UNIT 5 DRYING – CONTROLING OF MICROORGANISMS

Structure

5.0 OBJECTIVES

After studying this unit, you should be able to:

- know the importance of dehydrated fruits and vegetables;
- have an idea about the drying/dehydration theories of fruits and vegetables;
- have the knowledge about the microorganisms involved in dried products;
- know the different kinds of microorganism associated with dried foods; and
- know about the microbial spoilage of dried fruits and vegetable products.

5.1 INTRODUCTION

Drying or dehydration is accomplished by the removal of water from the fruits and vegetables below a certain level at which enzyme activity and growth of microorganisms is affected adversely. The dried fruits and vegetable are called as high sugar high acid foods or high value low volume foods. These dried or concentrated products save energy, money and space in shipping, packaging, storing and transportation. Dehydration or drying process usually involves heating, in which water is removed from solid or near solid substances. The

term **drying** is generally used for drying of the produce under the influence of non-conventional energy sources like sun and wind. **Dehydration** on the other hand refers to the process of removal of moisture by the application of artificial heat under controlled conditions of temperature, relative humidity and airflow. The sun drying is a slow process and thus, not suitable for many high quality products. Generally, it lowers the moisture contents below about 15%, which is too high for storage stability of numerous products.

5.2 PRINCIPLES

The basic principle in the process of drying or dehydration is the removal of sufficient moisture to protect the product from spoilage. The process reduces the amount of available moisture i.e. the water activity (a_w) and hence, product becomes shelf-stable and is preserved for quite a long period. Moisture-solid, relationship in fruits and vegetables are more complex than in inorganic materials as the matter in fruits and vegetables exhibits an energetic retention of moisture and the moisture is bound to the solid. The solid skeleton consists essentially of numerous cells joined together to provide a network of capillaries; some of them are very fine. First the moisture in the larger capillaries has to be evaporated then only the moisture in the finer capillaries can be removed. The cell walls act as semi-permeable membranes for the diffusion of moisture, which is mainly held osmotically. Finally, there is a small amount of moisture adsorbed on the skeletal frame in multi molecular layers. In order to dehydrate any product specific requirements need to be fulfilled so that the product retains as much as possible, its original characteristics.

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. What do you mean by drying and dehydration?

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2. What are the main objectives of drying?

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3. What is the role of air in the process of drying or dehydration?

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4. How the fruits & vegetables are more complex than inorganic?

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5.3 MECHANISM OF DEHYDRATION

The changes during dehydration can be largely explained in terms of heat and mass transfer phenomena. A cue of food in the course of dehydration loses moisture from its surface and develops dried layer with remaining moisture confined to its centre. From the centre to the surface moisture gradient will be stabilized. The outside dried layer acts as an insulation barrier against rapid heat transfer into the food pieces; this is further decreased by air voids formed by evaporating water. In addition to less driving force from decreased heat transfer, the centrally remaining water also now has further to travel to get out of the food piece than did surface moisture at the start of drying. In addition, as the food dries it approaches its normal equilibrium relative humidity, as it does; it begins to pick up molecules of water vapour from the drying atmosphere as fast as it loses them. When these rates are equal drying ceases.

5.4 THEORY OF DRYING

There are two steps involved in drying and dehydration.

5.4.1 Heat Transfer Theory

Transfer of heat consists of transferring of molecular or atomic motion from one region to another. There are three broad mechanisms by which such transfer can occur, conduction, convection, and radiation. In conduction, the energy is transmitted from particle to particle by a process of direct contact. Transfer of heat by convection involves bulk mixing of fluids of different temperatures. Radiation is the transfer of energy from a radiating source through space, which may or may not be occupied by matter. It is by radiation that we receive all our energy from the sun.

