UNIT 7: SOLS, GELS AND EMULSIONS

Structure

7.1 INTRODUCTION

Foods are generally complex materials. The properties of their components determine the quality of food. The food components are in the form of solids, in solutions or in the form of colloids - sols or emulsions. These undergo various physical and chemical changes when exposed to different conditions. Knowledge of the scientific principles of these changes is necessary to understand and control the changes occurring in foods during the various aspects of food handling. We shall discuss these scientific principles governing the physical and chemical properties of foods with special emphasis on colloidal systems in this unit.

Objectives

After studying this unit, you will be able to:

- define colloids and enlist the types of colloidal dispersions
- understand properties of colloidal systems that help in distinguishing them from solutions
- classify colloidal systems
- differentiate between sols, suspensions and gels
- define foams and discuss their application in food preparation
- explain the types of emulsions, their formation and stability

7.2 COLLOIDS, COLLOIDAL SYSTEMS AND APPLICATIONS OF COLLOIDAL CHEMISTRY TO FOOD PREPARATIONS

Foods contain a high percentage of water in which other nutrients present are dispersed. The existence of the colloidal state was first recognized by Thomas Graham (1850), the father of colloidal chemistry. He classified the organic compounds present in foods into two categories:

- Colloids
- Crystalloids

What is the difference between the two categories? Let's find out.

The word colloid, you may be interested to know, is derived from the Greek word "kolla" meaning "glue" and is defined as a system containing particles of size from one millimicron to 0.1 micron (10^{-6} to 10^{-4} mm). *Colloids* are compounds with large molecular weights, which form dispersions only with water. e.g. starch, proteins, glycogen, agar-agar.

Crystalloids, on the other hand, are compounds with small molecular weights, which can form true solutions. e.g. sugars and amino acids.

Figures 7.1 and 7.2 illustrates the colloidal range of particle size.

Figure 7.1: Colloidal Range of Particle Size

Figure 7.2: Size of Colloidal particles vs Water molecules

Solids, liquids and gases may be dispersed in water to form either solutions or colloids. Let us learn what the difference between the two is.

A *solution* is a homogenous mixture of two or more different substances. For example salt in water form a solution. This means that the dissolved substances (i.e. salt which is called the solute) and the medium in which they are dissolved (i.e. water which is the solvent) are uniformly distributed throughout the whole of the solution.

A *colloidal system, on the other hand,* is a heterogeneous system. The material that forms the base of the system is called *the dispersion medium* or *the continuous phase*. The material that exists in the colloidal condition is called the *dispersed medium or the discontinuous phase*. All three states of matter- gaseous, solid and liquid – may be obtained in the colloidal condition. Let us get to know more about colloids and colloidal system by learning about their classification.

7.2.1 Classification of Colloidal Systems

Thomas Graham referred to colloids as the study of sub microscope dispersion. According to him, it dealt with the dispersed systems of a definite size. Dispersions are classified on the basis of the size of the particles. The particles are dispersed through out the solvent in the form of molecules or ions (molecular dispersion) and it is a one phase system with molecules having dimensions below 1 nm. If the particles range in size from 1 mm to 0.5 mm, they can remain dispersed for a long time without precipitation and constitute a *colloidal system*. When the size of the dispersed particles is more than 0.5 mm it is termed *coarse dispersion or suspension.*

Colloidal systems are not restricted to the dispersion of a solid in liquid. Each of the three states of matter - gaseous, solid and liquid – can be dispersed in a medium which may be gaseous, liquid or solid. Accordingly, colloidal systems can be classified based on the physical state of the two phases present: the dispersed phase and the dispersing medium Systems with two phases can occur in eight different combinations, as highlighted in Table 7.1 presenting the classification of colloidal systems.

Table 7.1 Classification of colloidal systems

Dispersed Phase	Dispersing Medium	Name	Examples
Liquid	Gas	Fog	Aerosol sprays
Solid	Gas	Smoke	Smoked fish
Gas	Liquid	Foam	Whipped cream, meringue
Liquid	Liquid	Emulsion Oil in water Water in oil	 Milk, french dressing Margarine
Solid	Liquid	Sol	Whey, skimmed milk, starch suspension
Gas	Solid	Solid froth, foam	Bread, *idli*, candy floss
Liquid	Solid	Liquid inclusion	Gelatin, jellies, fruits, vegetables, meat products
Solid	Solid	Solid sol	Candies

Note: mixtures of gases do not form colloidal mixtures. They are solutions.

