Course Code – SIUSBOT64 – Credits 4 – Paper – IV - Post harvest technology: Preservation of Fruits and Vegetables (15 Lectures)

- **Drying - Under natural conditions (Sun drying)**
- **Dehydration - Under artificial conditions - hot air drying, vacuum drying, osmotic drying, crystallized or candied fruits, fruit leather, freeze drying (freeze-dehydration)**
- **Freezing - cold air blast system, liquid immersion method, plate freezers, cryogenic freezing, dehydrofreezing.**
- **Canning**
- **Pickling - in brine, in vinegar, Indian pickles**
- **Preservation using sugar concentrates - jams, jellies and fruit juices**
- **Chemical preservatives**
- **Antioxidants**

Post harvest technology: Preservation of Fruits and Vegetables

Food preservation is the process of treating and handling food to stop or greatly slow down spoilage (loss of quality, edibility or nutritive value) caused or accelerated by micro-organisms. Maintaining or creating nutritional value, texture and flavour is important in preserving its value as food. This is culturally dependent, as what qualifies as food fit for humans in one culture may not qualify in another culture.

Preservation usually involves preventing the growth of bacteria, fungi, and other micro-organisms, as well as retarding the oxidation of fats which cause rancidity. It also includes processes to inhibit natural ageing and discolouration that can occur during food preparation such as the enzymatic browning reaction in apples after they are cut. Some preservation methods require the food to be sealed after treatment to prevent recontamination with microbes; others, such as drying, allow food to be stored without any special containment for long periods.

Relatively long term preservation of food may be achieved by physical and chemical processes those sterilize the food or render it incapable of supporting the growth of microorganisms. These processes include drying, spray drying, freeze drying, freezing, canning and adding chemical preservatives. Other methods that not only help to preserve food, but also add flavour, include pickling, salting, preserving in vinegar or in sugar concentrates. Their brief account is as follows:

DRYING AND DEHYDRATION

It is one of the oldest methods of food preservation. It involves evaporation or removal of water or moisture from the food to inhibit the growth of microorganisms and to hinder the quality decay in storage. In food preservation, the principal process concerned is the respiration. Bacteria yeasts and moulds need the water in the food to grow. Removing of water inactivates the enzymes required for respiration. Therefore, drying effectively prevents the microorganisms from surviving in the food. To prevent the spoilage of the product, the rate of drying is relatively rapid. Drying also reduces the weight of the product.

In general, the horticultural products are dried in two ways, viz., under natural conditions (sun drying) and under artificial conditions (dehydration). In either case the drying is carried out by means of warm dry air. Sun drying is relatively inexpensive in locations where summers are sufficiently warm and dry. However, sun drying requires considerable land and presents sanitation problems. Dehydration is a more expensive process but has number of following advantages:

- Dehydration can be carried out independent of climate.
- Drying time is reduced and quality may be improved.
- The yield of product dried in dehydrator is slightly higher than that of sun dried product because in dehydration sugar is not lost as a result of continued respiration and yeast fermentation.

The brief account of natural drying and artificial drying is as follows:

I. **Drying under natural conditions:** It is carried out outdoors by using a simple method called sun drying which is as follows:

- **Sun Drying**

  Drying food using sun and wind to prevent spoilage has been practised since ancient times. For sun drying hot, dry, breezy days are the best. The principal environmental factors concerned with sun drying are degree and amount of sunshine and temperature and dryness of the air. In general, when the intensity and duration of sunlight are greater, the temperature is higher and the air becomes relatively drier. Due to this, the rate of drying is also greater. Thus, warm dry climates characterized by abundant sunshine will be more favourable to sun drying than that of cold dry climates. A minimum temperature of 86°F is needed with higher temperatures being better. It takes several days to dry foods out doors. Because the weather is uncontrollable, sun drying can be risky. Also, the high humidity in the South is a problem. Humidity below 60 percent is best for sun drying. Often these ideal conditions are not available when fruit ripens.