5.4.2 Mass Transfer Theory

The removal of moisture from a food product involves simultaneous heat and mass transfer. Heat transfer occurs within the product structure and is related to the temperature gradient between the product surface and the water surface at some location within the product. As sufficient thermal energy is added to the water to cause evaporation, the vapours are transported from the water surface within the product to the product surface. The gradient causing moisture – vapour diffusion is vapour pressure at the liquid water surface, as compared with the vapour presser of air at the product surface. The heat and the mass transfer within the product structure occurs at the molecular level, with heat transfer being limited by thermal conductivity of the product structure, while mass transfer is proportional to the molecular diffusion of water vapour in air. The rate of moisture diffusion can be estimated by the expression for molecular diffusion. The mass flux for moisture movement is a function of the vapour pressure gradient as well as the mass diffusion for water vapour in air, the distance for water vapour movement within the product structure and temperature. The transport of vapour from the product surface to the air and the transfer of heat from the air to the product surface is a function of the existing vapour pressure and temperature gradients, respectively, and the magnitude of the convective coefficient at the product surface.

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. In the food product how the changes are occurred.

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2. What are the main mechanisms by which heat can transfer?

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3. How the evaporation is occurred during drying?

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4. What are the functions of vapour pressure and temperature gradient?

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5.5 IMPORTANCE OF WATER ACTIVITY (a_w)

Water activity (a_w) is defined as the ratio of the vapour on the aqueous solution to that of pure water at the same temperature i.e.

a_w = Vapour pressure of solution at T^{o}C

Vapour pressure of pure water at T^{o}C.

Water activity is also equal to the equilibrium relative humidity (ERH);

$$a_w = \frac{\text{Equilibrium relative humidity}}{100}$$

The a_w has a major role to play in microbiological spoilage and chemical changes produced in the food. The principles of water and microorganisms relation includes:

1) Water activity, rather than water content, determines the lower limit of available water for microbial growth. Most bacteria do not grow below a_w 0.91 and most molds cease to grow at water activity of 0.80. Some xerophylic fungi have been reported to grow at water activities of 0.65, but the range of 0.70 – 0.75 is generally considered their lower limit.

2) Environmental factors affect the level of water activity required for microbial growth. The less favourable the other environmental factors (nutrients, pH, oxygen pressure, temperature) the higher becomes the minimum a_w at which microorganisms can grow.

3) Some adaptation to low water activities occurs, particularly when a_w is depressed by addition of water soluble substances (principle of IMF – Intermediate Moisture Food), rather than by water crystallization (frozen foods) or water removal (dehydrated foods).

4) When water activity is depressed by solutes. The solutes themselves may have effects that complicate the effect of a_w per se. For instance, at a given a_W microbial growth is less effectively depressed by glycerol than by sodium chloride. More recent (IMF – Intermediate Moisture Food) have resulted in the following additional findings.

   a) Water activity modifies sensitivity of microorganisms to heat, light and chemicals. In general organisms are most sensitive at high water activities (i.e. in dilute solution) and minimum sensitivity occur in intermediate moisture. Minimum water activities for production of toxins are often higher than those for microbial growth. The phenomenon may represent an important safety factor in the distribution of dehydrated and intermediate moisture foods.

b) The effect of water on chemical reactions in foods are more complicated than are its effect on microbial growth. It plays one or more of the following roles; a) as a solvent for reactant and for products, b) as a reactant (e.g. in hydrolysis reactions) c) as a product of reactions and d) as a modifier of the catalytic or inhibiting activities of other substances (e.g. water in activities some metallic catalysts of lipid per oxidation).

All microorganisms have an optimal and minimal water activity for growth. Adjusting the a_w of a product by addition of solutes or the removal of water, to a point below the minimal a_w of the normal spoilage flora results in a microbiological stable product. Many of the products contain viable microorganisms and spores, which are not able to germinate because of the restrictative a_w. In fabrication of a product with a reduced a_w other factors which would affect the growth of microorganisms present need to be considered, since the a_w on microorganisms is influenced by pH, oxygen level, temperature, nutrient content, and possibly food preservative, either natural or added.

Water activity (a_w) influences the physical, chemical and microbiological properties of many substances. The shelf life of foods, their colour, stability, taste, texture, vitamin content, aroma, mold formation and microbiological growth properties are influenced directly by the a_w value. a_w measurement is required to meet standards like FDA – Food Drug Act, USDA – United State Department of Agriculture, GMP – General Manufacturing Practices, HACCP – Hazard Analysis and Critical Control Points, and BIS 15000 – Bureau of Indian Standards: The foods types and range of a_w is discussed as given below.