Depending upon the relative affinity of the dispersed phase for the dispersion medium, colloidal dispersions are, further divided into two classes.

- lypophilic (water loving colloids)
- lypophobic (water repelling colloids)

If the affinity between the dispersed phase and the medium is high, the dispersed phase is said to be lyophilic (solvent loving) or hydrophilic, in the case of an aqueous dispersion. Gelatin dispersed in water is an example of a lyophilic colloidal system. Other examples of hydrophilic colloids are biopolymers such as seaweed gums, pectic substances and proteins and hydrophilic complexes found in skim milk, egg yolk and brewed coffee.

If the affinity of the dispersed phase to go into or to remain in colloidal dispersion is slight, the dispersed phase is said to be lyophobic (solvent repelling) or hydrophobic when the medium is water. Oil dispersed in water as in the case of butter and margarine, is an example of a lyophobic system. Lyophobic colloids are mainly the aqueous dispersions of inorganic substances rarely recountered in food systems.

After having understood the concept and classification of colloids, let us learn about the properties of colloidal systems.

7.2.2 Properties of Colloidal Systems

Colloidal systems exhibit certain unique characteristics that help in distinguishing them from solutions. We will briefly review these properties now.

A. Tyndall Effect

One of the best ways to distinguish a solution from a colloidal dispersion is to use a strong beam of intense light. As the beam passes through a colloidal dispersion, it leaves a bright definite path, as the result of scattering or diffusing of light rays by their deflection from the surface of colloidal particles. This is known as *Tyndall effect* and is shown in the Figure 7.3. The particles may not be visible, but their presence and motion may be detected by the nature of the reflections. An important property of a colloid is this movement of the colloidal particles, brought about by the bombardment of thousand of molecules in the gas or liquid in which they are suspended. This molecular movement of the colloidal particles is known as the *Brownian movement* and is shown in the Figure 7.4.

Figure 7.3: The Tyndall Effect

Figure 7.4: Brownian Movement

B. Electric Charge

Colloidal particles are electrically charged. Some colloidal particles carry a positive charge (+), others a negative charge (-). The ionic charge is the same for all the charged particles in a given mass of material. This is why colloidal particles remain in suspension: particles with like charges do not clump together because they are repelled by one another as illustrated in the Figure 7.5.

Figure 7.5: Similarly charged colloidal particles deflect each other by electrical repulsion.

C. Adsorption

Colloidal particles attract and hold to their surfaces the molecules of various gases, vapors and other matter with which they come into contact. This phenomenon is called adsorption. Adsorption plays a very important part in the character of the colloid .By adsorption the particles acquire an electric charge which governs the stability of the colloid. The phenomenon of adsorption finds widespread application in food preparations. For e.g. a too salty soup stock may be made more palatable by the addition of egg white, which when cooked, will gather and hold the salt on to the surface of its particles and settle down to the bottom of the soup vessel.

D. Imbibition

The ability of colloids to pick up water and swell when they come in contact with water is called imbibition. Imbibition is usually accompanied by the evolution of heat and the added materials such as acids and alkalis have a marked effect on the degree of swelling.

E. Viscosity and Plasticity

Various degrees of viscosity and plasticity are encountered in colloids. Viscosity may be described *as resistance to pouring. Plasticity* is the property of solids that enables them *to hold their shape under small pressure*.

Colloidal systems range in degree of viscosity and plasticity according to the following environmental factors:

- Temperature affects the viscosity of a colloid. Generally, its viscosity decreases as the temperature increases. For e.g. milk becomes less viscous at high temperatures; such colloidal gels as gelatin and agar are less viscous at high temperatures than low ones.

- The viscosity of a colloid also increases with the concentration and aggregation of dispersed particles. For e.g. cream becomes more viscous when there is an increase in the number and aggregation of fat particles in it.
- Increased amounts of protein solids also bring amount an increase in viscosity. Thus the viscosity of custard is related to the amount of egg protein dispersed in the liquid.

In our discussion above, we highlighted the properties of colloids. Next, we shall focus on solutions and their properties. But first, attempt the exercises presented in the Check Your Progress Exercise 1. This will help you recapitulate what you have learnt so far.

Check Your Progress Exercise 1

1. Define colloids.

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2. Differentiate between colloids and crystalloids.

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3. What do you understand by the terms 'dispersion medium' and 'dispersed medium'?

