
UNIT 4 FORMS OF WATER IN FOODS, SORPTION AND DESORPTION OF WATER IN FOODS AND WATER ACTIVITY

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4.0 OBJECTIVES

After reading this unit, you should be able to:

- state the meaning of water activity and water sorption isotherms;
- explain the properties of water in solutions;
- describe the effect of water activity on various biochemical reactions, microbial growth, food preservation, etc.; and
- discuss the water activity in packaged and stored food.

4.1 INTRODUCTION

All foods provided by nature, contain water. High water content in foods is most likely to show rapid deterioration due to biological and chemical changes. Our ancestors found that spoilage could be delayed or prevented by drying perishable foods. The water in foods serves as a solvent for many constituents. The removal of water will concentrate these constituents. The increasing concentration, rather than decreasing water content, preserves the food. Water can be removed by heat, sun's radiation, salt or sugar. Thus, any method increasing the concentration of a food's aqueous phase enhances its stability.

Therefore, study of water in foods is also a study of aqueous solution in which the solutes, by their nature and concentration, alter the physical properties of the solvent. It is the state of water in food which influences the microbial growth, enzymatic and non-enzymatic reactions. By controlling the water content, or concentrating the food solution, we may stabilize the food for a longer period. The water content influences the biological or chemical changes, and these changes affect the taste, texture and appearance of the food.

Thus, there is a water related criteria, viz. water content, solute concentration, osmotic pressure, equilibrium relative humidity (E.R.H.), and water activity (a_w). It is the water activity, which is the most useful expression of water requirements for microbial growth and enzyme activity. It becomes more important in defining the quality of food material. Thus, by controlling the water activity of fruits and vegetables, we may predict the freshness, or storability of their processed products.

4.2 PROPERTIES OF WATER IN SOLUTIONS

Water has its own property. When solutes are dissolved in water, the water molecules become oriented with respect to solute molecules. In simple word water molecules and solute molecules are engaged with each other. The water molecules become less free to escape from the liquid into the vapour phase, and the vapour pressure is lowered. There is a relationship between solutes concentration and vapour pressure of liquid or solution. It indicates that with increase in solute concentration, vapour pressure decreases, and it lowers the freezing point but it raises the boiling point of the solution.

The water activity is described as the ratio of water vapour pressure of food (solution) to the water vapour pressure of pure water (solvent) at the same temperature and expressed by

$$a_w = P/P_o$$

P = Vapour pressure of food

P_o = Vapour pressures of pure water

It is expressed as a fraction but under equilibrium condition, equilibrium relative humidity (E.R.H.) is equal to $a_w \times 100$, provided that its vapour pressure is not reduced. The pure water has the water activity of 1.00, which is equivalent to an E.R.H. of 100 per cent. Thus, a food with a water activity of 0.8 would produce an E.R.H. of 80 per cent.

Any addition of solutes in water influences the water activity. For example, an ideal solute of 1 molal concentration has a_w 0.9823, but glycerol has 0.9816, sucrose has 0.9806, while has sodium chloride 0.967. The difference in water activity may be small for non-electrolytes but for electrolytes the difference in water activity is always great. It increases with the increase in the number of ions generated per molecule.

4.3 WATER SORPTION ISOTHERMS

A percentage of total water in a food is strongly bound to specific sites, e.g. hydroxyl groups of polysaccharides. When all sites are (statistically) occupied by adsorbed water the moisture content is termed monolayer value. This monolayer value represents the moisture content at which the food is most stable.

It influences certain chemical reactions. For example, lipid oxidation rates increase at water contents below the monolayer, while rates of non-enzymatic browning increase above it. The capillary forces in foods also influence the water activity, generally it depresses water activity.

To understand the water relations of a food, the water activity levels corresponding to a range of water content must be determined. The data are plotted to provide a water sorption isotherm (Figure 4.1).