A_w range	**Upper limit values for micro-organisms**	**Foods in this range**
1.00-0.95	*Pseudomonas, Escherichia, Proteus, Shigella, Clesiella, Bacillus, Clostridium, perfringens,* some yeast	Perishable (fresh) food and fruit in tins, vegetables, meat, fish and milk, cooked sausage, backed bread, food with a content up to 40% weight sucrose or 7% common salt.
0.95-0.91	*Salmonella, Vibrio parahaemoliticus, C. botulinum, Serratia*, *Lactobacillus, Pediococcus,* some mold, yeast	Some cheese (cheddar, Swiss, Muenster, and Provolone) smoked meat (ham) some fruit juice concentrates, food with a 55% weight sucrose (saturated) or 12% common salt.
0.91-0.87	Many types of yeast *(Candida, Torulopsis, Hansenula), Micrococcus*	Matured sausages (salami), cake, dry chesses, margarine, and food with a 65% weight sucrose (saturated) or 15% common salt.
0.87-0.80	Most types of mold (mycotoxic *Penicillium), Staphylococcus aureus,* most *Saccharomyces* (bialii) spp. ,	Most fruit juice concentrates, sweetened milk, chocolate syrup, maple and fruit syrup, flour, rice, pulses with a water content 15-17%, fruitcakes traditional smoked hams.

	Deboryamyces	
0.80-0.75	Most types hallophilic bacteria, mycotoxic aspergilli	Marmalade, jam, fruit jelly, marzipan, glace fruit, some types of marshmallow.
0.75-0.65	Xerophylic mold *(Aspergillus chevalier, A. candidus, Wallemia semi), Saccharomyces bisporus*	Rolled oats with a 10% water content, naught, fondant, marshmallows, grouts, molasses, raw sugar, some dried fruit, and nuts.
0.65-0.60	Osmophyilc yeast *(Saccharomyces rouxi)*, some mould *(Aspergillus echinulatus, Monascus bisporus)*	Dried fruit with 15-20% water content, some types of toffee, caramel, honey
0.5	No microbial growth	Noodles, Spaghetti, pasta. etc. with about 12% water content, spices with about 10% water content
0.4		Egg powder with about 5% water content
0.3		Biscuits, crackers, bread crust, cookies, etc. with about 3-5% water content
0.2		Powder milk with about 2-3% water content, dried vegetables/ fruit with about 5% water content, cornflakes with about 5% water content fruit cake, rustic, crackers, biscuits

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. Name some of products which have the a_w between 0.65-0.60.

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2. Name the microorganisms, which are found at a_w between 0. 65-0.60.

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5.6 MICROORGANISMS ASSOCIATED WITH DRIED FRUITS AND VEGETABLES

Microorganisms are associated, in a variety of ways, with all of the food we eat. They may influence the quality, availability, and quantity of our food. Naturally occurring foods such as fruits and vegetables normally contain some microorganisms, and may be contaminated with additional organisms during handling. Food serves as a medium for the growth of microorganisms, and this growth may cause the food to undergo decomposition and spoilage. Food may also carry pathogenic microorganisms and as a result transmit diseases. Dried foods have been used for centuries and they are more common throughout the world than frozen foods. Reducing the moisture content of their environment below a critical level can prevent growth of all microorganisms. The critical level of moisture is determined by the characteristics of the particular organisms and the capacity of the food item to bind water so that it is not available as free moisture.

Check Your Progress Exercise 4

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

1. In what way microorganisms affect the products.

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2. How the growth of microorganisms can be arrested.

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5.7 MICROBIOLOGY OF FRUITS AND VEGETABLE

5.7.1 Microbiology of Fresh Fruits and Vegetables

Fruits and vegetables are normally susceptible to infection by bacteria, fungi and viruses. Microbial invasion of plant tissue can occur during various stages

of fruits and vegetables development and hence to the extent that the tissues are infected the likelihood of spoilage is increased. A second factor contributing to the microbial contamination of fruits and vegetables pertains to their post harvest handling. Mechanical handling is likely to produce breaks in the tissue, which facilitates invasion by microorganisms. The pH of fruits is relatively acid ranging from 2-3 for lemons to 5.0 for bananas. This resists bacterial growth but does not retard fungal growth. The range for vegetables is slightly higher pH 5.0 to 7.0 and hence they are more susceptible than fruits to attack by bacteria.

