UNIT 15 INTRODUCTION TO FOOD PRESERVATION AND PROCESSING

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15.0 OBJECTIVES

After reading this Unit, we shall be able to:

- describe the basic principles and techniques of food preservation;
- apply various food preservation & processing techniques;
- comprehend the comparative advantages and efficiency of these techniques; and
- discuss the emerging trends in food processing and preservation.

15.1 INTRODUCTION

The history of food preservation is presumably as old as the evolution of the mankind, the *Homo sapiens* itself. There is evidence in recorded history dating back to 3000 years B.C. about converting the harvest surplus of grape into wine and preserving milk by making yoghurt, cottage cheese, butter and ghee. Preservation by sun-drying of fruits, vegetables, meats, etc; is older than recorded history and was prevalent even before the discovery of fire by man. The Indian sub-continent figures prominently in the evolution of food processing and preservation.

Food preservation is the process of treating and handling food in such a way as to stop or greatly slow down its spoilage and to prevent food borne illness while maintaining the food item's nutritional value, texture and flavor.

Food processing is the set of methods and techniques used to transform raw ingredients into food for consumption by humans or animals. The *food processing industry* utilises these processes. Food processing often takes clean, harvested or slaughtered and components convert into attractive and marketable food products. Various techniques are used for this purpose:

1. **Addition of heat (or Thermal processing):** Application of heat helps preserve food by inactivating the enzymes, destroying the microorganisms of both spoilage and public health concern. If it is appropriately packaged to prevent recontamination, the food can be stored for extended periods of time. Pasteurization processes only deal with mild heat, aiming at providing short-term extension of shelf life, in combination with refrigeration, whereas the commercial sterilization process (canning) produces shelf-stable products. The heat treatment achieved during the cooking of foods also helps to render the food more safe and palatable.

2. **Removal of heat (or cooling or refrigeration):** Since most of the biological, biochemical, physiological, and microbial activities increase or decrease with temperature, control at temperature (refrigeration) remains the most widely used method today to keep food fresh. Because the spoilage activities are not completely stopped, refrigeration only provides temporary shelf-life extension. On the other hand, freezing terminates most of these microbiological and physiological activities (except chemical and some enzymatic changes). The freezing process can provide a long storage life, especially when the product is frozen and stored at temperatures below-18^{o}C.

3. **Removal of moisture (or drying or dehydration):** All life-sustaining activities require the use of water, available as free moisture in foods. By removing or reducing the moisture content, the food can be rendered stable, because most of the spoilage activities are stopped or retarded. This is the principle used in such processing applications as drying, concentration, and evaporation.

4. **Controlling water activity:** It is not just the presence of moisture in foods that renders them unstable. It is the availability of moisture for their activities. Water activity is a measure of the available moisture. A water activity level of 0.75 is considered the minimum required for most activities. Water can be bound to salts, sugars, or other larger molecules, which makes it unavailable. Such conditions can exist in dried products, intermediate moisture foods, concentrates, etc.

5. **Addition of preservatives, (sugar, salt, acid):** These have specific roles in different products. Preservatives can selectively control the activities of

microorganisms and enzymes. Sugar and salt can control the water activity. Some acids (for example, acetic acid- vinegar) have antimicrobial properties. Products such as jams, jellies, preserves, pickles, bottled beverages, etc., make use of such concepts.

6. **Other techniques:** Other techniques, such as irradiation, exposure to ultraviolet light, high-intensity pulsed light, pulsed electric field, high pressure, etc., have different mechanisms for controlling the spoilage activity in foods and have been used for shelf-life extension.

   There are **secondary objectives** of food processing as well. They include diversification of products to provide variety, taste, nutrition, etc., to provide end-use convenience, facilitate marketing, prepare food ingredients through isolation or synthesis, and to produce non conventional foods.

15.2 METHODS OF FOOD PRESERVATION

15.2.1 Thermal Processing

Thermal processing implies the controlled use of heat to increase, or reduce depending on circumstances, the rates of reactions (which could be microbiological and/or enzymatic and/or chemical in nature) in foods.

(i) Effect of thermal processing on microbiological activity

Thermal processes are primarily designed to eliminate or reduce the number of microorganisms of public health significance to an acceptable level (commercial sterility) and provide conditions that limit the growth of pathogenic and spoilage microorganisms. Whereas pasteurization treatments rely on storage of processed foods under refrigerated conditions for a specified maximum period, sterilization processes are intended to produce shelf-stable products having a long storage life. Destruction of *C. botulinum* is the main criterion, from a public health point of view, in the sterilization of low acid foods (pH>4.5), whereas other spoilage type microorganisms are employed for acid foods.

(ii) Effect of thermal processing enzyme activity

Several enzymes (peroxidase, lipoxygenase, pectinesterase), if not inactivated, can cause undesirable quality changes in foods during storage, even under refrigerated conditions. For thermal processing of acid foods and pasteurization of dairy products, inactivation of heat-resistant enzymes (pectinesterase, phosphatase, peroxidase) is often used as basis. In conventional thermal processes, most enzymes are inactivated either because the processes are so designed using them as indicators, or their heat resistance is lower than other indicator microorganisms. Some of these oxidative enzymes have been reported to have a very low temperature sensitivity as compared with the microorganisms.

(iii) Effect of thermal processing on food quality

The application of food processing techniques that extend the availability of perishable foods also limits the availability of some of the essential nutrients. Maximizing nutrient retention during thermal processing has been a considerable challenge for the food industry in recent years. The major concern from a food processing point of view is the inevitable loss of heat-labile nutritional elements that are destroyed, to some degree by heat. The extent of these losses depends on the nature of the thermal process (blanching, pasteurization, sterilization). The major emphasis in food processing operations is to reduce these inevitable losses through the adoption of the proper time temperature processing conditions, as well as appropriate environmental factors (concentration, pH, etc.) in relation to the specific food product and its target essential nutrient.