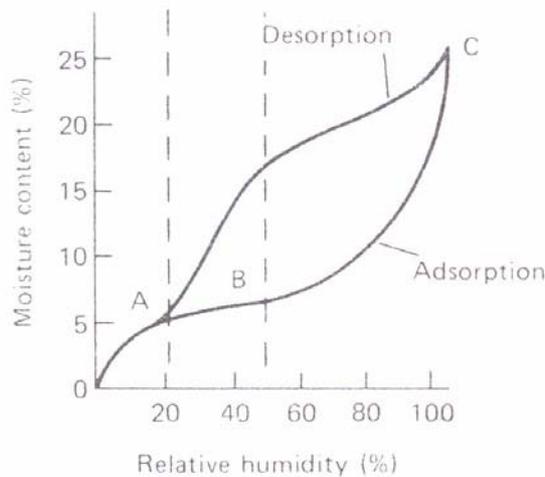


Figure 4.1: Water sorption isotherms

The graphical relationships between water content and water activity (a_w) are termed “isotherms” and the loop is termed as hysteresis loop. Any changes in temperature affect this relation. Thus, water taken by a dry food is termed adsorption and water removed from a moist material is termed desorption. The difference is greatest at lower temperature (5°C) and not detectable at higher temperature (60°C).

There are different stages of water sorption. In theory, the course of water sorption by a dry material is first by the formation of a monolayer, followed by multiplayer adsorption, the uptake into pores and capillary spaces, dissolution of solutes, and entrapment of water at higher levels of water activity. These phases or stages vary in the food product depending upon chemical composition and structure. Thus, we find that water activity plays a great role in the study of freezing and dehydration of fruits and vegetables. By controlling water activity of the food, oxidative changes and microbial growth can be checked. The water activity can be a basis for the standard specification of food material. And it also becomes the basis of guidelines, for pickled, fermented and acidified foods.

4.4 WATER ACTIVITY AND METHODS

The water in food, which is not bound to its molecules, can support the growth of microorganisms. This unbound or free water is also termed as water activity (a_w).

The water activity and moisture content of a food are not the same. The various foods may have exactly the same moisture content but have different water activities. For example, jams, jellies and plum puddings have $0.8 a_w$, while dried fruits have $0.6 a_w$.

The water activity can determine the shelf life of a food. There are several factors, including the temperature and pH, that influence the growth of the organisms in food, but water activity may be the most important factor in

**Food Preservation
through Water
Removal**

controlling spoilage. The water activity can predict which microorganisms will and will not be potential cause of spoilage. Hence, the water activity plays a role in determining the activity of bacteria or enzyme, which can have a major impact on the colour, taste and aroma of the product. There are several food preservation methods which to eliminate spoilage by reducing the availability of free water to microorganisms. The processes such as concentration, dehydration, freeze-drying and freezing can reduce the amount of free water in a product.

Water activity or equilibrium relative humidity of a food effects its quality during processing storage, transportation, marketing etc. Any change in the water activity of specific food may lead to the changes in its quality.

Moisture measurement techniques have been classified into three groups based on function: (i) water activity, (ii) atmospheric relative humidity, and (iii) total moisture. The first group deals with direct water activity / E.R.H. measurements as related to foods. The second group deals with relative humidity measurements, which covers food related activities, for example, ambient relative humidity in food storage areas. The third group deals with measurement of total moisture content, regardless of the condition or degree of water binding. These measurement methods are listed below.

Graphic Interpolation, Bithermal Equilibrium, Manometer, Hair Hygrometry, Isopiestic Equilibration, Electric Hygrometry, Chemical Methods, Freezing Point Depression, Dew Point Methods, Relative Humidity Methods, Thermometric Methods, Total Moisture Methods, Gravimetric, Gas Chromatography, Karl Fischer Titration, Nuclear Magnetic Resonance, Thermal Analysis, Moisture Evolution Analysis, Infrared, Vacuum Oven Drying, Solvent Extraction.