5.7.2 Microbiology of Dried Fruits and Vegetables

The microorganisms on most of the dried fruits vary a few hundred per gram of fruits to thousands, and in whole fruits they are mostly on the outer surfaces. Spores of bacteria and molds are likely to be most numerous. When part of the fruit has supported growth and sporulation of mold before or after drying, mold spores may be present in large numbers. The number on the vegetable just before drying may be high because of contamination and growth after blanching and the percentage killed by the dehydrating process usually is less than with the more acid fruits. If drying trays are improperly loaded, souring of such vegetables as onions or potatoes by lactic acid bacteria with marked increase in number of bacteria, which may take place during the drying process. The risk may be grater of the fruits and vegetables, which are not blanched before drying like onion. Microbial counts on dried vegetables range from negligible to millions per gram. A number of genera of bacteria found on dried vegetables includes: *Escherichia, Enterobactor, Bacillus, Clostridium, Micrococcus, Pseudomonas, Streptococcus, Lactobacillus* and *Leuconostoc*. Of these, *Lactobacillus* and *Leuconostoc* species are predominant in many samples of dehydrated vegetables.

Dried fruits become musty of molds and dried vegetables soft or slimy if kept in a damp atmosphere in unsealed containers. Hence, proper sealing and storing of containers at ambient temperature and in a dry place is important. Dried fruits and vegetables should be packed in moisture proof containers. Higher density polythene (HDP) package of multiple aluminium foil are utilized for packing of dried vegetables.

The bacteria, such as *Bacillus* sp., *Clostridium* sp., *Micrococcus* sp, *Streptococcus* sp., and *Pseudomonas* sp. are common as soil and water borne. Bacteria capable of causing food poisoning such as *Salmonella* sp. and *Clostridium botulinum*, are not found in dehydrated foods as in case of dehydrated onion where the microbial load is influenced by the following factors:

1. The load and types of microorganism present on the raw material.
2. Pre-treatment given to the material
3. Time lag between preparation and dehydration
4. Drying time and temperature
5. Moisture content of the finished product
6. In plant sanitation,
7. Packaging and storage conditions of the finished product.

One of the important types of microbiological spoilage in onion during dehydration is fermentation and souring, which are undesirable and make the product sub-standard. Sour onions have characteristics sour taste commonly

associated with vegetable tissues undergoing lactic acid fermentation. Onion slices do not dry properly. Pink discolouration and off taste are indications of spoilage. Bacteria, which predominate in fresh onions, include representatives of the genera: *Lactobacillus* and *Aerobactor*. Fresh onions juice sterilized by filtration suppressed the growth of *Bacillus subtilis* and *E. coli*. but did not prevent the growth of *Lactobacillus brevis* and *Aerobactor aerogens*. In good quality of dehydrated onion many aerobic bacilli and other soil and water borne bacteria are not found which may be due to the toxicity of constituents present in fresh onions.

To check the souring and fermentation as well as to reduce the microbial load to the minimum the following points should be closely watched:

1. Onion bulbs selected for dehydration should be free from disease and blemish
2. Onions should be thoroughly washed after peeling in 3-5 ppm chlorine water.
3. The cut slices should be dried immediately under controlled conditions so that the finish product can be obtained in the minimum time having moisture at 6-7 percent.
4. Sanitary conditions and workers hygiene in the factory should be controlled and
5. Proper packing room facilities and nitrogen gas packaging are important for the storage of finished product

The number of microorganisms and their kinds vary at different stages of processing such as

5.7.3 Before Reception at the Processing Plant

The microbiology of foods before their reception at the processing plant is likely to be similar whether the foods are to be dried, chilled, frozen, canned or otherwise processed. Fruits and vegetables have soil and water organisms on them when harvested, plus their own natural surface flora and spoiled parts contain the microorganisms causing the spoilage. Growth of some of these organisms may take place before the foods reach the processing plant if environmental conditions permit. Thus piled vegetables may raise temperature and stimulate the growth of slime- forming, flavour harming, or even rot-producing organisms.