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4. Fill in the blanks :

Dispersed Phase	**Dispersing Medium**	**Name**	**Examples**
--------------	Gas	Fog	Aerosol sprays
Solid	--------------	Smoke	Smoked fish
--------------	Liquid	Foam	Whipped cream
Liquid	--------------	Emulsion Oil in water Water in oil	 Milk Margarine
Solid	Liquid	--------------	Whey
Gas	Solid	--------------	Bread, *idli*
Liquid	Solid	--------------	Gelatin, jellies, fruits, vegetables, meat products
Solid	Solid	--------------	Candies

7.3 DEFINITION AND PROPERTIES OF SOLUTIONS

Solutions, as you learnt earlier, are a homogeneous mixture of two or more different substances. This means that the molecules of the dissolved substances (solute) and the medium in which they are dissolved (solvent) are uniformly distributed throughout the whole of the solution. Solubility is the *amount of solute that can be dissolved in a given amount of solvent at a given temperature*. The effect of temperature on solubility varies with solutes. Increasing temperatures increases the solubility of some solute but has no effect on the solubility of others.

The concentration of a solution is the amount of solute dissolved in a specified amount of solvent or solution. When the concentration reaches a point when no more solute can dissolve in a solvent at a particular temperature, the solution obtained is said to be *saturated.* If a saturated solution of a solid is prepared at or near the boiling point of the solvent, on cooling the solid crystallize out e.g. sugar. Although fully cooked, sometimes the crystals may not separate out as in the case of fondant. Such a solution holds more solute than can normally be present at the same temperature. This solution is said to be *super saturated*. Supersaturated solutions are unstable and become more unstable as the degree of super saturation increases. Crystals do form ultimately when the solution becomes fairly cool, but the nature and size of the crystal varies. The phenomenon is of importance in sugar cooking. Different types of Indian sweets are prepared using this physical property of sugar solution.

Several properties of solutions are particularly important in food preparations. Amongst these are colligative properties, such as vapour pressure, boiling point, freezing point and osmotic pressure. Colligative properties are *the properties of solution which depend on the number of molecules present and not on their chemical nature are known as*. Let us understand these properties of solutions and their applications.

A. Vapour Pressure

The intermolecular forces in a liquid prevent most molecules from escaping from the surface. However, due to molecular collisions, some molecules have sufficient kinetic energy to escape from the liquid. This causes the evaporation of the molecules into the gaseous state. Any liquid, therefore, has above its surface, a certain amount of material in the form of vapour. Vapour molecules move in all directions. Some of the liquid get condensed. When the rate of evaporation and condensation are equal, an equilibrium is established. *The pressure exerted by vapour above the liquid when equilibrium exists is vapour pressure.* The vapour pressure is temperature dependent.

When a solid is dissolved in a volatile solvent the vapour pressure of the solution is less than the vapour pressure of the pure solvent because of the presence of solute molecules. In a solution, the number of solvent molecules at the surface is reduced and therefore the rate of evaporation is less than for the solvent. The extent of lowering is proportional to the number of molecules of solvent compared with the total number of solvent plus solute molecules. For e.g. when equal quantities of sucrose and sodium chloride are dissolved in a known amount of water at constant temperature, the lowering of the vapour pressure of water by sodium chloride is twice as much as that of sucrose, because sodium chloride contains twice as many of number of icons as the number of sucrose molecules in the solution.

B. Boiling Point

There are certain properties of solutions which are directly connected with vapour pressure and one of it is boiling point. You must have observed that water boils at a temperature of 100°C. This is because a liquid boils when its vapour pressure is equal to external pressure. The normal boiling point (BP) refers to *an external pressure which is equal to the atmospheric pressure (760 mm Hg)*, which for water is 100°C. With an increase is pressure, the boiling point increases, e.g., the boiling point of water at 770 mm is 100. 37°C. You must have noticed that in a pressure cooker the water boils at 121°C at 103 kg/kilo pascal, for this a greater pressure must be overcome and thus the boiling point can be elevated. Conversely, the boiling point can be lowered at a reduced atmospheric pressure as in high altitudes i.e. if you boil potatoes at a hill station, it will take longer time to cook as compared to the planes. For every 290 m increase in altitude above sea level, the boiling point of water is lowered by 1°C.

This property of water is useful in the processing of foods, such as jams, jellies, syrups, confectionary etc. which are liquids at higher temperatures.

C. Freezing Point

The freezing point of a material is the temperature at which it changes from a liquid to a solid. A liquid freezes when its vapour pressue is equal to the vapour pressure of its solid. The freezing point of water is 0°C.