The control of water activity in processed products of fruits and vegetables is essential for maintenance of their wholesomeness, safety, texture, and for suppression of undesirable enzymatic and chemical changes. These objectives can be achieved by utilizing water activity adjustment as a legitimate means of food preservation. The water activity adjustment in a food is also affected by a large number of substances added to the food.



Check Your Progress Exercise 1

- Note:** a) Use the space below for your answer.
b) Compare your answers with those given at the end of the unit.

1. Describe water activity.

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2. What do you understand by water sorption isotherms?

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3. List some methods which can measure the water activity.

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4. Why measurement of water activity is essential?

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4.5 EFFECT OF WATER ACTIVITY ON ENZYME REACTIONS

Enzymes are proteinaceous substances that catalyze organic reactions. The enzymatic reactions may be beneficial or detrimental changes occurring in foods. For example, the addition of a proteolytic enzyme, which acts as a chill proofing agent, to beer to prevent precipitation of proteins when it is refrigerated. These enzymes develop in foods through the growth of specific types of microorganisms. For example, proteases and lipases synthesized by the mould, *Penicillium roqueforti* that produces desirable flavours during ripening of blue cheese.

Certain enzymes catalyze detrimental changes in food, such as non-microbial decomposition of fruits and vegetables during handling and storage. The enzymes, viz. peroxidase may cause browning; ascorbic acid oxidase may cause oxidation of ascorbic acid. It is therefore, important to thwart the activities of these naturally occurring enzymes in foods. Blanching of fruits

and vegetables by hot water or steam is one method to inactivate enzymes and prevent the deleterious changes.

The enzymes also produce free radical by hydrolytic reactions. The water participates actively in these reactions. These reactions are not limited with low moisture foods, since many enzymatic reactions cease at higher concentration than that required for hydrolysis. At low water activity levels free mobile water monolayer is not available to carry out reactions. Under such conditions the enzymatic reactions are suppressed. But, when the water activity of food increased, the enzymatic reaction rates increase. Thus, by controlling water activity, we can check the enzymatic reaction rates. In other words, we may increase the rates of beneficial reactions and reduce the rates of deleterious reactions, and maintain the desired quality of foods.

There are certain enzyme preparations, which can be used to affect desirable changes in foods, These enzyme preparations can be stabilized by use of certain substances such as sodium chloride, glycerol, or propylene glycol. There are other factors, which also affect the stability of enzymes in foods, such as temperature, pH, ionic strength, moisture level, nature of food, time of storage, presence of activators and inhibitors, etc.

The enzymatic activity virtually ceases at water activity values below monolayer value. This is due to the low substrate mobility and its inability to diffuse to the reactive site on the enzymes.

Fungal proteolytic enzymes are strongly inhibited by 2-3% sodium chloride (NaCl), as the activity is in the range of 0.6-0.8. The optimal water activity levels for invertase activity is greater than 0.997. In a glycerol / water mixture, lipoxidase and peroxidase exhibit optimal activity in the range of 0.94-0.97 water activity.

4.6 EFFECT OF WATER ACTIVITY ON NON-ENZYMATIC BROWNING REACTIONS

The water activity plays a great role in influencing the non-enzymatic browning (NEB) reactions in the processed fruit and vegetable products. The substrates for NEB are the reducing sugars such as glucose and fructose and amino groups of amino acids or proteins. Sucrose may be a substrate but does not cause browning. Hydrolysis of sucrose into glucose and fructose during processing may cause browning. A number of factors such as temperature, pH, and water activity also affect the NEB reactions. They are called the formation of browning or Maillard reaction products. These browning reactions deteriorate the quality of the processed products.

The water activity that causes the maximum rate of browning varies with different foods. At low water activity browning is reduced due to lower mobility of reactants, whereas at higher a_w browning is maximum. During browning, condensation reaction produce water and at higher moisture levels, browning is inhibited by end product inhibition. At higher moisture contents, water dilutes the reactants and the rate of browning falls.