  Fruits which can be sun dried include raisins, apricots, peaches, figs, pears etc. Similarly certain spices like dhaniya, jeera, black pepper, cinnamon etc. can also be sundried for their long term preservation. The high sugar and acid content of fruits make them safe to dry in the sun. Vegetables are not recommended for sun drying. Vegetables are low in sugar and acid. This increases the risks of spoilage.

  The trays used for sun drying are made of screen or wooden rods. Most woods are fine for making drying racks or trays. Screens need to be safe for contact with food. The best screens are stainless steel, Teflon coated fiberglass or plastic. Screens made up of hardware-cloth should be avoided. It is a galvanized metal cloth that is coated with cadmium or zinc. These materials can oxidize, leaving harmful residues on the fruits or vegetables. Similarly, screens made up of copper and aluminum should also be avoided. Copper destroys vitamin C and increases oxidation. Aluminum tends to discolor and corrode.

  Fruits or vegetables to be dried in the sun are placed on the trays. The trays are then placed on the blocks to allow better air movement around the fruits and vegetables. Because the ground may be moist, it is best to place the racks or screens on a concrete platform or block or if possible over a sheet of aluminum or tin. The reflection of the sun on the metal increases the drying temperature. The trays are covered with cheesecloth to protect the fruits and vegetables from birds and insects. At night, in cooler climate, the air or vapours may get condensed back and could add moisture to the product and thereby, may slow down the drying process. Therefore, the trays are brought indoors or under shelter at night.

  Recent efforts to improve the sun drying process have led to technique called solar drying. The solar dryer is a box like dehydrator which uses the sunlight as the source of heat. A foil surface present inside the dehydrator helps to increase the temperature. Ventilation speeds up the drying time. Shorter drying times reduce the risks of food spoilage or mold growth.

II. Drying under artificial conditions: Many times drying the horticultural produce under artificial conditions is referred to as dehydration. Drying artificially consists of passing the heated air over the product. Most of the foods can be dried indoors using modern dehydrators, convection ovens or conventional ovens. Microwave ovens are recommended only for drying herbs, because there is no way to create airflow in them. The principal factors concerned with such type of drying are temperature and dryness of air and the velocity of the air. Heating of the air is necessary to increase its drying capacity. Higher the temperature without impairing the quality of product, greater will be the rate of drying and lesser will be the reduction in the quality of the product.

i. Hot air drying: In it huge dehydrators are used. Heating of the air reduces the relative humidity of the air and enlarges the driving force for drying. Besides, higher temperatures speed up diffusion of water from the produce, so drying becomes even faster. However, product quality considerations limit the applicable rise to air temperature. An excessively hot air almost completely dehydrates the solid surface. Due to this, the pores of the surface shrink and almost close, leading to crust formation or hardening product, which is usually undesirable and reduces the quality and market value of the product.

Many types of hot air dehydrators are used for fruit and vegetable drying. After being sorted, washed, peeled and trimmed, the fruits to be dehydrated may be treated with sulphur dioxide fumes. The process is called **bleaching**. Sulphur dioxide fumes acts as a bleaching agent in lighter coloured fruits and as a chemical aid to preservation. Safe drying temperature for fruits is approximately 60^{0}C (140^{0}F). The moisture content of fruit is reduced to 15-25%. In dehydration of vegetables, enzyme systems are first inactivated by heating them in boiling water or steam. The process is called **blanching**.

In the world, a greater quantity of fruits is preserved by drying than by any other method of preservation. Among the important dried fruits are raisins, apricots, dates, fig, banana, peach, apple and pear. In contrast, the quantity of dried vegetable in the market is relatively small. The potatoes are the most important dried vegetables. Most successfully dried vegetable products are used as flavouring agents, e.g., onion, garlic, parsley, celery, fenugreek, palak, mushrooms etc.). Some times these dried vegetables are used in manufacturing of different products like soup mix, noodles mix, vegetable masala cubes, stew mix, upama mix etc.