You can modulate the freezing point of water by dissolving a non-ionizing solute in it. For e.g. a mole of sodium chloride or calcium chloride could depress the freezing point of water by 3.72°C and 5.58°C.

The practical importance of this is that a mixture of ice, water and salt gives freezing mixtures. Ice and water alone are in equilibrium at 0°C, but if salt is added, some ice will melt in order to reduce the temperature to the new equilibrium position. This principle is used in making home-made ice. The freezing point of milk is 0.53^{o}C. Its freezing point is determined by its soluble constituents, lactose and salts, present in it. Since these soluble components vary in milk only slightly, the freezing point remains almost constant. This makes it possible to determine any dilution of milk. Addition of 1% by volume of water to milk rises the freezing point by approximately 0.0055^{o}C.

D. Osmotic Pressure

Osmosis, as you may already know, refers to the flow of solvent into a solution, or from a more dilute solution to a more concentrated solution, when the two liquids are separated from each other by a semi-permeable membrane. The membrane contains minute pores through which the solvent molecules can travel. The phenomenon of osmosis causes a change in the relative volume of the two liquids separated by the semipermeable membrane. The volume of the solution that becomes more dilute increases. Osmotic pressure is the pressure required to prevent that increase in volume or osmosis. Unlike solutions, colloids have little or no osmotic pressure. Hence, there is no passage of colloidal particles through animal membranes or cellulose walls.

The phenomenon of osmosis occurs in food. For e.g. when you stew fruits, the fruit increases in size, as the water flows with the fruit tissues. When the sugar concentration becomes higher than that of the fruit, the fruit will shrink due to the passage of water through the skin of the fruit into the syrup.

E. Viscosity

Viscosity, as you may already know, is associated with fluid flow. It is the internal friction which tends to bring to rest portions of the fluids moving relative to one another. This is measured in relation to some standard viscosity, generally of water at 25^{o}C. A number of factors affect the viscosity of a fluid; for instance, large changes take place due to temperature.

Viscosity determination is useful in the study of consistency of foods. Viscometric measurements are made in food industry for the study of food structure. Viscosity has an effect or heat transfer during pasteurization in the preparation of certain food materials, such as fruit juices. Viscosity is measured by viscometer.

F. Specific Gravity

The density of a substance is defined as mass per unit volume. The density of a substance is a characteristic property and has a definite value at a given temperature and pressure. The density of one substance in relation to the density of another material (e.g. water) is known as specific gravity. Therefore, specific gravity is the weight of a given substance referred to the weight of an equal volume of water at a definite temperature.

The specific gravity of foods, depend upon this components. The specific gravity of milk, for e.g., is greater than that of water. The average specific gravity of milk is 1.032 (at 15.5^{o}C); it ranges from 1.027 to 1.035. If the fat content of milk increases, the specific gravity decreases (upto to 0.93) and if the non-fat components increase, the specific gravity increases.

The importance of specific gravity, is utilized in the purchase of products like syrups, jams, jellies, milk (especially when whole milk is adulterated by addition of water) cream, ice-cream and alcoholic beverages. Specific gravity indicates the amount of air incorporated into the products (lightness of products), such as shipped cream, egg white foam, creamed shortening and cake batter.

Check Your Progress Exercise 2

1. Define the following terms:

a) Solubility

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b) Concentration

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c) Boiling point

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d) Osmosis

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e) Specific gravity

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2. What do you understand by the term 'colligative properties'?

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3. The vapour pressure of a solution depends on the number of solvent molecules. Explain how?

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4. How can you modulate boiling point and freezing point of a solution?

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5. Explain the role of surfactants in a solution.

In the last two sections, we learnt about colloids, solutions and their properties. Next, let us look at some of the colloidal systems such as sols, suspensions, emulsions etc. We start with sols, gels and suspensions.

7.4 SOLS, GELS AND SUSPENSIONS

What are sols? *A colloidal system in which solid particles are dispersed in a liquid is referred to as a sol*, to distinguish it from a true solution. In a true solution, the substances separate into molecules and ions that disperse homogenously throughout the volume of the solvent. But when a protein such as gelatin is dispersed in water, the solution-like mixture that results is a sol. Examined under a microscope, the individual protein particles are large enough to be distinguished from the dispersion medium.

Sols resemble liquids in their main physical properties – that is, they flow and they do not show rigidity of form. However, when a sol assumes a rigid form, it is referred to as a *gel*. There is no distinct line of separation between a sol and gel; infact some sols become gel by increasing the concentration of dispersed solids or micelles. A typical sol is a fluid whereas a typical gel has a certain amount of rigidity. The difference between a sol and a gel has been illustrated in Figure 7.6.