15.2.2 Thermal Processes

(i) Blanching

Blanching perhaps represents the least severe heat of the above processes; however, nutrient loss during blanching can occur due to reasons other than heat, such as leaching. Steam and hot water blanching are the two most commonly used blanching techniques. These conventional processes are simple and inexpensive but are also energy intensive, resulting in considerable leaching of soluble components (which occur both during heating and cooling), and produce large quantities of effluent. With steam blanching, it is possible to significantly reduce the effluent volume, as well as leaching losses. The individual quick blanching (IQB) technique is an innovation based on a two-stage heat-hold principle and has been shown to significantly improve nutrient retention. The vegetables are heated in single layers to a temperature high enough to inactivate the enzymes, and in the second stage they are held in a deep bed long enough to cause enzyme inactivation.

Depending on the method of blanching, commodity and nutrient concerned, the loss due to blanching can be up to 40% for minerals and vitamins (especially vitamin C and thiamin), 35% for sugars, and 20% for proteins and amino acids. Blanching can result in some undesirable color changes resulting from the thermal degradation of blue/green chlorophyll pigments to yellow/ green pheophytins. Chlorophylls are sensitive to pH and presence of metal ions. Alkaline pH and chelating agents favour better retention of the green color. Whereas texture degradation is characteristic of most heat treatments, low-temperature blanching has been shown to improve the texture of some products (carrots, beans, potatoes, tomatoes, cauliflower) due to activation of the pectin methyl esterase enzyme.

(ii) Pasteurization

Pasteurization is a heat treatment applied to foods, which is less drastic than sterilization, but which is sufficient to inactivate particular disease-producing organisms of importance in a specific foodstuff. Pasteurization inactivates most viable vegetative forms of microorganisms but not heat-resistant spores. Originally, pasteurization was evolved to inactivate bovine tuberculosis in milk. Numbers of viable organisms are reduced by ratios of the order of 10^{15}:1. As well as the application to inactivate bacteria, pasteurization may be considered in relation to enzymes present in the food, which can be inactivated by heat. The same general relationships as were discussed under sterilization apply to pasteurization. A combination of temperature and time must be used that is sufficient to inactivate the particular species of bacteria or enzyme under consideration. Fortunately, most of the pathogenic organisms, which can be transmitted from food to the person who eats it, are not very resistant to heat.

The most common application is **pasteurization of liquid milk.**

We have learnt that the nutritional and sensory characteristics of most foods are only slightly affected by the pasteurization process because of its mild heat treatment. However, because it is only a temporary method of shelf-life extension, the product quality continues to change (deteriorate) during storage.

The shelf life depends on the post –pasteurization packaging conditions and storage environment. The most important nonacid liquid food is milk, which has received much attention as a result. Fat-soluble vitamins A,D,E and K are relatively insensitive to heat, and generally there are no losses of these vitamins when milk is pasteurized. The extent of loss in thiamin, vitamin B_6, vitamin B_{12}, and folic acid due to pasteurization is less than 10%. Vitamin C can be lost up to 25%. In milk, pasteurization has no pronounced effect on colour. Colour differences between raw and pasteurized milks are attributed mainly to the homogenization. Small losses of volatile aroma compounds occur during the mild heat treatment of pasteurization. Colour changes in fruits and vegetable are mainly caused by enzyme activity (polyphenoloxidase) and the presence of oxygen. Deaeration prior to pasteurization excludes oxygen, and the heat treatment inactivates the enzyme to minimize colour deterioration of fruits and vegetables.

(iii) Sterilization

As discussed earlier, sterilization processes are more severe with respect to the heat treatment given generally to achieve commercial sterility. Obviously, these products will be subjected to a nutrient loss. The following nutrients are more sensitive to destruction by heat: vitamins A, B_1, B_6, B_{12}, C, D, E, folic acid, inositol, and pantothenic acid, and amino acids such as lysine and threonine. Because of the possibility of using numerous (infinite) time-temperature combinations for achieving thermal sterilization, the influence of the process cannot be easily quantified. The severity of the heat treatment is determined by the pH of the food (low-acid foods require more severe heat treatment to ensure the destruction of C.*botulinum*); the composition of the food (protein, fats, and high concentrations of sucrose increase the heat resistance of microorganisms); the heating behavior of the food (conduction, convection); the nature, size, and shape of the container; as well as the nature and mode of application of the heating medium. Agitation during processing offer additional variables to optimize the process.

Studies of the microorganisms that occur in foods, have led to the selection of certain types of bacteria as indicator organisms. These are the most difficult to kill, in their spore forms, of the types of bacteria which are likely to be troublesome in foods.

15.2.3 Thermal Death Time

It has been found that microorganisms, including *C. botulinum*, are destroyed by heat at rates which depend on the temperature, higher temperatures killing spores more quickly. At any given temperature, the spores are killed at different time durations, some spores being apparently more resistant to heat than other spores. If a graph is drawn, the number of surviving spores against time of holding at any chosen temperature, it is found experimentally that the number of surviving spores fall asymptotically to zero.

An enzyme present in milk, phosphatase, is destroyed under somewhat the same time-temperature conditions as the *M. tuberculosis* and, since chemical tests for the enzyme can be carried out simply, its presence is used as an indicator of inadequate heat treatment. In this case, the presence or absence of phosphatase is of no significance so far as the storage properties or suitability for human consumption are concerned.

The processes for sterilization and pasteurization illustrate very well the application of heat transfer as a unit operation in food processing. The temperatures and times required are determined and then the heat transfer equipment is designed using the equations developed for heat-transfer operations.