Most of the dried fruits can be stored for 1 year at 60° F, 6 months at 80° F. Dried vegetables have about half the shelf-life of fruits. To store any dried product longer, placing them in freezer becomes the best option.

ii. **Vacuum drying:** As the name suggest, the atmospheric pressure surrounding the product is reduced. Vacuum drying is a form of preservation in which a food is placed in a large container from which air is removed. Water vapour pressure within the food is greater than that present outside it and water evaporates more quickly from the food than in a normal atmosphere. Thus, it promotes a rapid loss of water from the tissues. In this type of drying, the heat is supplied by conduction or radiation (or microwaves) while the vapour thus produced is removed by the vacuum system. After drying the product, it can also be vacuum packed. Vacuum-packing stores food in a vacuum environment, usually in an air-tight bag or bottle. Due to vacuum, oxygen is unavailable, hence bacteria can not survive in such environment and food spoiling gets slowed down. Vacuum drying is biologically desirable since some enzymes that cause oxidation of foods become active during normal air drying. These enzymes do not appear to be as active under vacuum drying conditions. Two of the special advantages of vacuum drying are that the process is more efficient at removing water from a food product and it takes place more quickly than air drying. Vacuum drying and packing is commonly used for preserving nuts, peaches and apricots.

iii. **Osmotic drying:** Osmotic drying mainly depends on the process of osmosis. Osmosis is the diffusion of water molecules across a semi-permeable membrane from a region of high concentration to a region of low concentration until a state of dynamic equilibrium is reached. More specifically, it is the movement of water across a partially permeable membrane from an area of high water potential (low solute concentration) to an area of low water potential (high solute concentration) until there is an equal concentration of fluid on both sides of the membrane. It is a physical process in which a solvent moves, without input of energy, across a semi-permeable membrane (permeable to the solvent, but not the solute) separating two solutions of different concentrations.

In osmotic drying, the fruits or vegetables are dried in a hypertonic solution of sugar (mainly fruits) and/or salt (mostly vegetables). Due to addition of such solution, osmosis occurs and it results in the movement of water from fruit (having high water potential and low solute concentration) to the hypertonic solution (having low water potential and high solute concentration) through the semi-permeable fruit rind, peel or surface. Thus, due to osmotic drying, water or moisture present in the fruits or vegetables comes out and drying is facilitated.

iv. **Crystallized or candied fruits:** Most liquids freeze by crystallization i.e. formation of crystalline solid from the uniform liquid. Crystallization consists of two major events, nucleation and crystal growth. Nucleation is the step where the molecules start to gather into clusters, on the nanometer scale, arranging in a defined and periodic manner that defines the crystal structure. The crystal growth is the subsequent growth of the nuclei that succeed in achieving the critical cluster size**.** Crystallization is the main principle behind the crystallized or candied fruit formation.

Candied fruit, also known as **crystallized fruit** or **glace fruit**, has been around since the 14th century. Recipes vary from region to region. Whole fruit, smaller pieces of fruit, or pieces of peel, are placed in heated in highly concentrated sugar syrup which absorbs the moisture from within the fruit and eventually preserves it. Depending on size and type of fruit, this process of preservation can take from several days to several months. The continual process of drenching the fruit in syrup causes the fruit to become saturated with sugar, preventing the growth of spoilage microorganisms. Then the final product is dried and packed. The glace fruits will keep for a number of years without any additional methods of preservation.

Fruits which are commonly candied include dates, cherries, plums, peaches, apricots, pears, pineapple, apples, melons, citrus fruits, amala, raw mango and ginger. **Marmalade** or **Succade** is the candied peel of any of the citrus species, especially from *Citrus medica* which is distinct with its extra thick peel; in addition, the taste of the inner rind of the citron is less bitter than those of the other *Citrus* fruits.

v. **Fruit leather**: It is a tasty, chewy, dried fruit product. Fruit leathers are made by pouring pureed fruit onto a flat surface for drying. When dried, the fruit is pulled from the surface and rolled. The final product is shiny and has the texture of leather hence the name 'Fruit leather'. Fruits suitable for fruit leather production include Apple, Banana, Cherry, Citrus, Coconut, Peach, Pear, Pumpkin, Raspberry, Strawberry and Blueberry. Fruit leather is produced commercially as follows:

- Ripe or slightly overripe fruit is selected.
- Fruits are washed, dried properly and fruit-peel, seeds and stalk are removed.
- Fruits are cut into chunks and are measured (2 cups of fruit yield 13" x 15" inch fruit leather).
- Fruit chunks are ground into smooth puree.
- 2 teaspoons of lemon juice or 375mg of ascorbic acid is added for 2 cups of light colored fruit pulp to prevent darkening.
- To sweeten the fruit leather, ¼ to ½ cups of sugar or honey for 2 cups of fruits is added. Honey is best for longer storage because it prevents crystals. Sugar is fine for immediate use or short storage.
- Then the puree is dried to get fruit leather.
- **Drying the Leather:** The fruit puree dried in the oven or in sun by spreading it on a sheet or plastic wrap. In a dehydrator, specially designed plastic sheets are used which withstand that temperature. The fruit pulp is spread evenly on the sheets or tray to a thickness of 1/8 inch. Then it is dried at 60^0C (140°F) until no finger-indention is left on touching the fruit pulp at the center. This could take about 6 to 8 hours in the dehydrator, up to 18 hours in the oven and 1 to 2 days in the sun.
- **Packaging the fruit leather:** When warm, the fruit leather is peeled from the plastic wrap, cooled completely and rewrapped in new plastic sheet. Then these wraps are packed in clean moisture-vapor-resistant containers. Glass jars, metal cans or freezer containers are good storage containers, if they have tight-fitting lids. Plastic freezer bags are acceptable.
- **Shelf-life:** Fruit leathers should be stored in a cool, dry, dark place. Fruit leathers should keep for up to 1 month at room temperature. To increase its shelf life further, placing them in freezer becomes the best option.

vi. **Freeze drying or freeze-dehydration**: A recent technological development called freeze- drying / Freeze dehydration / lyophilization / cryodesiccation has increased the use of drying as a preservation technology. It is a dehydration process typically used to preserve a perishable material or make the material more convenient for transport. The method dries the horticultural produce without destroying their physical structure. Freeze-drying works by freezing the material and then reducing the surrounding pressure and adding enough heat to allow the frozen water in the material to sublime directly from the solid phase to the gas phase.

Freeze drying is often carried out under high vacuum to allow drying to proceed at a reasonable rate. Freeze drying is possible at atmospheric pressure in dry air. However, many times, high vacuum pumps are used to reduce the pressure, if required. If using a vacuum pump, the vapour produced by sublimation is removed from the system by converting it into ice in a condenser, operating at very low temperatures, outside the freeze drying chamber. This process avoids collapse of the solid structure, leading to a low density, highly porous product which is able to regain the solvent quickly, whenever required.

In biological materials or horticultural produce, freeze drying is regarded as one of the best methods which help to retain the initial properties of the produce. The quality of the freeze dried product is much higher than that of the product dehydrated by other methods. The storage period of dried materials get extended at cool temperatures. However, at high humidity, mold growth can become a problem. Freeze dried fruits include apple, blueberry, raspberry, peach strawberry, mango, banana, chikoo, kiwi, lemon and guava. Freeze dried vegetables include onion, garlic, cucumber, cabbage, potato, okra, cauliflower, sweet corn and peas. Freeze dried herbs include coriander, chillies and mint.

Freeze-drying process: There are three stages in the complete drying process: freezing, primary drying and secondary drying. Their brief account is as follows:

I. **Freezing**: In it the food is placed in a freeze-drying flask which rotates in a bath, called a shell freezer. The shell freezer bath is cooled by mechanical refrigeration by using dry ice and methanol or liquid nitrogen. On a larger scale, freezing is usually done using a freeze-drying machine. In this step, it is important to cool the material below its triple point, the lowest temperature at which the solid and liquid phases of the material can coexist. This ensures that sublimation will occur in the following steps.

   Larger ice crystals are easier to freeze-dry. To produce larger crystals, the product should be frozen slowly or can be cycled up and down in temperature. This cycling process is called annealing. However, in the case of food with formerly-living cells, large ice crystals will break the cell walls, resulting in cell destruction, rehydrating the food and gives poor texture. Smaller ice crystals are slower in freeze-dry. In this case, the freezing is done rapidly, in order to lower the temperature below the triple point, thus, avoiding the formation of large ice crystals. The ideal freezing temperatures range between −50°C and −80°C. The freezing phase is the most critical in the whole freeze-drying process, because the product can be spoiled, if done badly.