Browning that occurs during processing or storage may either increase or decrease the acceptability of a food. For example, in a dehydrated pea soup stored at 54°C, a steady increase in browning rate occurs as the relative humidity of the system is increased. The maximal rate occurs in the 65-70%

relative humidity range. Thus, the temperature and moisture content during storage influence the browning rate in dehydrated products. NEB is a serious problem in the production of intermediate moisture food (IMF), since they are poised at 0.6-0.8 water activity, which places them well within water activity ranges for optimal browning. If the water activity is reduced to the range of 0.40 to 0.50 from 0.65 to 0.75 the browning of IMF can be reduced.

It is clear from the above discussion that maximal browning reaction rates in fruit and vegetable products occur in the 0.65-0.75 water activity range. By checking the water activity we can reduce the non-enzymatic browning.

4.7 EFFECT OF WATER ACTIVITY ON MICROBIAL GROWTH AND SURVIVAL

4.7.1 Microbial Growth

Food is spoiled by microorganisms, i.e. bacteria, yeast and moulds. There are four main phases of the growth cycle of these microorganisms, viz. the lag phase, the logarithmic phase, the stationary phase, and the death phase. Bacteria, yeasts and fungi reproduce by different methods such as binary fission, budding or by hyphal extension, respectively. But the phases through which these organisms pass are broadly similar.

The first phase, i.e., the lag phase, is the period of adjustment or adaptation. Physiologically the microorganisms are very active during this phase. The organisms are metabolizing, but there is a lag in cell division. At the end of the lag phase, each organism divides. However, since all the organisms do not complete the lag period simultaneously, there is a gradual increase in the population until the end of this period, when all cells are capable of dividing at regular intervals. The lag phase is followed by rapid growth, i.e., the exponential or logarithmic phase. During this period, the population is nearly most uniform in terms of chemical composition of cells, metabolic activity, and other physiological characteristics.

The logarithmic phase of growth is followed by a levelling off, the stationary phase. During this phase, the population remains constant for a time, perhaps because the reproduction rate is balanced by an equivalent death rate. Following the stationary phase, the organisms may die faster than new ones are produced, if indeed some organisms are still reproducing. During the death phase, the number of viable organisms decreases exponentially, essentially the inverse of growth during the lag phase.

We should understand that the important criterion in the water relations of a particular microorganism is the minimal water activity permitting growth. From the point of view of food technology and preservation of fruit and vegetable products, less extreme effects may also be detrimental. For example, at certain water activity levels, the population of a microorganism may be insufficient to produce a toxic product or an infectious dose. The reduced water activity along with another chemical or physical agent such as pH or common salt may have synergistic inhibitory effect on the growth of any microorganism. Thus, it is important to consider the effects of water activity on microbial growth and survival.

In general, the microorganisms associated with foods, moulds are more tolerant of a decreased a_w than yeasts, and yeasts are more tolerant than bacteria. In high moisture foods ($a_w > 0.90$) bacteria are mainly responsible for spoilage, food poisoning or fermentation. In intermediate moisture foods (a_w 0.90-0.60) yeasts and moulds are of significance in spoilage. However, most microorganisms are inhibited in low moisture foods ($a_w < 0.60$).

The a_w of most fresh foods is above 0.99. Most spoilage bacteria do not grow below a_w of 0.91 while spoilage moulds can grow as low as 0.80. With respect to food poisoning bacteria, *staphylococcus aureus* has been found to grow at as low as 0.86, while *clostridium botulinum* does not grow below 0.95 a_w . Just as yeasts and moulds grow over a wider pH range than bacteria, the same is true for a_w . The lowest reported values for bacteria of any type is 0.75 for halophilic bacteria, while xerophilic moulds and osmophilic yeasts have been reported to grow at a_w values of 0.65 and 0.60, respectively.

Inhibition of microorganisms in a food is frequently not caused solely by a decrease in a_w , but may also be influenced by pH, temperature, nutrition, preservatives or a competitive microflora. At any temperature, the ability of microorganisms to grow is reduced as the a_w is lowered. The range of a_w over which growth occurs is greatest at the optimum temperature for growth. The presence of nutrients increases the range of a_w over which the organisms can survive.