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, in your opinion, is the role of food technology in the modern society?

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2) What are the four basic methods of processing foods ?

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3) What is pasteurization? Who invented it?

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4) What is the difference between pasteurization, UHT treatment and sterilization?

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15.2.4 Food Drying/ Dehydration

Drying or dehydration is one of the oldest methods of preserving food. Primitive societies practised the drying of meat and fish in the sun long before recorded history. Today the drying of foods is still important as a method of preservation. Dried foods can be stored for long periods without deterioration occurring. The principal reasons for this are that the microorganisms which cause food spoilage and decay are unable to grow and multiply in the absence of sufficient water and many of the enzymes which promote undesired changes in the chemical composition of the food cannot function without water.

The low water content attained by drying extends the shelf life of dried foods without the need for refrigerated storage or transportation. As well, available surplus can be converted to stable forms. For example, liquid milk is highly perishable, whereas milk powder is more stable and easy to preserve and handle. Other examples of dehydrated products in this category include egg and juice powders. Usually, a significant reduction in weight and bulk volume occurs during drying, which can lead to savings in the cost of transportation and storage. The rapid reconstitution characteristics and relatively good organoleptic qualities of many modern dehydrated products make them acceptable as convenience foods. A quick look around a modern supermarket will reveal a wide range of dried foods. Examples of such foods include instant coffee, tea, milk, chocolate, instant drinks, soup mixes and instant meals containing dried vegetables, breakfast cereals, and cereal products such as rice, baby foods containing dried cereals, pasta, dried vegetables (such as potato flakes or granules), peas, beans, carrots, dried meat and fish ingredients, dried fruits for use as snacks or in desserts or baked products, and many more for use in home cooking. To provide such a comprehensive range of products, it is obvious that food dehydration constitutes a large and very significant part of manufacturing or food processing activities worldwide.

Drying processes fall into three categories:

- Air and contact drying under atmospheric pressure. In air and contact drying, heat is transferred through the foodstuff either from heated air or from heated surfaces. The water vapour is removed with the air.
- Vacuum drying. In vacuum drying, advantage is taken of the fact that evaporation of water occurs more readily at lower pressures than at higher ones. Heat transfer in vacuum drying is generally by conduction, sometimes by radiation.
- Freeze drying. In freeze drying, the water vapour is sublimed off frozen food. The food structure is better maintained under these conditions. Suitable temperatures and pressures must be established in the dryer to ensure that sublimation occurs.

(i) Heat requirements for vaporization

The energy, which must be supplied to vaporize the water at any temperature, depends upon this temperature. The quantity of energy required per kg of water is called the **latent heat of vaporization**, if it is from a liquid, or **latent heat of sublimation** if it is from a solid. The heat energy required to vaporize water under any given set of conditions can be calculated from the latent heats given in the steam table, which is available in any standard thermal processing text book, as steam and water vapour are the same thing.

(ii) Heat transfer in drying

We have been discussing the heat energy requirements for the drying process. The rates of drying are generally determined by the rates at which heat energy can be transferred to the water or to the ice in order to provide the latent heats, though under some circumstances the rate of mass transfer (removal of the water) can be limiting. All three of the mechanisms by which heat is transferred - conduction, radiation and convection - may enter into drying. The relative importance of the mechanisms varies from one drying process to another and very often one mode of heat transfer predominates to such an extent that it governs the overall process.

In cases where substantial quantities of heat are transferred by radiation, it should be remembered that the surface temperature of the food may be higher than the air temperature. Estimates of surface temperature can be made using the relationships developed for radiant heat transfer although the actual effect of combined radiation and evaporative cooling is complex. Convection coefficients also can be estimated using the standard equations.

For freeze drying, energy must be transferred to the surface at which sublimation occurs. However, it must be supplied at such a rate as not to increase the temperature at the drying surface above the freezing point. In many applications of freeze drying, the heat transfer occurs mainly by conduction.

As drying proceeds, the character of the heat transfer situation changes. Dry material begins to occupy the surface layers and conduction must take place through these dry surface layers which are poor heat conductors so that heat is transferred to the drying region progressively more slowly.

(iii) Drying and water activity

Dehydration accomplishes preservation in two major ways. First, it removes the water necessary for the growth of microorganisms and for the enzymatic activity. Second, by removing the water, it increases the osmotic pressure by concentrating salts, sugars, and acids, creating a chemical environment unfavorable for the growth of many microorganisms. The microbial stability of dehydrated foods results from the interruption of vital processes essential to microbial growth or spore germination. The number and types of microorganisms that can be associated with foods are extremely large. Moreover, they differ, depending on the type of foods. And might not remain constant during the life of a food. These can originate from the raw material or from contaminations (by people, animals, insects, water, air, contact surface, etc.).

The water activity of fresh fruits, vegetables, meats, and milk falls in the range of 0.97 to 0.99. Most dehydrated foods exhibit a maximum water activity below 0.70, which is below the minimum value for food pathogens. Only *Staphylococcus aureus* is capable of growing at a_w of 0.85. Fungi (yeasts and molds) tend to grow more slowly than bacterial unless bacterial growth is limited, but they are also more resistant to harsh environmental conditions and can cause spoilage under these conditions. Some molds can produce mycotoxins that can result in a variety of acute and chronic toxicities for human beings and animals. Examples of foods in which mycotoxins can be present include grains, nuts, figs, cocoa, coffee, etc. The reduction of water activity is not sufficient to destroy all microorganisms. During air drying, the increased temperature of the food could affect the living forms of microorganisms, but spores of species of *Bacillus* or *Clostridium* are relatively unaffected. As well, drying does not necessarily destroy food toxins (from *C. botulinum*, *S. aureus or B. cereus*) occurring as contaminants prior to or during drying. Other microorganisms such as viruses, protozoa, algae, and prions are not known to grow on foods. Therefore, only their pathogenicity or toxigenicity and their resistance to thermal drying are normally considered. These microorganisms are more sensitive than most vegetative bacteria.