II. **Primary drying:** During the primary drying phase, the pressure is lowered and enough heat is supplied to the material for the sublimated water to evaporate. In this initial drying phase, about 95% of the water in the material is sublimated. This phase may be slow (of several days in the industry), because, if too much heat is added, the material's structure could be altered. In this phase, pressure is controlled through the application of partial vacuum. The vacuum speeds up the process of sublimation. Furthermore, a cold condenser chamber and/or condenser plates provide a surface for the water vapour to re-solidify on. This condenser plays no role in keeping the material frozen; rather, it prevents water vapor from reaching the vacuum pump, which could degrade the pump's performance. Condenser temperatures are typically below −50°C.

III. **Secondary drying:** The secondary drying phase aims to remove unfrozen water molecules, since the ice was removed in the primary drying phase. This part of the freeze-drying process is governed by the material's adsorption isotherms. In this phase, the temperature is raised higher than in the primary drying phase and can even be above 0 °C, to break any physico-chemical interactions that have formed between the water molecules and the frozen material. Usually the pressure is also lowered in this stage to encourage desorption.

   After the freeze-drying process is complete, the vacuum is usually broken with an inert gas, such as nitrogen, before the material is sealed. At the end of the operation, final residual water content in the product is extremely low and is around 1% to 4%.

Properties of freeze-dried products

- If a freeze-dried substance is sealed to prevent the re-absorption of moisture, the substance may be stored at room temperature without refrigeration, and be protected against spoilage for many years.

- Preservation is possible because the greatly reduced water content inhibits the action of microorganisms and enzymes that would normally spoil or degrade the substance.
- Freeze-drying also causes less damage to the substance than other dehydration methods using higher temperatures.
- Freeze-drying does not usually cause shrinkage or toughening of the material being dried. In addition, flavours, smells and nutritional content generally remain unchanged, making the process popular for preserving food.
- Freeze-dried products can be rehydrated (reconstituted) much more quickly and easily because the process leaves microscopic pores. The pores are created by the ice crystals that sublimate, leaving gaps or pores in their place. This is especially important when it comes to pharmaceutical uses. Freeze-drying can also be used to increase the shelf life of some pharmaceuticals for many years.

Applications of freeze-drying in food industry: Freeze-drying is used to preserve food and make it very light-weight. The process has been popularized in the forms of freeze-dried ice cream. It is also popular and convenient for hikers because the reduced weight allows them to carry more food and reconstitute it with available water. Instant coffee is sometimes freeze-dried. Freeze-dried fruits are used in breakfast cereal (Cornflaks). Culinary herbs are also freeze-dried. Freeze-drying process is used more commonly in the pharmaceutical industry.

FREEZING

Freezing is one of the most commonly used processes commercially and domestically for preserving a very wide range of food. In physical science, **freezing** or **solidification** is the process in which liquid turns into solid on cooling beyond its freezing point. In freezing, the temperature of a food is reduced below the freezing point and a proportion of water undergoes a change in its state to form ice crystals. The freezing rate is very important for the type of ice crystals formed. Slow freezing gives big ice crystals; they stick to and destroy the structure of the product. Rapid freezing gives many small ice crystals; they leave the structure of the product intact. Industry standard for freezing of the food is to lower the temperature below -18^{0}C. Normally, the product is frozen -20^{0}C to -24^{0}C.