Factors affecting the germination of spores *clostridium botulinum* have indicated interaction or combined effects of a_w , temperature, pH, oxidation – reduction (O-R) potential, and sodium chloride and sodium nitrate concentrations. Addition of solutes such as glycerol and common salt also influences the water activity of a solution. This shows the availability of solvent or water in a solution, since it reduces with the addition of solutes. Such conditions also influence the growth of microorganisms. For example, non-osmophilic yeast, *saccharomyces*, grows at water activity levels down to 0.93-0.92 in sodium chloride and to 0.91-0.90 in sucrose media. But the osmophilic yeast will grow in more concentrated environment, i.e., sugar rich and salt-rich foods.

Thus, depending upon the type of microorganism, water activity along with solutes and other factors can be selected to enhance or restrict their growth.

4.7.2 Microbial Survival

The survival of microflora is of concern during two stages of fruits and vegetables. Firstly for short period during processing and secondly for long periods during storage. We should adopt measures to prevent the growth of these microflora. We are concerned especially with the survival of microorganisms in commercially processed fruit and vegetable products. These may be frozen, dried or canned products.

Similar to the rate of multiplication, the rate of inactivation of microorganisms tends to be exponential. It shows that the same proportion of the viable population will be inactivated in each succeeding unit of time. If we plot, the number of viable cells against time, a linear curve would be obtained, and from it rate of death can be determined. This is generally expressed as the decimal reduction time or D-value. It is the time required to destroy 90 percent of the

organisms. Mathematically, it is equal to the reciprocal of the slope of the survivor curve and is a measure of the death rate of an organism.

Storage stability of frozen and dried foods

A large number of microorganisms have been reported to grow at and below 0°C. Their growth at and below freezing temperatures depends on several factors of foods, namely, nutrient content, pH, and the availability of liquid water. The a_w of foods may be expected to decrease as temperatures fall below the freezing point. In fruit juice concentrates which contain comparatively high levels of sugars, these compounds tend to maintain a_w at levels higher than would be expected in pure water, thereby making microbial growth possible even at subfreezing temperatures. Bacteria differ in their capacity to survive during freezing, with the cocci being generally more resistant than gram negative rods. Of the food poisoning bacteria, salmonellae are less resistant than *staphylococcus aureus* or vegetative cells of *clostridia*, while endospores and food poisoning toxins are apparently unaffected by low temperatures.

The heat resistance of microbial cells increases with decreasing humidity or moisture. The preservation of foods by drying is based on the fact that microorganisms and enzymes need water in order to be active. Although some microorganisms are destroyed in the process of drying, this process is not lethal to microorganisms, and indeed many types may be recovered from dried foods. Osmophilic yeasts such as *Saccharomyces rouxii* strains have been reported to grow at an a_w of 0.65 under certain conditions. The most troublesome group of microorganisms in dried foods are the moulds, with the *Aspergillus glaucus* group being the most notorious at low a_w values. In the absence of fungal growth, desiccated foods are subjected to certain chemical changes which may result in the food becoming undesirable upon holding.

Drying usually is accomplished by the removal of water, but any method that reduces the amount of available moisture, i.e., lowers the a_w , in a food is a form of drying. Thus, for example, dried fish may be heavily salted so that moisture is drawn from the flesh and bound by the solute and hence is unavailable to microorganisms. Sugar may be added, as in sweetened condensed milk, to reduce the amount of available moisture.

The potentials of reduced water activity in food preservation with the following considerations are:

- i) an a_w of 0.85 inhibits the most common food pathogens,
- ii) bacterial spore germination is inhibited at relatively high a_w values,
- iii) non-sporeformers, which can grow at an a_w below 0.95, are susceptible to pasteurizing temperatures,
- iv) sub-optimal conditions of growth impose inhibition at higher levels of water activity,
- v) organisms that will grow at low water activities multiply very slowly, and
- vi) yeasts and moulds can be suppressed by antimycotics.