Along with water activity, many other factors will influence the microbial growth such as temperature, pH, nutrients, preservatives, other food components, and oxygen content. It is important to remember that for the same food water content, several water activity values are possible. This will influence significantly the shelf life of foods.

A dehydrated product remains stable only when it is protected from the subsequent exposure to the surrounding environment (e.g. water, air, sunlight and contaminants). Hence, appropriate packaging of a dried product is an important consideration.

15.2.5 Cooling and Freezing

The situation during freezing is one of product cooling, while in the case of thawing, it is of product warming. During freezing, there will be an initial drop in the temperature of the product from its initial level (usually at a temperature above its freezing point) until it reaches its initial freezing point. Then, the temperature of the product remains relatively steady as the latent heat is removed. For food products, rather than a constant temperature, it slowly drops until the majority of water is frozen as ice and then drops more rapidly as the ice temperature is lowered further.

On the other hand, in the case of thawing, the material is initially frozen. To a completely frozen product at a temperature far below its freezing point, heat is added so it warms up. As with the freezing process, the temperature of ice along the surface first rises until it reaches the freezing point. Following this time, the latent heat is added, and the ice begins to melt.

Thus, in the freezing process heat is removed from water, and during the thawing process heat is added to ice. Thermal conductivity and thermal diffusivity of ice are much larger than that of water. So, under comparable conditions, which process will last longer – freezing or thawing? Freezing, when the food water is frozen to ice or thawing, when the product ice melts into water? Answer: Freezing? No! It is thawing that takes longer to accomplish. Why? See the explanation below.

Note that, during freezing, after the phase change process has begun, the latent heat of ice needs to be removed from the product. As the heat gets removed, the water layer on the surface first gets frozen, and then the layer next to it and so on. So, as the freezing process proceeds, we have an increasing layer of ice, through which the heat from the inner unfrozen layers are removed. Hence, during the freezing process, the transfer of heat is essentially through an expanding ice layer. During thawing, as the heat is added to the ice, the surface of frozen material melts, forming a layer of water. As more heat is added, more ice melts and hence the water layer expands. Added heat needs to be transferred to the inner ice layers through the enlarging water layer. Hence, the thawing process is driven by the addition of heat through a layer of water that is increasing in size. Thus, in the thawing process, the heat transfer is through and expanding layer of water.

The different methods of freezing are generally grouped as :

1. Air freezing
2. Plate freezing
3. Liquid immersion freezing
4. Cryogenic freezing

(i) Air freezing

Air freezing is one of the most common methods of commercial freezing. The material, packaged or unpackaged, is frozen by exposure to air at temperatures ranging from -18 to -40^{O}C. Slow or “sharp” freezing refers to freezing in a room under very slow air circulations. This should be more closely called “still air freezing,” and the “sharp” appears to be a misnomer. It is not common either. This process is obviously undesirable because the freezing will be very slow and tend to produce large ice crystals that damage the product quality. The slow cooling of the product might also allow some of the undesirable activity of enzymes and microorganisms prior to the completion of freezing, again damaging the product quality. Air blast freezing refers to freezing the product in a powerful blast of circulating cold air at temperatures ranging from -18 to -40^{O}C under forced circulation. Various systems are available including cabinet, tunnel, belt, fluidized bed, etc. The product can be placed on trays or one conveyor. When the latter is employed, it is sometimes referred to as a "tunnel" freezer. In this case, generally, the product is conveyed through an insulated tunnel through which cold air is forced to flow at high velocity. Usually, a counter current flow is employed. The conveyor length is designed such that by appropriately varying the conveyor speed, a variety of products are frozen as they emerge out of the tunnel. Fluidized bed freezing is another form of air blast freezing. Here, particulate foods, such as peas, kernel corn, cut beans, brussels, sprouts, strawberries, cherries, etc., are fluidized by a powerful blast of cold air. Typically, the product is placed on a perforated mesh or belt to a layer of 1-to-10-cm thick. Then the cold air is passed from below, under such pressure and velocity that the product will actually float in the air current. Due to thorough contact with the medium and agitation, the freezing is accomplished at a very fast rate. A similar setup is sometimes used for non fluidizable products like fish fillets. Basically, this is similar to tunnel freezing, except that the cold air is passing from bottom to top rather than the counter current system of the tunnel. This type of freezing is referred to as "through flow" freezing, because the air flows through the product.

(ii) Plate freezing

In this type of freezer, the food, generally in regular-sized packages, is frozen by contact with a metal plate, which is cooled either by circulating cold brine or refrigerant. Generally, double contact plates are employed between which the packaged products are sandwiched under a slight pneumatic pressure, which provides a good contact between the package and the contact surface. Heat transfer occurs from both sides of the package. This has some advantages over the air-freezing technique by way of minimizing moisture loss from the product during freezing.

(iii) Liquid-immersion freezing

As the name indicates, this technique involves immersion of the product, packaged or non packaged, in the cooling medium. The process is relatively fast, because heat transfer from direct contact liquid medium is much more efficient than from air. Aqueous solutions of propylene glycol, glycerol, sodium chloride, calcium chloride, and sugars have been tried (for example, in the freezing of orange juice concentrates).