Freezing slows down both food decay and the growth of micro-organisms. Freezing gives the product a longer shelf life. Besides the effect of lower temperatures on reaction rates, freezing makes the water less available for bacterial growth. Freezing preserves the food from the time it is prepared to the time it is eaten. There are following types of freezing techniques which are used industrially:

- **Cold air blast system:** Cold air blast system is one the oldest and commonly used freezing equipment system, due to its temperature stability and versatility for several types of products. It is the cheapest way of freezing and has the added advantage of a constant temperature during frozen storage. In it, air blast freezers are used. These freezers either use still air or forced air as a freezing medium and based on them they are named as still air blast freezer and forced air blast freezers respectively. The forced air freezer is an improved version of the still air freezer and consists of air circulation by convection inside the freezing room. In the air blast freezer, freezing is accomplished by placing the food in freezing rooms called sharp freezers. Cold air at -30^{0}C to -40^{0}C is circulated over the food at a velocity of 1.5 to 6 m/s. Air is cooled by the refrigerants like ammonia or Freon. Freezing time in sharp freezers is largely dependent on the temperature of the freezing chamber and initial temperature, type and size of product.
  There are a considerable number of designs and arrangements for air blast freezers, primarily grouped in two categories depending on the mode of process, either as batch process or as continuous process. In batch blast freezers, the food is stacked on trays in rooms or cabinets. However, in this type, over-loading may be a problem for these types of freezers, thus the process requires closer supervision than continuous systems. Continuous freezers are the most suitable systems for mass production of packaged products with similar

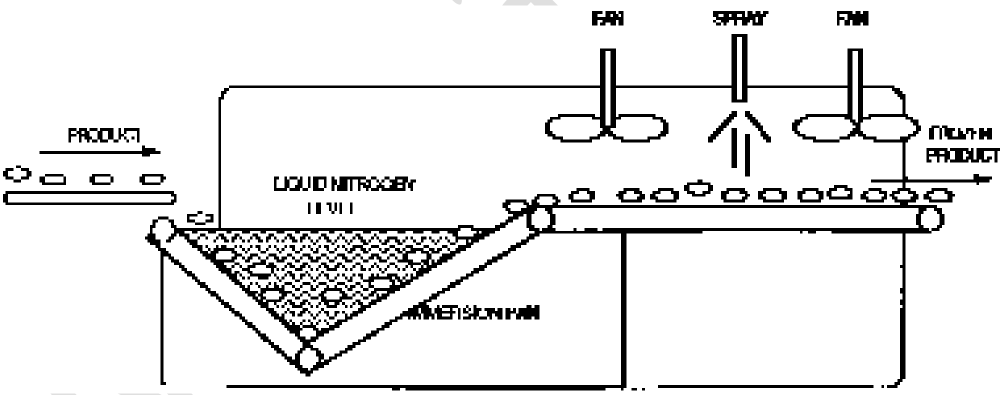
freezing times. In continuous equipment, the trays with food are stacked on trolleys or the food is moved through the freezing tunnel by conveyor belts. Sometimes, multiphase tunnels are applied with a number of belts. In such arrangement, the product falls from one belt to other. This falling helps to break the clumps of the frozen food. The thickness of the food layer present on the belt may vary from 25 to 125mm.

In air blast freezers, large volume of air is recycled. This can cause freezer burns and oxidative changes in case of unpackaged food. Moisture from the food is transferred to refrigeration coils. Hence, the refrigeration coils have to be defrosted regularly. Depending on the size of the food and package, freezing takes several hours. Food frozen by cold air blast system mainly includes green peas, corn kenels, strawberry, raspberry and mulberry.

- **Liquid immersion method:** The liquid immersion method is based on use of cooled freezing media called refrigerants. The refrigerants used in the freezing system should be safe without taste, odour, colour or flavour. For successful freezing; products should be greater in density than the solution.

  The method uses liquid immersion freezer which consists of a tank containing a refrigerant such as glycol, glycerol, sodium chloride, calcium chloride or mixtures of salt and sugar solution. In it, packaged food is passed through a bath of such refrigerated solution on a submerged mesh conveyor. The product is immersed in this solution or sprayed while being conveyed through the freezer. Thus, by this method the food comes in indirect contact with the refrigerants. This results in fast temperature reduction through direct heat exchange and thereby, high freezing rates are obtained. The product gets frozen in few minutes.

  Direct immersion of a product into a liquid refrigerant is the most rapid way of freezing since liquids have better heat conducting properties than that of air. Therefore, this method is more efficient than that of cold air blast method. It is used for freezing the concentrated orange juice in cans.