Check Your Progress Exercise 2

Note: a) Use the space below for your answer.
b) Compare your answers with those given at the end of the unit.

1. How does water activity affect enzymatic reactions?

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2. Explain “controlling water activity can reduce non-enzymatic browning.”

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3. Describe the effects of water activity on the microbial growth.

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4.8 EFFECT OF WATER ACTIVITY ON PACKAGING AND STORAGE

The conditions during storage and transport should be maintained in such a way so that any deterioration is kept to a minimum. These problems are influenced by the temperature and relative humidity during storage and by the type of package in which foods are stored. Therefore, we should consider the water activity requirement in the packaging, storage and transportation of food products.

i) Transportation of processed products

During transportation of processed products the moisture migration may cause condensation. This has proved to be a problem in successful transportation of some commodities due to differences in climatic zones. For example, if cooling is followed by an increase in atmospheric temperature then humidity causes condensation on the inner surface of any container. This causes an increase in the relative humidity of the air above 90 per cent, but aeration can reduce it to a safe level.

Similarly, condensation of moisture on the surface of containers such as canned foods may spoil the label, corrode the can and mould attack. This type of problem can be prevented by drying the container before loading and lacquering the can from outside.

In the atmosphere of equilibrium relative humidity (ERH) a commodity at low water activity, even small decrease in air temperature may cause moisture condensation. For example, the air at 70 per cent ERH and 30°C becomes saturated and hence prone to moisture condensation if its temperature falls by only 6°C, such conditions may also permit the mould growth.

ii) Packaged products

Packaging generally reduces the atmosphere of a commodity to a minimum, hence protects it from outside sources, particularly the migration of moisture and variation in temperature. The quality of a food depends upon its properties, packaging material and the storage environment. We are concerned with the changes influenced by water activity, particularly appearance, taste, odour and texture, resulting from microbiological and biochemical changes. Packages are expected to provide adequate degree of protection to the product. With advances in packaging technology, packages are often expected to provide nutritional and constitutional information to sell the product. The packaging material has to provide desired water activity, which is the main concern. But, there are special requirements that include protection from light and oxygen, retention of preservatives, fragility of the product and the ease with which the package can be filled, handled and stored. Properly sealed cans and glass bottles give complete protection to the packed food against the intake of gases, moisture and microorganisms. The more attention should be given to the flexible films or packaging materials, which exhibit a very wide range of moisture (vapour) and gas permeability.

iii) Packaging materials

The basic flexible materials of importance are aluminium, plastic, regenerated cellulose and paper. The overall permeability of aluminium foil and laminate is near zero. The permeability of plastic film is governed by its thickness. Thicker films generally have lower permeability, greater strength and higher cost. In food packaging application, the materials are combined by lamination, coating or co-extrusion, and they may have properties different from the basic or individual film. Type of food product, its hygroscopicity, environment inside and outside of package, handling during storage, marketing, transportation, etc., usually govern this

type of combination of packaging materials. Sometimes, microbiological problems may arise. When moist product is packed in impermeable or low permeable materials, such as glass, metal or films coated with polyvinylidene chloride or polyvinyl chloride, the food will equilibrate with the internal atmosphere of the package, and cooling may cause condensation of moisture, resulting in high water activity in which microbial growth may occur. Hence, we should see that product of relatively low water activity be packed in moisture impermeable packages and some measure of microbial control should also be used. Although, when high water activity products are packed in permeable material, then care must be taken to prevent excessive moisture loss from the product. This can be achieved by careful selection of wrapping material or by control of humidity in the surrounding atmosphere of the package.