(iv) Cryogenic freezing

Cryogenic freezing provides for a very rapid freezing by virtue of the very low temperatures of the cooling medium. Liquid nitrogen and liquid or solid carbon dioxide are common cryogenic freezing agents. Liquid nitrogen boils at -196^{O}C, whereas solid CO_2 sublimes at -79^{O}C. The sublimation process, which takes CO_2 from solid to vapour, can absorb about three times the latent heat picked up by liquid N_2 (246 to 86Btu/lb). In this procedure, the product is generally conveyed through the freezing chamber by way of a tunnel. As the product enters, it will meet the emerging vapors of the nitrogen gas at about-30 to -40^{O}C, which pre cools the product. The product is frozen in the freezing chamber at the center of the tunnel, with a brief exposure to a spray of liquid N_2. The conveyor speed determines the contact time. Following this, the product will flow out along with the vapors of N_2, where is gets equilibrated to the desired finishing temperatures. Application with CO_2 involves tumbling of the product with powdered CO_2, which might not be desirable for delicate products.

Liquid CO_2 acts somewhat differently in a freezer than liquid nitrogen. CO_2 is piped to the tunnel as a high-pressure liquid (300 psi), but once is exits the injection orifice, it instantaneously expands into a mixture of gas and tiny dry ice solid particles (15-109^{O}F). The dry ice solid, commonly referred to as dry ice "snow," is driven into the surface of the food product, where the heat from the food product rapidly causes the dry ice to "sublimate," or phase directly from a solid into a gas.

15.2.6 Food Preservation Using Chemicals

Many chemicals are used today in the preservation of foods. They range from very simple substances such as salt and sugar, to complex compounds such as benzoates. The following table lists some of the most common chemical preservatives used today and the foods that they are used in. Keep in mind that all of these chemicals have been deemed GRAS (generally regarded as safe) in the amounts that are specified.

Table 15.1: List of some common chemical preservatives.

Chemical	Amount GRAS	Organism(s) affected	Use in Foods
Sulfites	200 - 300 ppm	Insects & microorganisms	Dried fruits, wine, lemon juice
Dehydroacetic acid	65 ppm	Insects	Strawberries
Sodium nitrite	120 ppm	Clostridia	Cured Meats
Ethyl formate	15 - 220 ppm	Yeasts & molds	Dried fruits and nuts
Propionic acid	0.32%	Molds	Bread, cakes, cheeses
Sorbic acid	0.2%	Molds	Hard cheeses, cakes, salad dressings
Benzoic acid	0.1%	Yeasts & molds	Margarine, relishes, soft drinks, ketchup, salad dressings

The above table 15.1 is only a partial list of chemicals that are used in food preservation. The chemicals listed have complex mechanisms by which they inhibit their target organisms. We will take an in-depth look at two substances that use the same mechanism and which have been used since ancient times: salt and sugar.

(i) Salt and Sugar Preservation

These substances use a mechanism that can be employed by other means: drying. However, the result is the same. As we will discuss later, most microorganisms cannot live in a relatively dry environment. This is what salt and sugar accomplish. When a microbe is in a non-saline environment, available water can pass through the membrane of the microbe easily. In the non-saline environment, water inside and outside of the cell comes into equilibrium because of diffusion. Diffusion is the process by which water moves from areas of low concentration of solutes to areas of high concentration of solutes. (A solute is any substance that can be dissolved in water). This means that the amount of water moving out of the cell is the same as water moving into the cell. This must happen for the organism to survive. However, if we add salt to the water to make a saline environment, this creates an isotonic condition for the cell. It means that there is more water moving out of the cell than moving into the cell. This results in slower growth for the microbe or even death. Because of the drying effect of salt it has been used for thousands of years. It usually takes about 20% salt to inhibit microbes. *However, there are some microbes (as you will see later) that can survive high salt concentrations*. Sugar has the same mechanism as salt, but it takes much more sugar (~6X) than salt to produce the same effect.

(ii) Other preservatives

The chemical preservatives given in the table and sugar and salt have a direct effect on organisms. However, there are other chemicals that have a preservative effect without directly targeting an organism. These include antioxidants, flavoring agents, and spices. Other direct chemicals include antibiotics and antifungals.

Use of chemical preservatives is guided by the law of the land where it is manufactured and/or intended to be sold. The legal requirements vary from nation to nation. Except salt, sugar and vinegar which are naturally occurring substances, the upper limit of other permitted chemicals are guided by the law. Also, there are strict guidelines governing labelling of foods preserved by chemicals. The general perception is that addition of chemicals can be detrimental to human health over long periods and hence this method is avoided as far as possible these days.

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) As a method, in what way is hot air drying superior to sun-drying?

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2) Which are the foods that are normally preserved by refrigeration?

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3) What precautions would you take while thawing frozen foods and why?

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15.2.7 Minimal Processing of Fresh Foods

The concept of minimal processing applies mostly to vegetables, fruits and juices. The principles and applications of hurdle theory are used together with the development of emerging techniques for the minimal fresh processing or fresh-cut industry to improve the quality, safety and shelf-life of plant-derived commodities in order to satisfy increasing consumer demand.

There is growing interest in this concept in the food industry as the consumer demand for healthier and fresher food products is rising every year. The main spoilage changes that affect minimally fresh processed fruits and vegetables, as well as how the traditional processing and preservation techniques solve these problems, are tackled in this exciting new branch of food technology. Also the need for seeking alternatives or secondary techniques which use mild but reliable treatments in order to achieve fresh-like quality and safe products with a high nutritional value is considered. Additionally, there is focus on the keys for the production of safe foods, which include screening materials entering the food chain, suppressing microbial growth and reducing or eliminating the microbial load by processing and preventing post-processing contamination. Some successful combinations of sub-inhibitory processes, based on the application of a combination of various mild treatments, take advantage of the synergisms of the different preservation hurdles known as ‘hurdle technology’. The success of the new technologies also depends on a good understanding of the physiological responses of microorganisms to stresses imposed during food preservation.