5.7.4 In the Plant before Drying

Growth of microorganisms that begun on foods before they have reached the drying unit may continue up to time of drying. Also equipment and workers may contaminate the food. Some of the pre-treatment reduce number of organisms while other may increase them, but the foods may be contaminated after these treatments. The grading, selection, and sorting of fruits and vegetables, influences kinds and number of microorganisms. The elimination of spoiled fruits and vegetables or of spoiled parts reduced number of organisms in the product to be dried.

Washing of fruits and vegetables removes soil and other adhering materials and serves to remove microorganisms. There also possibility of adding organisms if the water is of poor quality.

Peeling fruits or vegetables, especially with steam and slicing or cutting reduces the number of organisms if equipment is adequately cleaned and sterilized.

Dipping in dilute alkali as applied to certain fruits before sun drying may reduce the microbial population.

Blanching or scalding vegetables reduces the bacterial numbers greatly, as much as 99 percent in some instances. Sulphuring of fruits and vegetables also causes a great reduction in number of microorganisms and serves to inhibit growth in the dried product.

5.7.5 During the Drying Process

Heat applied during a drying process causes a reduction in total number of microorganisms, but the effectiveness varies with the kinds and numbers of organisms originally present and the drying process employed. Usually all yeasts and most bacteria are destroyed, but spores of bacteria and molds commonly survives, as do vegetative cells of a few species of heat resistant bacteria, improper conditions during drying may even permit the growth of microorganisms. More microorganisms are killed by freezing than by dehydration during the freezing- drying process.

5.7.6 After Drying

If the drying process and storage conditions are adequate there will be no growth of microorganisms in the dried foods. During storage there is a slow decrease in number of organisms, the microorganisms that are resistant to drying will survive best: therefore the percentages of such organisms will increase. Especially resistant to storage under dry conditions are the spores of bacteria and molds, some of the micrococci, and micro bacteria. There may be some opportunity for contamination of the dried food during packaging and other handling subsequent to drying.

Special treatment given to some dry foods will influence microbial numbers e.g. sweating of dry fruits to equalize moisture may permit some microbial growth. Pasteurization of dry fruits will reduce number of microorganisms. Some products are re-packaged for retail sales hence subjected to contamination. The microbial content and the temperature of water used to rehydrate for dried foods also affect the number of microorganisms if rehydration done in water at 50°C the number of microorganisms will be more and number of microorganisms is almost eliminated when the product is rehydrated at 85 to 100°C.

Check Your Progress Exercise 5

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

1. Write the name of microorganisms, which spoil attack to the fruits and vegetables.

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2. What are the factors that affect the microbial load in the finished products?

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3. Write few points that help to check the incidence of souring, fermentation, and microbial load.

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4. What are the factors, which reduce the microorganisms in fresh fruits and vegetables?

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5. Write few treatments which given to dehydrated fruits for control of microorganisms.

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5.8 SURVIVAL OF MICROORGANISMS IN DRIED FOODS

The survival of microorganisms in dried foods can be markedly affected by a_w level. There are important interaction between a_w and such factors as pH, oxygen and food composition. For many foods, deterioration during storage in the dry state is least at the relatively low a_w levels. Survival of pure cultures of vegetative bacteria equilibrated to a range of a_w levels after freeze drying have shown clearly the increase in survival that accompanies reduction in a_w level to 0.1 -0.2. Survival of *Salmonella newport* at 0.0 a_w, after freeze –drying in papain digest, was nearly maximum in vacuum, but was very poor when stored in air. Although *Pseudomonas fluorescense* proved more susceptible to death on storage, the qualitative response to a_w was similar. Death of bacteria during storage at reduced a_w levels is greatly influenced by the nature of solution from which they had been dried.

5.8.1 Survival at Freezing Temperatures

Freezing and frozen storage may reduce greatly the viability of populations of sensitive microorganisms. The latter include the vegetative cells of yeasts and molds and most gram-negative bacteria. Gram-positive bacteria, especially cocci, are more resistant, and for these reasons enterococci are frequently claimed to be more suitable than *Escherichia coli* as indicators of fecal contamination in frozen foods. Many fungal spores also show this level of resistance, however bacterial spores are least affected by freezing.