iv) Unrefrigerated packaged products

Dehydrated vegetables, which have water activity of 0.30 or below, require protection against moisture and oxygen. Laminates of polyethylene, aluminium foil and paper have been successfully employed for packaging dehydrated vegetables. Dehydrated soups are also packaged similar to dried vegetables, which provide full protection to the product. The dried fruits have much higher water activity levels, may be stored safely in relatively permeable film, where ambient humidity is very low. The potato chips and roasted nuts which depend on their appeal and crispness are not susceptible to unsuitable storage conditions. These products have substantial amount of lipids, hence need additional protection, and therefore hence packaged with nitrogen gas. But for long storage costly items like nuts vacuum packaging in cans or glass jars require. However, for retail marketing, these products are successfully packaged in a wide variety of materials with low water vapour transmission rate, and oxygen permeability. For example, cellulose-plastic combination, poly vinylidene chloride coated-cellulose or polypropylene are used.

v) Refrigerated packaged products

Generally, fresh fruits and vegetables are kept in cool store at suitable temperatures and relative humidity (RH). For example, cured onions and garlic can be stored at 0°C with RH 65-70 per cent, whereas vegetables like cabbage, carrots, cauliflower, leafy greens, green peas, turnip require 95 per cent of RH. Apples are stored at 0-3°C with 85-90 per cent RH depending upon non-chilling and chilling sensitive varieties.

A compromise is required between packaging material of fresh fruits and vegetables that retain water and maintain crispness, but cause condensation and fogging of the films and those which permit loss in weight and crispness, but do not fog. Sometimes, adequate perforations are made in the package for minimum respiration without physiological disorders in the living tissues. Frozen vegetables are commonly packed in polyethylene or paperboard, waxed or plastic coated moisture proof film, to minimize oxygen uptake and loss of moisture. The frozen fruit juice concentrates are packaged in hermetically sealed tin cans or aluminium laminated composite containers.

Check Your Progress Exercise 3

- Note:** a) Use the space below for your answer.
b) Compare your answers with those given at the end of the unit.

1. Describe the role of water activity in packaged products during storage?

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4.9 LET US SUM UP



The fruits and vegetables by nature contain high water; consequently they are highly perishable products. Most likely they show rapid deterioration due to biological and chemical changes. Water acts as a solvent in the food products. The solutes present in aqueous phase, by their nature and concentration, alter the properties of solvent. It is the state of water in food products, which influences the microbial, enzymatic and non-enzymatic reactions. Thus, controlling the water content or concentrating the food solution, the food may be stabilized for a longer period. The solution of food (fruits and vegetables) has its properties, and may be expressed as water activity. The water activity is certainly related with properties of food and has great importance to study its influence on microbial growth/ survival, moisture content of food, packaged food during storage, transport and preservation.

Many enzymatic reactions cease at higher water content than that is required for hydrolysis. At low water activity levels, the free moisture is not available, hence enzymatic reactions are suppressed. The maximum non-enzymatic reactions occur in food equilibrated to 0.65-0.70 water activity, but reduce at higher and lower water activity levels.

The lower level of water activity suppresses microbial growth in food products. Removal of water from foods, reduces its water activity, hence preservation is affected.

Properly prepared fruit and vegetable products, packed in appropriate packaging material and stored under controlled conditions have longer shelf life.

4.10 KEY WORDS

- Water activity** : Water activity (a_w) is the ratio of vapour pressure of food (p) and pure water (p_o), and expressed by $a_w = p/ p_o$
- Sorption isotherm** : Water sorption isotherm is a graphical presentation of data which shows the water relationship of a food.

Concentration	:	It is the removal of water from foods mostly by heat application and concentration of soluble solids or solutes.
Enzyme	:	Enzyme may be defined as proteinaceous compounds that catalyse organic reactions.
Preservation	:	Methods to hold food for a longer period than generally kept at ambient conditions. Food is safe, nutritious and free from any microbial infection.
Halophilic bacteria	:	They are salt tolerant bacteria. The extremely halophilic bacteria have evolved to grow only at low levels of water activity and only when these levels are produced by high sodium chloride concentrations.
Osmophilic yeast	:	Sugar tolerant yeast.
Adsorption	:	The taking up of one substance at the surface of another.
Desorption	:	Removal of adsorbed water from a solid. Reverse process of adsorption.
Adsorption isotherm	:	The relation between the amount of a substance adsorbed and its pressure or concentration at constant temperature.
Xerophilic	:	Microorganisms able to inhabit places where the water supply is scanty, or where conditions, e.g., excess of salt, make it difficult to take in water.



