed at a distance. The electrical resistance is measured with the help of Wheatstone bridge. The specific conductance is calculated from the measured resistance of the cell filled with solution e.g. milk. Thus

$$\text{Specific conductance} = \frac{K}{R}$$

Where K= cell constant determined with cell of solutions of known conductance and R = measured resistance in ohms.

Specific Conductance of milk: The specific resistance of milk is low with an average value of 0.005 ohm^{-1}. During **mastitis** the value increases due to the presence of various ions of milk. The various ions responsible for the conductivity of milk are sodium, potassium and chloride ions. In mastitis and colostrum milk these ions are abnormally high. .

Check Your Progress 12

1. Define electrical conductivity

.....

.....

.....

.....

2. Explain specific conductivity. Name the ions responsible for specific conductivity of milk.

.....

.....

.....

.....

9.14 LET US SUM UP

Milk possess characteristic physico-chemical properties which are specific in nature. These are due to the constituents present in milk. These physico-chemical properties include specific gravity/density, pH, buffering, viscosity, surface tension, freezing point, oxidation-reduction, specific heat, boiling point and electric conductivity. Understanding these properties can be used advantageously for processing of milk & milk products. Such properties have great potential for detecting the adulteration. For example adulteration of milk can be detected by specific gravity, freezing point and refractive index. Likewise, adulteration of ghee can be detected by refractive index. Some of these properties have been discussed.

9.15 KEY WORDS

Ions	:	Negatively or positively charged particles.
Calorimeter	:	An instrument for determining heat of energy on burning the substance.
Buffer	:	A substance which resist changes in pH.
Carbon dioxide	:	CO_2 gas present in air
Lactic acid	:	An acid developed in milk through the action of microbes on lactose.

9.16 SOME USEFUL BOOKS

Jenness R and Patton S, (1959). Principles of Dairy Chemistry, John Wiley, New York

Ling, E.R. (1956). Text Book of Dairy Chemistry, Vol 142 Chapman and Hall, London.

Webb, B.H. and Johnson, A.A. (1965). Fundamentals of Dairy Chemistry, AVI Publishing Co., Connecticut, USA

9.17 ANSWERS TO CHECK YOUR PROGRESS

Your answers should include following points.

Check Your Progress 1

1) i. The normal range of lactometer reading for cow milk is between 26-30 and 28-32 for buffalo milk

2) i. It is 1.028

3) i. Density is mass per unit volume. It is expressed in gm/ml

Check Your Progress 2

1) i. Viscosity is nothing but resistant of a liquid or gas towards flow. It is expressed in centipoise which is one hundredth of a poise.

2) i. Homogenization results in sub division of fat which increases viscosity.

3) i. Method employed for measuring viscosity are

- Ostwald pipette
- MacMichael viscometer
- Falling ball viscometer

Check Your Progress 3

1) i. Surface tension is expressed as the force acting at right angles to any line one cm of length on the surface of a liquid. Surface tension is expressed in dynes/cm.

2) i. Ring and drop weight method.

3) i. It is due to substances present in milk. Notably they are fat and protein which lower down the surface tension of milk compared to water.

Check Your Progress 4

1) i. When light passes from a less denser medium such as air to a more denser medium such as water it is bent or refracted. Magnitude of this bending when expressed as a ratio of sins of the angles of incidence and refraction of the light, is the refractive index.

2) i. Immersion refractometer and Abbe's refractometer

3) i. Sugar content, purity of ghee, adulteration of milk with water.

Check Your Progress 5

1) i. Thermistor cryoscope and Hortvet cryoscope method

2) i. 0.530 to 0.550.

3) i. $\frac{0.530 - \Delta T}{0.530} \times (100 - SNF)$ = Freezing point or F.P.

4) i. Due to dissolved substances of milk notably milk salts and sugars etc. These substances affect the F.P of milk and lower down the freezing point of milk.

5) i. Fiske cryoscope and Advanced milk cryoscope

Check Your Progress 6

1) i. Boiling point of milk is higher than that of water because of the presence of dissolved substances in milk which raises the boiling point.

2) i. Boiling point of milk is 100.45^0C

Check Your Progress 7

1) i. The specific heat of a substance is the amount of heat required to raise the temperature of a given mass of the substance one degree centigrade, compared with the amount of heat required to raise equal mass of some standard substance one degree centigrade. Water is taken as a standard and its specific heat is 1

2) i. Specific heat of

Milk – 0.9454

Skim milk –0.933 to 0.954

Cream (30% fat)- 0.85 at 40^0F, 0.98 at 60^0F

3) i. The specific heat of skim milk is lower than that of milk. This is due to higher specific heat of fat.

Check Your Progress 8

1) i. Acidity due to natural components such as phosphate, citrate and proteins, etc., is called natural acidity. Acidity due to lactic acid is called developed acidity. The constituent for developed acidity are mainly lactic and some organic acids.

2) i. Clot on boiling test. It is related to developed lactic acid acidity, which makes the milk to clot at 0.18% lactic acid acidity to clot on heating milk.

3) i. It is easier to calculate acidity using NaOH because titre value is directly related to acidity of milk.

Check Your Progress 9

1) i. pH refers to H^+ ion concentration, pH= — log C_H+. Natural pH of milk is between 6. 6 to 6.8

2) i. Range 1 to 14, pH 7.0

3) i. pH paper and electrical method.

Check Your Progress 10

1) i. Buffering may simply be defined as resistance towards changes in pH.

2) i. Constituents of milk responsible for buffering of milk are

- CO_2
- Phosphate
- Citrate
- Proteins
- Lactate

Check Your Progress 11

1) i. Oxidation- reduction potential is the process of loss or gain of electrons with the development of a potential.

2) i. E_h involve measuring the potential. A+ ive potential is the loss of electrons. A-ive potential is gain of electrons. Exchange of electrons generates an electromotive force i.e. emf in the system. This is simply called as oxidation-reduction potential.

3) i. Bacterial metabolism, presence of Cu

Check Your Progress 12

1) i. Electric conductivity may be defined as a measure of the ability of a solution to carry electric current as obeyed by ohm's law.

2) i. Specific resistance is defined as the resistance in ohms of a column of solution I cm long and 1 sq cm in cross-section. The electric conductivity is a measure of specific conductance, which is reciprocal of specific resistance. The ions responsible of specific conductance are sodium, potassium, phosphate and citrate.