The rate of freezing influences the survival, because of it influences the size of ice crystals and hence the degree of mechanical damage caused to cellular structures. Rapid freezing is less damaging than slow freezing. It is the range of temperature between freezing point of a food and its eutectic, influences the a_w of food, but not its overall solute concentration. The eutectic means that the solute remain in equilibrium in frozen food. A frozen food held at -20^oC has an a_w of 0.823, irrespective of its composition. Although composition of food does not control a_w, it can have a marked influence on survival of microorganisms frozen in food. Sugars, sugar alcohol, glycols, and proteins, may have protective effect. The added sucrose has effect on the survival of *Torula* sp. in frozen orange juice.

5.8.2 Survival at Moderate Temperatures

Many sterile foods are microbiologically stable in the moderate or room temperature range. The majority of dried or concentrated foods owe their stability to reduced level of a_w. However, if rehydrated before consumption, regain the ability to support microbial growth, so that the capacity of contaminating organisms to survive the period of low a_w storage is of obvious relevance. Studies on survival of pure cultures of vegetative bacteria equilibrated to range of a_w levels after freeze drying have shown clearly the increase in survival that accompanies reduction in a_w level to 0.1-0.2. In dried foods the bacteria during storage at reduced a_w levels is greatly influenced by the nature of solution from which they had been dried. While non-reducing sugars are protective, and reducing sugars accelerate bacterial inactivation.

5.8.3 Survival at Elevated Temperatures

Microorganisms vary in heat resistance, the more resistant bacteria (e.g. *Bacillus stearothermophillus*) producing spores with decimal reduction times in neutral foods as long as 4 minutes at 121°C. or 40 minutes at 110°C. Yeast ascospores are only slightly more heat resistant than vegetative yeast cells. The qualitative effect of moisture upon microbial heat resistance is well known-moist heat is a much more effective sterilizing agent than dry heat and, wherever, practicable, steam sterilization is preferred as being much more rapid than hot air (dry) sterilization. Water activity is also likely to be significance in the heat treatment of foods in the intermediate moisture range, Pasteurization temperature for salmonellae, staphylococci, and yeast (50-60°C) death rates are lowest in the a_w range 0.75- 0.85 in glycerol adjusted solutions. Osmophilic yeasts respond similarly to salmonellae when heated in sucrose solution with decimal reduction times increasing as a_w decreases from 0.995 to 0.85. These organisms are more heat sensitive than salmonellae.

5.9 MICROBIAL SPOILAGE OF DRIED FOODS

Spoilage of dried fruits and vegetables by insects

All organisms require water for carrying on their life processes. If the microorganisms cannot acquire the water it either dies or its further growth is arrested. Potential spoilage of a dried fruit, then depends upon how available water is to the spoilage microorganisms, it is therefore the thin demarcation line of water activity, which establishes dehydration as a good preservative techniques.

Removing the water from the fruit and vegetables is to reduce its availability to the microorganisms. In a moist solid substance, the water vapour pressure is lower than the vapour pressure of free water at the same temperature because, in a solid substance, water reacts with polar group such as –CO -, - NH, -OH. Still further vapour pressure inside of capillaries (between plant cells) is lower than the vapour pressure of a plane surface of water. As the solutes present in the fruit are dissolved in water the vapour pressure is depressed. Certain osmophilic yeasts and certain xerophilic molds and fungi are able to live and proliferate at water activities of low values. These are the microorganisms responsible for the spoilage of dried fruit and vegetables. Bacterial growth of generally impossible when a_w is reduced below 0.90. The growth of normal yeast is generally impossible when the a_w is reduced below 0.88. The growth of normal molds is generally impossible below 0.80. Each organism has its own characteristics optimum a_w at which growth will occur. Molds are the most troublesome group of microorganisms will grow at a_w values below 0.70.

Dried fruits and vegetables are also subjected to insect attack when not dried and stored properly. Insect not only consumes foodstuffs but also leave much debris that spoils the appearance of the product. These insects can be killed either by heating or by fumigation. In heat treatment, dried fruits are dipped in boiling water or in dilute solution of salt (NaCl –$NaHCO_3$) and then, redried at 54-65^oC. Dried vegetables may be heated directly without preliminary dipping. Fumigation with ethylene oxide inside the storage chamber also reduces attack by insects.