- **Plate freezers:** Many times air blast freeing method is replaced by use of mechanized plate freezer as they have large capacity, low labour requirements. Plate freezer is the most common type of contact freezer.

  Construction: A plate freezer consists of vertical or horizontal hollow, flat plates constructed from aluminium or steel. A complete freeze unit is formed by staking number of plates horizontally one above the other. The stack of plates is placed inside the steel frame and each plate is connected to the adjacent plate. The plates move apart and create gap for the carton to be placed between the two adjacent plates. Each plate is connected to the refrigeration unit by a pair of flexible hoses. The plate freezer has insulated housing around the plate stack. Heat is transferred from the cartons directly plates, h hence high heat transfer rates are achieved.

  Working: In it, Hydraulic rams are used to move the plates and to apply even pressure on the cartons between the plates during freezing. The metal plates are cooled by using a refrigerant of about -30^{0}C to -40^{0}C temperature. The carton is pressed between these hallow plates, either horizontally or vertically, with a refrigerant circulating inside the plates. This improves the contact between the food and frozen plates. One advantage of such freezer is that little dehydration of the food takes place, which reduces the frequency of defrosting. With refrigerants at a temperature around -30⁰C to -40⁰C, it takes less than 24 hours to freeze the carton.

A special form of a plate freezer is the scraped surface freezer this consists of a freezing cylinder containing rotating knives which remove the frozen material from the freezing surface. This type of plate freezers are used in freezing of fruit juices and ice-creams.

Advantages:

- ➢ Faster temperature reduction.
- ➢ Flat cartons with minimum bulge allowing safe stacking in the cold stores to greater heights without the necessity for racking.
- ➢ Better storage capacity in containers.
- ➢ Low requirement of refrigeration due to absence of high frequency fans in the freezer.

Disadvantages:

- ➢ Higher capital cost.
- ➢ A larger charger of refrigerant is required.
- ➢ All cartons should be of equal height for simplifying the loading process.

- **Cryogenic freezing**: Cryogenic freezing is a relatively new method of freezing in which the food is exposed to an atmosphere below -60°C through direct contact with liquefied gases such as nitrogen or carbon dioxide. This type of system differs from other freezing systems, since it is not connected to a refrigeration plant; the refrigerants used are liquefied in large industrial installations and shipped to the food-freezing factory in pressure vessels. Thus, the small size and mobility of cryogenic freezers allow for flexibility in design and efficiency of the freezing application. Low initial investment and rather high operating costs are typical for cryogenic freezers.

  Cryogenic preservation or freezing is a process where cells or whole food products are preserved by cooling to low sub-zero temperatures, such as −196 °C (the boiling point of liquid nitrogen). At these low temperatures, any biological activity, including the biochemical reactions that would lead to cell death, is effectively stopped. However, during cryopreservation, the effects like extracellular ice formation, dehydration, intracellular ice formation may occur which can cause damage to the food product. Hence to reduce these effects, cryoprotectants are used. A cryoprotectant is a substance that is used to protect biological tissue from freezing damage such as ice formation or dehydration. Cryoprotectants mainly used for fruit and vegetable preservation different types of sugars. These are inexpensive and do not pose any toxicity concerns. Besides, the common cryoprotectants used in food industry are DMSO (dimethyl sulfoxide), Glycerol, Propylene glycol, Sucrose, Trehalose.

  Cryogenic storage at very low temperatures increases the shelf life of the food. For such preservations, many items, Fridges, deep freezers and extra cold deep freezers, all similar to domestic ones, are used. Generally, the ultracold temperature of liquid nitrogen at -196°C is required for successful preservation of the more complex biological structures to virtually stop all biological activity. When having reached the frozen stage, the preserved material is relatively safe from further damage.

- **Dehydrofreezing:** Dehydrofreezing is a new method of food preservation which involves partial dehydration of the food followed by its quick freezing. It is a process used for preservation of fruits and vegetables by evaporation of 50–60% of the water before the freezing of the fruits and vegetables.