Emerging technologies like high pressure processing, pulsed electric field processing, pulsed light processing, ohmic heating, etc. are used for keeping microbial and sensory quality of minimally fresh processed fruits, vegetables and juices especially relating to disinfection of the products. Novel modified atmosphere packaging, hydrogen peroxide, ultraviolet-C radiation, ozone, acidic electrolysed water, biocontrol cultures, organic acids, chlorine dioxide or hot water treatments have been tried to ensure food safety and quality.

As consumers increasingly perceive fresh food as healthier than heat-treated food, it motivates a general search for food production methods with reduced technological input. This phenomenon was observed over the last few years since the *per capita* consumption of fresh fruits and vegetables has increased significantly over the consumption of processed vegetables such as canned vegetables. However, a food which meets nutritional requirements is unlikely to be accepted by consumers if they do not like the flavour or other quality attributes, and herein lies another challenge to food technologists.

Fruit & vegetables are the major dietary sources of substances with antioxidants and free radical scavenging properties like anthocyanins and other phenolic compounds, of high importance from the human nutritional point of view. Carotenoids, tocopherols and vitamin C are also appreciated due to their possible role in the prevention of several human diseases. Advances in agronomic, processing, distribution and marketing technologies, as well as the current preservation techniques, have enabled the produce industry to supply nearly all types of high-quality fresh fruit and vegetables to those who desire and are willing to purchase them year round. Despite the benefits derived from eating raw fruits and vegetables, safety is still an issue of concerns as these foods have long been known to be vehicles for transmitting infectious diseases.

Whole fruit and vegetable products are highly susceptible to deterioration between harvest and consumption. Since minimal processing damages plant tissues, leading to additional quality losses, the derived fresh-cut commodities are in fact more sensitive to disorders than the original. The main features are the presence of cut surfaces and damaged plant tissues, the minimal processing that cannot guarantee microbial stability of the product, the active metabolism of the plant tissue and the limited shelf life of the product. Therefore, deterioration of minimally fresh processed fruits and vegetables is mainly due to further physiological ageing, biochemical changes and microbial spoilage which originate changes in respiration, ethylene emission, transpiration and enzymatic activity of the living tissues after harvesting and processing. Many of the compositional changes influence their colour, texture, flavour and nutritive value.

As mentioned, the traditional processing of this kind of product usually consists of a sequence of operations (trimming, peeling, cutting, washing/ disinfection, drying and packaging) and, generally, the extension of the shelf life depends on a combination of correct chilling treatment throughout the entire chill chain, dips in anti-browning solutions, optimal packaging conditions (usually MAP) and good manufacturing and handling practices in well designed factories. Additionally, some authors have proposed the use of edible coatings in combinations with anti-browning compounds to improve the colour preservation of fresh-cut fruit.

Once these traditional processing and preservation techniques have been able to provide food products with acceptable sensorial and microbial quality, the next step forward is to design mild but reliable treatments in order to achieve fresh-like quality and safe products with a high nutritional value. Therefore, the minimally fresh processing industry is currently seeking alternatives or secondary technologies to maintain most of the fresh attributes, storage stability and above all safety of fresh processed fruits and vegetables, meanwhile extending their shelf-life, although long shelf-life is not the most important selling argument anymore, with the market trends tending towards more fresh-like products.

Production of safe food includes screening materials entering the food chain, suppressing microbial growth and reducing or eliminating the microbial load by processing and preventing post-processing contamination.

15.2.8 Other Emerging Techniques

(i) Modified atmosphere packaging (MAP)

It is well known that MAP has been successfully used to maintain the quality of minimally fresh processed fruits and vegetables. However, novel MAP technologies that allow an extension of the shelf-life are still much demanded by producers and distributors. It was observed that exposure to high O_2 alone did not strongly inhibit microbial growth and the results were highly variable. On the other hand, many authors have found that superatmospheric O_2 (higher than 70kPa O_2), when combined with increased CO_2 concentrations, inhibits enzymatic discoloration and microbial growth in fresh-cut vegetables and prevents anaerobic fermentation reactions. Therefore, it could be considered as a good alternative to conventional MAP with moderate-to-low O_2 and high CO_2 levels (Day, 2001). The development of new packaging materials will allow definitive avoidance of anaerobic conditions and a reduction in respiration rate, ethylene emissions, browning as well as weight loss in order to keep the fresh properties of minimally fresh processed fruits and vegetables longer, attenuating undesirable changes in sensory quality and controlling microbial growth. It is known as **'active'** and **'smart'** packaging, which responds actively to changes in the food package. As an example, smart packaging can now include materials designed to absorb or emit chemicals during storage, thereby maintaining a preferred environment within the package which maximizes product quality and shelf-life. Therefore, the use of non-conventional MAP combined with antimicrobial, moisture absorbers and edible films or those films fitted with porous substrates covered with side-chain crystallizable polymers or with an O_2 emitter and/or CO_2 or C_2H_4 scavenging devices will also have many potential applications.

(ii) Genetic Engineering

The possible use of genetic engineering to develop higher production and more resistant plant foods (GM Foods) is relatively well known. Currently, this technology is being used to introduce desirable attributes such as improved colour, aroma, flavour and taste of different fruit and vegetable products. In fact, the first transgenic product introduced as a food commodity was a tomato with reduced polygalacturonase activity. Although the huge advance of these techniques was in the last decade, there is still a lack of published information about the development of genetically modified fruit and vegetables which overcome some relevant problems of the post-harvest science such as chilling injury resistance, longer storage duration and pathogen resistance. Therefore, much more effort should be done in this area and recent advances in functional genomics should bring candidate genes to manipulate. In addition, the industry has to take into account the lengthy food safety studies required by legislation in many countries, particularly, the European Union.