Dried fruits become musty or moldy and dried vegetables soft or slimy if kept in a damp atmosphere in unsealed containers. Hence, proper sealing and storing of containers at ambient temperature and in a dry place is important.

Dehydrated fruits and vegetable potential defects and means to prevent them are given below:

Defects	**Causes**	**Prevention**
Molding	High product moisture, above equilibrium relative humidity corresponding to water activity $a_w = 0.70$.	Reduce water content down to optimum values; pack in hermitic airtight package.
Infestation	Presence in dried products of larva or insects.	Storage room disinfection with toxic gases. Fumigation of packed products and of packages. Disinfection by heat (60-65^oC) of products before packing.

Considering the variety of natural food substances and the methods by which each is handled during processing, it is apparent that practically all kinds of microorganisms are potential contaminants. The type of food substance and the method by which it processed and preserved may favour contamination by certain groups of microorganisms. Most foodstuffs serve as good media for the growth of many different microorganisms, and microorganisms' changes in appearance, flavour odour, and other qualities of foods. These degradation processes may be descried as follow;

Putrefaction

Protein foods + proteolytic microorganisms → amino acids + amines = ammonia + hydrogen sulphide.

Fermentation

Carbohydrate foods + carbohydrate-fermenting microorganisms → acids = alcohol = gases.

Rancidity

Fatty foods + lipolytic microorganisms→ fatty acids = glycerol.

Some microorganisms discolour foods as a result of pigment production. Microorganisms capable of synthesizing certain polysaccharides may develop in or on foods slimes.

Check Your Progress Exercise 6

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

1. At low moisture content how the growth of microorganisms is check.

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2. List the microorganisms, which are responsible to spoil the dried fruits and vegetables.

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3. Write the level of a_w at which the growth of bacterial, yeast and mould is impossible.

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4. What are the changes occur in the food products when they are attack by microorganisms.

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5.10 LET US SUM UP

The reduction in weight and bulk by drying and dehydration of the commodity can result in economies in cost of containers, shipping and distribution of dehydrated products. The dehydration also result in the production of convenience products e.g. instant coffee, instant milk and instant mashed potatoes. The production of dried fruits and vegetable products are less costly as there is a minimum of labour and processing equipment required. These products also require less space for storage then fresh canned or frozen fruits and vegetables.

Microorganisms are associated, in a variety of ways, with all of the food we eat. They may influence the quality, and availability of our food. Naturally occurring foods such as fruits and vegetables normally contain some microorganisms, and may be contaminated with additional organisms during handling. Food serves as a medium for the growth of microorganisms, and this growth may cause the food to undergo decomposition and spoilage. The microorganisms on most of the dried fruits vary a few hundred per gram of fruits to thousands, and in whole fruits they are mostly on the outer surfaces. Spores of bacteria and molds are likely to be most numerous. When part of the fruit has supported growth and sporulation of mold before or after drying, mold spores may be present in large numbers. Microbial counts on dried vegetables range from negligible to millions per gram. A number of bacteria found on dried vegetables includes: *Escherichia, Enterobactor, bacillus, Clostridium, Micrococcus, Pseudomonas, Streptococcus, Lactobacillus* and *Leuconostoc*. Of these, *Lactobacillus* and *Leuconostoc* species are predominant in many samples of dehydrated vegetables.

Water activity (a_w) influences the physical, chemical and microbiological properties of many foods. The shelf life of foods, their colour, stability, taste, texture, vitamin content, aroma, and microbiological growth properties are influenced directly by the a_w value. The survival of microorganisms in dried foods can be markedly affected by a_w level, there are important interaction between a_w and such factors as pH, oxygen and food composition. Certain osmophilic yeasts and certain xerophilic molds and fungi are able to live and proliferate at water activities of low values. These microorganisms are responsible when water activity (a_w) is reduced below 0.88, and the growth of normal yeast is generally impossible below the water activity (a_w) of 0.88.

5.11 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 $aw = p/p_o$.

Dehydration : Removal of moisture under controlled conditions of temperature, air flow and humidity.

Drying : Drying of the product under the source of non-conventional energy sources like sun and wind.