Figure 7.6: Difference Between a Sol and a Gel

During sol -gel transformation, a three dimensional network is formed by the interlocking of dispersed particles. The liquid phase is entrapped in the interstitial areas of this structure. When this happens, the sol loses its fluidity and becomes a gel. The change from sol to gel may be brought about by a change in the concentration of dispersed phase or a change in temperature .Gelatin dispersed in hot water is a sol, but when cooled it becomes a rigid, transparent gel. Other examples of sols that turn to gels are fruit jellies and custards.

Many gels lose liquid upon standing and the gel structure shrinks. *This is called weeping or syneresis*. The liquid that collects around a glass of fruit jelly or a dish of custard is an example of syneresis. Let us learn more about the properties of sols and gels.

7.4.1 Properties of Sols

Sol, you learnt earlier, is *a solid liquid dispersion with solid or semi-solid particles dispersed in a continuous liquid phase.* For e.g. starch in cold water. Sols exhibit characteristic optical properties. They may have an opaque or clear appearance to the naked eye and when viewed under a microscope, but the dispersed particles are sufficiently large to scatter and polarize the incident light to some extent. This is known as the *Tyndall effect*. You have learnt about the properties of colloids earlier. These properties are basic to sols.

When you view a sol through an ultra microscope, you will observe that colloidal particles appear to be in a state of rapid and irregular motion called the brownian movement. You may recall reading about the Brownian movement earlier under the properties of colloids. The movement is caused by the constant bombardment of the dispersed particles by the molecules of the dispersion medium. The smaller the size of the colloidal particles, the more vigorous is its Brownian motion.

In a sol possessing a continuous aqueous phase, the colloidal particles have an electrically charged surface. The ionized groups of proteins and phosopholipids can be the sources of the charges. In the presence of a small quantity of dissolved electrolyte, sol particles selectively adsorb ions of one type from the solution.

The adsorption of ions by colloidal particles is a major factor in stabilizing a colloidal dispersion, since the colloidal particles in a given system have the same charge they repel each other and hence the tendency to coalesce is reduced. Addition of salts to a sol causes precipitation. Charged particles have strong attraction for the polar water molecules and therefore are hydrated, probably having a complete envelop of water molecules.

Addition of salt helps in the withdrawal of water from the hydrated surfaces of the particles and this helps precipitation. Sols, unlike solutions, have low osmotic pressure. Thus, they cannot pass through animal membranes or through cellulose walls in plants. In lyophobic sols, there is little interaction between the dispersed phase and the dispersion medium. Consequently, properties like viscosity and surface tension of such sols are the same as these of the dispersion medium at the same temperature. In the lyophilic sols, owing to the salvation of the dispersed phase, there is difference in properties. The viscosity of lyophilic sols is greater than that of the dispersion medium and is increased marked by a decrease in temperature or an increase in particle concentration. At particle concentration greater than 20 percent, sols may exhibit elasticity.

7.4.2 Gels and its Properties

You already know that sol is free flowing liquid at room temperature, when it becomes relatively firm, it is called a *gel*. There are a number of factors that affect the strengths, elasticity and brittleness of the gel such as concentration of the jelling agent (particulates), salt content, pH and temperature. Polysaccharides, proteins or colloidal complex particles, such as caseinate micelles form gels at levels of 10% or less. Gums, pectin and gelatin form gels at levels of 1% or less. Salts and pH influence gel formation adversely or favourably depending upon the concentration. By the reduction in the number of charged particles, by the adjustment of pH or addition of salt, a sol can be transformed into a gel. Addition of sugar which competes with water in the continuous phase helps gel formation when used in the proper portion. Change in temperature has an effect on gel formation; low temperatures reduce the mobility of the colloidal molecules in the sol and increase the viscosity. This condition facilitates gel formation.

The rigidity of gel changes with time leading to *syneresis*, which involves release of water and contraction of gel volume. The amount of liquid released varies with the type of gel and the conditions under which it is prepared.

After gels, it is the turn of suspensions. What are suspensions? How do they differ from sols? Let's find out.

7.4.3 Suspensions

Sol, we learnt is a colloidal system, in which solid particles are dispersed in a liquid. When the particles of a solid are separated into large aggregates of particles and dispersed in a liquid, the food system is referred to as a *suspension.* In a suspension, the particles tend to sink to the bottom of the mixture if they are heavier than the liquid but rise to the top if they are lighter. A mixture of flour and water is an example of a mixture in which the particles are heavier than the liquid. If it is stirred and heated, a suspension of this kind will change to a gel.