4.11 ANSWERS TO CHECK YOUR PROGRESS EXERCISES

Check Your Progress Exercises 1

Your answers should include the following points:

1. The water activity is described as the ratio of vapour pressure of solution (food) and vapour pressure of solvent (water) and expressed by

$$a_w = p / p_o$$

$$a_w = \text{Water Activity}$$

p = Vapour pressure of solution (food)

p_o = Vapour pressure of solvent (water)

Under equilibrium condition, E.R.H. is equal to $a_w \times 100$. Provided that its vapour pressure is not reduced. The pure water has an a_w of 1.00, which is equivalent to an E.R.H. of 100 per cent.

2. To understand the water relations of a food, the water activity levels corresponding to a range of water contents must be determined. The data are plotted to provide a water sorption isotherm. The water sorption isotherm is a graphical presentation of data, which shows the water relationships of a food. It is useful in showing at what water contents certain desirable or undesirable levels of water activity are achieved.

3. The following methods can be used to measure the water activity:

Graphical Inter Polation, Bithermal Equilibration Mamometry, Hair Hygrometry, Isopiestic Equilibration, Electric Hygrometry, Chemical methods, Freezing Point Depression and Dew Point Method.

4. The measurement of water activity in a food is essential for maintenance of their wholesomeness, safety, texture, and for suppression of undesirable enzymatic, and chemical changes.

Check Your Progress Exercises 2

Your answers should include the following points:

1. Enzymes are proteinaceous substances that catalyze organic reactions, which may be beneficial or detrimental, occurring in foods. The water participates actively in these reactions. Many enzymatic reactions cease at higher water content than that required for hydrolysis. At low water activity levels, the free mobile water is not available to carry out reactions. Under such conditions the enzymatic reactions are suppressed, but when water activity of food is increased, the enzymatic reactions rate gets increased. Thus, by controlling water activity we can check the enzymatic reactions.
2. The non-enzymatic browning is caused by reactions between glucose or fructose and amino group of food and influenced by water activity level. The maximum level of such reaction occurs in samples equilibrated to 0.65 to 0.70 a_w . But reduced at higher and lower levels of water activity. Thus, by controlling water activity, we can reduce the non-enzymatic browning.
3. For microbial growth optimum moisture content in food is essential beyond this limit the growth is suppressed. The lower level of water activity does not provide free moisture whereas concentration of solutes suppresses microbial growth. At very high water content dilution of nutrients prevent their growth.

Check Your Progress Exercises 3

1. Properly dried fruits and vegetables should be packed in such packaging materials, which do not permeate moisture vapour, light and gases. These food packages should be stored at desirable relative humidity and temperature. If there are differences in temperature and relative humidity in the packaged food and its surrounding atmosphere, then the moisture migration may cause condensation, which may create problems in the successful transportation. This can be reduced by aeration. Proper packaging also protects food by maintaining desirable water activity.

4.12 SOME USEFUL BOOKS

1. Hall, E.G. (1973) Mixed Storage of Foodstuffs. CSIRO Div. Foods Res., Circ. No. 9, Australia.
2. Mitchell, F.G., Guillou, L. and Parson, R.A. (1972) Commercial Cooling of Fruit and Vegetables. Univ. Calif., Div. Agric., SW. Manual No. 43, USA.
3. Troller, J.A. and Christian, J.H.B. (1978) Water Activity and Food. Academic Press, New York.
4. Verma, L.R. and Joshi, V.K. (2000) Post Harvest Technology of Fruits and Vegetables. Vol. 1 General Concept and Principles. Indus Publishing Company, New Delhi.