15.3 EMERGING TECHNOLOGIES FOR MINIMALLY PROCESSED FRESH FRUIT JUICES

The market for minimally processed refrigerated fruit juices, like ready-to-eat plant foods, has experienced substantial growth over the past few years. Traditionally, fruit juices were subjected to heat treatments between 60 and 100 degree C for a few seconds. However, by using this technology, undesirable reactions may take place producing unwanted changes in the product or by-product formation, which decrease the overall quality of the juices. Therefore, the development of emerging technologies, which use a lower temperature to the traditional heat treatment and guarantee a final food product which preserve the fresh properties of the fruit juices as much as possible, is needed. Their success relies on a mild preservation treatment (generally, heat) combined with chilling to keep flavour and nutritional properties. Some researchers contrast minimal processing techniques with thermal processing, however, developments in thermal technologies have been considered ‘minimal’ where they have minimized quality losses in food compared to conventional thermal techniques.

The emergence of novel spoilage microorganisms in juices also poses a new challenge for the correct preservation of these food products. Fruit juices have been considered for many years susceptible to spoilage only by yeast, moulds and lactic acid bacteria. Their acid pH, lower than 4.0 in most cases, was considered sufficient to prevent growth of almost all spore-forming microorganisms. This fact has allowed the fruit beverage industry to apply successfully a hot-fill-hold process to pasteurize these products. However, in the last few years an increasing number of incidents of spoilage of acid foods, such as fruit juices, has been reported. Most of these spoilage incidents have been related to spore-forming thermo-acidophilic microorganisms. Spoilage caused by this kind of microorganisms is difficult to detect. The juice appears normal or has light sediment and no gas is produced. Often, the only evidence of the alteration is a 'medicinal' or 'phenolic' off-flavour.

Only in the last ten years has there been any real recognition of mild preservation treatments as non-thermal methods to preserve food products and there is a growing interest for non-heat treatment of juices. The juices can be processed by using pulsed electric fields, high hydrostatic pressure, high intensity pulsed light, irradiation, new chemical and biochemical additives and, of course, the hurdle technology. The use of membrane disrupting novel preservation techniques, such as ultrasound, high pressure or pulsed electric field is based in their potentially synergistic effects with chill storage or mild heat treatment.

15.3.1 Pulsed Electric Fields

Pulsed electric fields (PEF) have been shown to be able to reduce the microbial population of refrigerated fruit juices, such as apple or orange and carrot juice. At the same time, this technology induces sub-lethal damage in bacteria, which causes a significant delay in their ability to grow and spoil the product. However, PEF can only be applied to liquid products. While the shelf-life of the orange juice processed with PEF was extended to 14 days, the non-treated juice was not acceptable after 4 days of storage. However, to prevent spoilage of orange-carrot juice, it would be necessary to combine an efficient PEF treatment with chilling temperatures during the distribution and storage periods and to guarantee low initial concentrations of contaminating bacteria in fresh-squeezed juice.

15.3.2 High Hydrostatic Pressure or High Pressure Technology

The application of high hydrostatic pressure for processing food products consists of a pressure treatment in the range of 4000-9000 atmospheres. The high hydrostatic pressure is used to inactivate microbial growth as well as certain enzymes to prolong the shelf-life of the food products, although the microbial inactivation will depend on the pH, food composition, osmotic pressure and the temperature of the environment. It is known that Gram negative bacteria are inhibited at lower pressure than Gram positive bacteria. The inhibition of microbial spores can be managed by combining the high pressure treatment with chilling temperatures.

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) Why has the demand for minimally processed foods increased in the recent years?

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2) What in your opinion is the significance of the modern super market in the present food chain?

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15.4 LET US SUM UP

The history of food preservation and processing is as old as that of human civilization. Need for food security, being an integral part of human development, has contributed to the gradual development of food processing and preservation techniques and technologies.

Food Technology/ Processing is a multi-disciplinary science requiring in-depth knowledge of several basic and applied sciences.

Some of the major food processing techniques of modern times are based on addition of heat/ thermal processing, drying/ removal of moisture, cooling/ removal of heat and addition of preservatives.

Some of the important reasons for resorting to food processing & preservation are: conversion of basic foods into forms that render them directly eatable, increasing the shelf life of foods-especially the perishables, making seasonal foods available round the year and making raw foods safe to eat.

Inspite of all the advances of food science and technology, there are still significant number of cases of food borne illnesses and contaminations even in advanced nations resulting in considerable productivity loss, medical costs and loss due to food recalls from the market. Therefore food safety is a major issue especially when it comes to processed food commerce and international trade. Food processing and preservation therefore plays a vital role in the long chain between farm and fork.

There is inevitably some loss of nutrition and quality during processing of foods as compared with raw foods. This has led to the modern trend of minimally processed foods and of the HACCP techniques.

The real challenge for the food technologist is to carry out food processing efficiently and hygienically with minimal losses in quantity and quality, using minimal quantities of energy, water and other inputs, while ensuring that the final product is tasty, nutritious and safe.