Blanching : Partial pre-treatment in which vegetables are heated in water or in steam to inactivate enzyme before processing.

Sulphuring : Exposing the fruits to the fumes of burning sulphur inside of closed chamber.

In-package desiccant : Packaging of the dried products with a material like calcium oxide or silica gel.

Sorption isotherms : Water sorption isotherms is a graphical presentation of data which shows the water relationship of food.

Preservation : Methods to hold food for a longer period than generally kept at ambient conditions. Food is safe, nutritive and free from and microbial infection.

ERH : Equilibrium Relative Humidity.

Osmotic dehydration : Removal of water through a membrane from higher concentration to lower concentration.

Sweating : Process for holding the dried fruits and vegetables in to bins or package for equalization of moisture

Pasteurization : Pasteurization of fruits and vegetable products by heat process below 100°C.

Rancidity : Discolouration of food products.

Processing : The application of heat to the fruit and vegetables after hermetic (air tight) sealing in containers is called the processing.

Spoilage : The food which has been damaged or injured which make the food undesirable for human use.

Rehydration ratio : Reconstitution ratio is the quantity of water replaced by dehydrated foods.

Reverse osmosis : Reverse osmosis means movement of water through the membrane by applying pressure on the solute side of the membrane in excesses of the osmotic pressure.

5.12 ANSWERS TO CHECK YOUR PROGRESS EXERCISES

Check Your Progress Exercise 1

1. Your answer should include the following points:

   - Drying of commodity in the sun with non-conventional sources of energy like sun and wind is called drying.
   - Drying the commodity under controlled conditions like temperature, relative humidity and airflow is called dehydration.

2. Your answer should include the following points:

    - To reduce the weight and bulk.
    - To reduce the water activity.

3. Your answer should include the following points:

    - To convey the heat to the product.
    - To let out the moisture from the product.

4. Your answer should include the following points:

    - They exhibit an energetic retention of moisture.
    - They bound the moisture to the solid content.

Check Your Progress Exercise 2

1. Your answer should include the following points:

    - Due to heat transfer to the product.
    - Due to mass transfer out the product.

2. Your answer should include the following points:

    - Heat transfer through conduction.
    - Heat transfer through convection.
    - Heat transfer through radiation.

3. Your answer should include the following points:

    - By addition of thermal energy to the product.
    - By transfer the heat to the product and water surface.

4. Your answer should include the following points:

    - Transfer of vapour from product surface to the air.
    - Transfer of heat from the air to the product.

Check Your Progress Exercise 3

1. Your answer should include the following points:

    - Dried fruits
    - Some types of toffee
    - Honey

2. Your answer should include the following points:

    - Osmophilic yeast
    - *Aspergillus echinulatus*
    - *Monascus bisporus*

Check Your Progress Exercise 4

1. Your answer should include the following points:

    - In the form of quality
    - In the form of availability
    - In the form of quantity

2. Your answer should include the following points:

    - By reduce the moisture content of the product.
    - By reduce the moisture content of their environment below critical level.

Check Your Progress Exercise 5

1. Your answer should include the following points:

    - Some of bacteria
    - Some of fungi
    - Some of viruses

2. Your answer should include the following points:

    - Load and types of microorganisms in raw material.
    - Time lag between preparation and drying.
    - Moisture content in the finished product.

3. Your answer should include the following points:

    - Bulbs should be free from diseases and blemish
    - Dried the cut slices immediately under control condition
    - Pack and stored under proper conditions

4. Your answer should include the following points:

    - Grading
    - Selection
    - Sorting

5. Your answer should include the following points:

    - Sweating
    - Pasteurization

Check Your Progress Exercise 6

1. Your answer should include the following points:

    - By arrest the growth of the microorganisms.
    - By destroys the microorganisms.

2 Your answer should include the following points:

- Osmophilic yeast
- Xerophilic molds
- Fungi

3. Your answer should include the following points:

- For bacterial growth a_w below, 0.90
- For yeast the a_w below, 0.88
- For mold growth the a_w below, 0.80

4. Your answer should include the following points:

- Changes in appearance
- Changes in flavour
- Changes in odour
- Changes in quality

5.13 SOME USEFUL REFERENCES

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