So it must be clear to you that both sol, suspensions are solid and liquid dispersions. You may recall reading earlier that colloidal system may also exist as gas and liquid dispersion, liquid in liquid dispersion etc. next, let us learn about gas and liquid dispersions.

7.5 FOAMS

Consider the following example. Take some liquid in a glass and agitate or shake it vigorously. What do you observe at the top of the liquid. Yes, a foam is formed. Foams are also considered colloidal dispersions. Foams are dispersions of gas or air bubbles in a liquid. Foam is created by agitation of a liquid with a consequent entrapment of air in the liquid film. Foam consists of more or less stable liquid-air interfaces, the air cells being surrounded by liquid films that constitute the continuous phase. The foaming properties of liquids depend on their viscosity and low air-liquid surface tension. The gas bubbles are separated from each other by liquid walls called films or camellia, which are elastic. The diameter of the foam bubbles range from about 1 mm to several centimeters. Depending on the bubble size and wall thickness, dense or light foams are formed.

The foams frequently used in cookery are whipped cream, ice cream, cake, bread, meringues, milk froth and gelatin. Food foams contain large amounts of entrapped gas. They have an extensive surface area between the gaseous and liquid phase, a higher concentration of the solute at the surface than in the bubble liquid, and walls which are rigid and elastic and reflect light so that they have an opaque appearance.

Let us learn in more details about how the foams are formed? Formation of a foam is dependent on a foaming agent in the continuous phase prior to dispersion of gas. The foaming agent must be adsorbed at the surface to reduce surface tension and provide a distinct surface layer which resists the coalescence of gas bubbles. Surface active lipids, glycosides, proteins are used as a foaming agent.

There are two basic methods in the formation of foams i.e. *whipping and condensation*. *Whipping* is the most common method used as it forms bubbles by cutting the surface and introducing air into liquid. Repeated action makes the bubbles progressively smaller and creates a fine dispersion which is foamy and light in texture. In the *condensation method* a pressurized solution is suddenly released to expand the number of gas bubbles which their ripe through the liquid. In this method, the size of the bubbles become larger with time and cannot form even textured foam. Factors such as surface tension, iso-electric point, solubility of surfactant and low vapour pressure affect the formation of foam.

What about foam stability? Foam stability can be determined by two factors i.e. *drainage and bubble size.* The volume of the liquid drained due to gravitational forces when foam is left to stand for some time (20-30 minutes) indicates stability of the foam. The greater the drainage the less stable is the foam and also the larger the size of the bubbles in a foam. In food industries undesirable foams may be formed. This is overcome by using antifoaming agents? What are these agents? We will find out.

7.5.1 Antifoaming Agents

In food industries, undesirable foams may be formed such as in concentration of fruit juices, coffee extracts, vegetable oils and syrups or in fermentative processes. This leads to loss of a product and reduced rate of processing. Antifoaming agents such as silicon oils (water insoluble dimenthy, polysiloxames) are used in the food industry. They spread as a monolayer and displaces the stabilizing foam film, resulting in the thinning of the bubble walls and can cause bursting.

In this section we have looked at gas and liquid dispersions. Next, an insight into liquid and liquid dispersion is presented.

7.6 EMULSIONS

You may have eaten Mayonnaise. Some of you may also know how it is made. Mayonnaise is a liquid in liquid dispersion, in fact a true emulsion. A true emulsion represents a colloidal dispersion of one liquid in another when both liquids are mutually immiscible. Emulsions exhibit the characteristics of colloidal systems, the particle of the dispersed phase being about 0.1 mm. The liquid in which the dispersion takes place is called the *continuous phase*.

A food emulsion is basically a two phase system consisting of a liquid, such as oil, wax or essential oil and water. An emulsion has 3 parts – dispersed phase, continuous phase and or emulsifier which is a surface active agent that decreases interfacial tension and forms physical barriers around each droplet to impede or present their coalescence. Emulsions are basically of two types:

- Oil in water (o/w), and
- Water in oil (w/o)

The oil in water emulsion consist of lipid droplets dispersed in water e.g. milk, cream, ice cream, mayonnaise, salad dressing (Figure 7.7). The water in oil emulsion is made up of water droplets dispersed in oil e.g. butter, margarine.