15.5 SOME USEFUL BOOKS

- B. Sivasankar. (2004). Food Processing and Preservation Prentice-Hall of India Pvt. Ltd
- Desrosier, N.W. (1963). The Technology of Food Preservation, AVI Publications.
- Eckles & Eckles. (1991). Technology of Milk & Milk Products, AVI Publications.
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- Gustavo V. Barbosa-Canovas (Ed), Grahame W. Gould (Ed). (2000). Innovations in Food Processing (Food Preservation Technology Series) : CRC Publishers
- Mahindru, S.N., (2000). Food Additives; Published by Tata McGraw Hill.
- Ramaswamy, H.S. & Michele Marcott. (2005). Food Processing – Principles & Applications; CRC Publications

15.6 KEY WORDS

Absorption	:	Uptake of moisture by dry foods.
Acid Food	:	A food with a pH of less than 4.6 and a water activity (a_w) equal to or greater than 0.85.
Additives	:	Chemicals added to improve their eating quality or shelf-life.
Decimal Reduction Time	:	The time needed to destroy 90% of micro-organism count (to reduce their numbers by a factor of 10).
Food Preservation	:	is the process of treating and handling food in such a way as to stop or greatly slow down its spoilage and to prevent food borne illness while maintaining the food item's nutritional value, texture and flavor.
Food Processing	:	is the set of methods and techniques used to transform raw ingredients into food for consumption by humans or animals. The *food processing industry* utilises these processes. Food processing often takes clean, harvested or slaughtered and components convert into attractive and marketable food products. Various techniques are used for this purpose.
HACCP	:	Hazard Analysis and Critical Control Points.
Heat Sterlization	:	Destruction of the majority of microorganisms in a food by heating.
Latent Heat	:	Heat taken up or released when a material undergoes a change of state.
Pulsed Electric Field Processing	:	Application of electric field with a strength in the range of 12-35 kV cm^{-1} to a liquid food in a short pulse (1-100 ps) produces lethal effect on micro-organisms.
Thermal Centre	:	The point in a food that heats or cools most slowly.
Thermal Death Time	:	The time required to achieve a specified reduction in microbial numbers at a given temperature.
Ultra High Tempera-ture (UHT) Treatment	:	Processing/ Heat sterlization at above 135°C for a few seconds.
Water Activity (a_w)	:	It is defined as the ratio of the vapor pressure of water in a material (p) to the vapour pressure of pure water (p_o) at the same temperature. It is ratio of moisture content of the product and the relative humidity of air surrounding it.

15.7 ANSWERS TO CHECK YOUR PROGRESS EXERCISES

Check Your Progress Exercise 1

Your answer should include following points:

1. Most of the foods we eat and raw materials for them are products of agriculture and hence seasonal in nature and with limited shelf life. Before they reach the consumers` tables, there are possibilities of losses and contamination which could pose serious economic and health issues. Modern food technology helps in ensuring that these foods are available to the consumer round the year in tasty and safe forms using a multi-disciplinary scientific & engineering approaches. Also such processing & preservation is done through food technology to achieve economies of scale, optimal energy & water consumption efficiencies and with minimal damage to the environment. Food processing and preservation is the largest industry in the world and hence there is a great responsibility on food technologists.

2. a-addition of heat (thermal processing)
   b-removal of heat (cooling or refrigeration)
   c-removal of moisture (drying or dehydration) and
   d-addition of preservatives

3. Pasteurization is a technique in which a liquid food is subjected to heat treatment with a particular time-temperature combination that would effectively destroy all the pathogenic micro-organisms. Milk, for instance is subjected to 72 degree celsius for 15 seconds for effective pasteurization. This process was invented by Louis Pasteur, a French microbiologist and hence has been named after him.

4 Pastuerization means elimination of *pathogenic* microorganism and not all microorganisms. In UHT and sterilization processes, we aim at elimination of *all* microorganism in food being processed. Further, UHT is meant for liquid foods while sterilization is a generic term used for all types of foods.

Check Your Progress Exercise 2

Your answer should include following points:

1. Sun-drying, as the name suggests makes use of the natural heat from the sun for drying of foods. Therefore it is prone to quality variations & problems since it depends on the vagarities of the weather. In rainy season or cloudy weather, the drying could take too long resulting in deterioration of food quality. On the other hand, hot air drying is done under controlled conditions of temperature, air velocity and of course, time. The results are much better and since the drying equipments are designed for better hygiene, the overall physical and microbiological quality of hot air dried foods is usually far superior.

2. The shelf life of raw foods, semi processed foods and intermediate & high moisture foods can extended by refrigeration. While the shelf-life benefits from refrigeration in case of raw foods like fruits & vegetables, raw milk, raw meat & fish may not be much, the benefits, in terms of shelf-life, could be significant in case of processed/semi-processed foods like dairy products, cooked/blanched meats/vegetables etc. Dried

products, sterile products packed under sterile conditions do not require refrigeration.

3. Frozen foods have to be thawed gradually to prevent cellular damage which could adversely affect their texture. Indiscriminate heating of frozen foods could also result in localized burning of foods which could cause havoc with their flavours and nutritional quality.

Check Your Progress Exercise 3

Your answer should include following points:

1. There is now a wave of *wellness* and not merely health in the more discerning sections of population all over the world. Fresh and natural foods as well as nutraceuticals are integral parts of this concept. People are now looking for fresh and natural products grown in an environmentally sustainable manner. However, getting such produce directly to the urban consumer is not always feasible. Therefore, the concept of minimally processed foods in conjunction with a reliable cold chain has become quite popular especially in advanced western nations. In fact this is the fastest growing segment of the retail food sector in the world today. In minimally processed foods the food technologist strikes a delicate balance between shelf life of processed foods and nutrition & safety. Minimally processed foods are more nutritious, healthy and flavoursome.

2. Supermarkets play a vital role in the modern food chain since it the main interface between the producer/processor and the consumer. The buying pattern of foods in the modern societal set up is a weekly / monthly visit to the nearby supermarket and buy one`s requirement of food and stack them at home in the refrigerator for consumption during the week or month. Major food companies vie for shelf space in popular supermarket chains and the latter are slowly but surely getting a stranglehold over the processors and producers in the food chain. There is a growing awareness about the influential role of the supermarkets and a debate is on about hefty percentage of the costs that is contributed by them in the overall costs of food chain management.