Figure 7.7: oil in water emulsion

Food emulsions must have the appropriate appearance (colour + opacity), texture (viscosity, plasticity and oiliness) and flavour for acceptance. Let us learn how the emulsions are formed next.

The most common method of preparing an emulsion is by mechanically dispersing one liquid phase in another by formation of small droplets. This takes place by a beater blade. A stable emulsion is not formed by merely mixing of the liquids. When the emulsion is left to stand, droplets in the dispersed phase coalesce due to surface tension. It is possible, however to stabilize an emulsion by adding a suitable substance termed emulsifier. How this is done? Let's find out in the following text.

Emulsions can be stabilized by the use of emulsifiers, finely divided particles adsorbed at the interface and water dispersible hydrocolloids. Emulsifiers may be in the form of proteins, gums, gels fatty acids and phospholipids. Materials used as emulsifiers have an electric charge opposite to that of the material to which they are added. The emulsifier reduces the interfacial tension existing between the water and the oil, thus making them less repellant to each other. This can be accomplished because one end (polar end) of the molecule of the emulsifier is soluble in water and the other end (non polar end) is soluble in oil (Figure 7.8). This permits a film to form around each tiny drop of oil that prevents the drops from running together.

Figure 7.8

There are many emulsifiers which are present in nature such as phospholipids e.g. lectin which is present in egg yolk which acts as a natural emulsifier in stabilizing mayonnaise emulsion. Hydrocolloids, such as plant gums and gelatin, act as stabilizers in oil-in-water emulsions by increasing the viscosity of the continuous phase or sometimes by forming a strong interfacial film around droplets of the dispersed phase. Lecithin, alginates, plant and seed gums, and cellulose derivatives, such as carboxymethyl-cellulose and hydroxypropyl methyl/cellulose gums are used as stabilizers.

Emulsions may also be stabilized by a process known as *homogenization*, in which the size of the dispersed fat globules is greatly reduced to more or less uniform diameter by application of considerable force. This prevents the fat globules from coalescing.
We will stop our discussion on emulsions here.

Check your progress Exercise 3

1. Fill in the blanks:
   a) Sols resemble liquids in their main physical properties – that is, they …………and they do not show …………………………………………………
   b) The process of loss of liquid from gels causing their shrinkage is called…………………………………………………………………………..
   c) Emulsions are of two types namely ………………… and ………………………
   d) Mayonnaise is an example of…………………. in ……………………emulsion.
2. Differentiate between sols and gels, giving examples.

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3. List a few factors that affect properties of a gel.

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4. Define the following terms:

a) Suspension

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b) Foam

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c) Emulsions

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d) Food emulsifiers

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5. How are foams formed? What are the factors affecting foam formation?

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6. How can emulsions be stabilized?

7.7 LET US SUM UP

Let us summarize all that we studied in this unit.

A colloidal system is a heterogeneous system consisting of two phases- the dispersed phase and the dispersing medium. Each of the three states of matter i.e. gaseous, solid and liquid can be dispersed in a medium which may be gaseous, liquid or solid. Eight classes of colloidal dispersions can be formed from the three states of matter. Gases may be combined with solids or liquids in colloidal dispersions, but mixtures of gases form solutions not colloids. Colloidal particles are in motion and are electrically charged. The colloid's property of adsorption makes it useful in cookery. Colloidal systems may be lyophilic or lyophobic.

Sols and suspensions are both solid in liquid dispersions with solid or semi-solid particles dispersed in continuous liquid phase. In a suspension, particles tend to separate, rising if lighter than the liquid and sinking if heavier. Gels are rather rigid colloidal systems.

Foams are colloidal dispersions of gas or air bubbles in a liquid. A true emulsion is a colloidal dispersion of two mutually immiscible liquids. An emulsifier aids stabilization of emulsions. Homogenization in which particle size is reduced also stabilizes emulsions.

7.8 GLOSSARY

Brownian movement **:** movement of the colloidal particles, brought about by the bombardment of thousands of molecules in the gas or liquid in which they are suspended.

Coalesce **:** come together and form one mass.

Food emulsifiers **:** surface active agents consisting of hydrophilic and hydrophobic components.

Interface **:** boundary between a liquid-liquid or a solid-liquid junction.

Interfacial Tension **:** the tension at liquid/liquid or liquid/ solid interfaces.

Lyophilic sols **:** sols formed spontaneously when the dry coherent material is brought in contact with the dispersion medium.

Lyophobic sols **:** sols that cannot be formed by spontaneous dispersion in the medium. They are thermodynamically unstable.

Specific gravity : weight of a given substance referred to the weight of an equal volume of water at a definite temperature.

Surface tension : forces causing a reduction in the surface area.

Surfactant : a substance which lowers the surface tension of the medium in which it is dissolved.

Syneresis : loss of liquid from gels upon standing and the shrinkage of gel structure.

Tyndall effect : a property exhibited by a colloidal dispersion, where a strong beam of intense light leaves a bright definite path through a colloidal dispersion.

7.9 ANSWERS TO CHECK YOUR PROGRESS EXERCISES

Check Your Progress Exercise 1

1. Colloids are the compounds with large molecular weights, which form dispersions only with water e.g. starch, proteins, glycogen and agar-agar.

2. Colloids are compounds with large molecular weights, which form dispersions only with water. e.g. starch, proteins, glycogen and agar-agar while Crystalloids are compounds with small molecular weights, which can form true solutions. e.g. sugars and amino acids.

3. The material that forms the base of a colloidal system is termed as dispersion medium or the continuous phase. While the material that exists in the colloidal condition is called as the dispersed medium or the discontinuous phase.

4.

Dispersed Phase	**Dispersing Medium**	**Name**	**Example**
Liquid	Gas	Fog	Aerosol sprays
Solid	Gas	Smoke	Smoked fish
Gas	Liquid	Foam	Whipped cream
Liquid	Liquid	Emulsion Oil in water Water in oil	 Milk Margarine
Solid	Liquid	Sol	Whey
Gas	Solid	Solid froth	Bread, *idli*
Liquid	Solid	Liquid inclusion	Gelatin, jellies, fruits, vegetables, meat products
Solid	Solid	Solid sol	Candies

Check Your Progress Exercise 2

1.

a) Solubility is the amount of a solute that can be dissolved in the given amount of solvent at a given temperature.

b) Concentration is the amount of solute dissolved in a specified amount of solvent or solution.

c) An external pressure which is equal to the atmospheric pressure is the boiling point.

d) Osmosis is the flow of solvent in the solution or from a more dilute solution to a more concentrated solution when the two liquids are separated through a semi-permeable membrane.

e) Specific gravity is the density of one substance in relation to the other material.

2. Properties of solution which depend on the number of molecules present and not on their chemical nature are known as colligative properties.

3. When a solid is dissolved in the volatile solvent, the vapour pressure of the solution becomes less than that of a pure solvent because of the presence of solute

molecules. The extent of lowering is proportional to the number of molecules of solvent compared with the total number of solvent and solute molecules. Hence showing that vapour pressure depends on the number of solvent molecules.

4. Boiling point: by modifying the pressure

   Freezing point: by dissolving a non-ionizing solute in the solution.

5. Surfactants or the surface active agents are used to reduce the surface tension between the polar and non-polar groups of a solution. These agents are absorbed at the surface of a solution.

Check Your Progress Exercise 3

1.

   a) flow; rigidity of form
   b) syneresis
   c) oil in water and water in oil
   d) oil in water emulsion

2. Sol is a colloidal system in which the solid particles are dispersed in a liquid. When a sol assumes a rigid form, it is referred to as gel. Examples of sols that turn to gels are fruit jellies and custards.

3. Concentration of the jelling agent, salt content, pH and temperature are the factors that affect the properties of a gel.

4.

a) Suspension is the separation and dispersion of the particles of a solid into large aggregates of particles in a liquid e.g., a mixture of flour and water.

b) Dispersions of gas or air bubbles in a liquid is referred to as foam for e.g., whipped cream, ice cream, cake, bread and gelatin.

c) Emulsion is a colloidal dispersion of one liquid in another when both liquids are mutually immiscible e.g., milk, cream, mayonnaise, salad dressing.

d) The surface active agents consisting of hydrophilic and hydrophobic moieties are the food emulsifiers e.g., phospholipids and proteins.

5. There are two methods of foam formation. These are discussed as follows:

- Whipping: The most common method, as it forms bubbles by cutting the surface and introducing air into the liquid. Repeated action makes the bubbles smaller and creates a finer dispersion, which is foamy and light in texture.
- Concentration: A pressurized solution is suddenly released to expand the number of gas bubbles. The size of the bubbles becomes larger with time and cannot form even textured foam.

The factors affecting foam stability are:surface tension, isoelectric point, solubility of surfactant and low vapour pressure.

6.

- Use of natural stabilizers such as lectin; hydrocolloids such as plant gums and gelatins; plant and seed gums; cellulose derivatives.
- Homogenization