  Dehydrofreezing is totally different from freeze-drying, which is an expensive commercial technique that creates a vacuum while the food is freezing. In dehydrofreezing, the foods are partially dried and are then frozen. Since they have been dried, they take less space. The low temperatures in the freezers protect the food from mold, bacteria and general spoiling. In addition, the taste, color, flavour, aroma and texture of such food are definitely better than foods that have been only dried or only frozen. Another great advantage of dehydrofrozen foods is that they reconstitute (rehydration) in about one-half the time required for dried foods. Thus, it is a quicker and easier option. It is commercial used to reduce the cost of shipping, handling and storage of fruits and vegetables.

Dehydrofrozen fruits include apples, peaches, grapes and strawberries while those of vegetables include red and green bell peppers, jalapeno peppers, tomatoes, onions, garlic, celery and mushrooms.

CANNING

Canning is a method of food preservation which involves cooking the food, sealing it in sterile airtight cans or jars and boiling the containers to kill or weaken any remaining bacteria as a form of sterilization. The airtight packaging prevents microorganisms from entering and proliferating inside. Canning is a way of processing food to extend its shelf life. The idea is to make food available and edible long after the processing time.

Foods have varying degrees of natural protection against spoilage and may require that the final step occur in a pressure cooker. High-acid fruits like strawberries require no preservatives whereas fruits such as tomatoes require longer boiling and addition of other acidic elements. Low acid foods, such as vegetables require pressure canning. Highly acidic foods having pH below 4.6 can be safely canned in boiling water bath, e.g., fruits, pickles, some vegetables. However, the foods with low acidity i.e. pH more than 4.6, need to be sterilized under high temperatures (116-130 °C). To achieve temperatures above the boiling point requires the use of a pressure canner. Foods that must be pressure canned include most of the vegetables and fruits.

Food preserved by canning or bottling is at immediate risk of spoilage once the can or bottle has been opened. Besides, lack of quality control in the canning process may allow ingress of water or micro-organisms. Most such failures are rapidly detected as decomposition within the can causes gas production and the can will swell or burst. To improve food safety for those who eat canned food, governments have enacted laws requiring alphanumeric codes being put on food cans during manufacture indicating information relevant to health, such as the date of canning, expiry date etc.

History and development of canning

During the first years of the Napoleonic Wars, there was requirement of increased regular supplies of quality food and their preservation. To fulfill this need of the larger armies of the period, the French government offered a cash award to any inventor who could devise a cheap and effective method of preserving large amounts of food. In 1809, a French confectioner and brewer, Nicolas Appert, observed that food cooked inside a jar did not spoil unless the seals leaked and developed a method of sealing food in glass jars. However, glass containers presented challenges for transportation. Later, the glass jars were replaced by commercial canneries with cylindrical tin or wrought-iron canisters/cans. Cans are cheaper, quicker to make and much less fragile than glass jars. Glass jars have remained popular for some high-value products and in home canning. Later on, a number of inventions and improvements followed and smaller machine-made steel cans were invented.

Canning containers

Apert's original container was a wide mouthed glass jar. Since then, the glass containers are improved a lot. Now modern jars are available. They are made up of steel coated with tin. Now days the trend is towards thinner and more evenly coated tin cans. However, tin coating may cause discolouration of highly coloured fruits, hence in such cases, enamel coated cans are used.

Aluminium containers are also available however, they do not withstand, the strong mechanical stresses. Therefore, they are used mostly for the products which do not require high vacuums or high temperatures for their processing, e.g., frozen fruits, fruit beers, wines, fruit juices.

Flexible plastic bags and laminated vacuum pouches are also in fashion. They are mostly employed for packaging of frozen, dried, unprocessed food. The bags can withstand steam pressure sterilization hence can be employed for the food that is packaged in hot condition.

Canning procedure

The raw food which is to be canned is harvested fleshly, inspected, graded, washed and then can be introduced in the cans. Many fruits are added directly added into the can after washing but many vegetables require blanching before canning. The process of blanching not only cleans the food but also sets the vegetable colour, soften the tissue and kill the microorganisms. After addition of fruits and vegetables into the cans, a highly concentrated sugar and salt solution is added into the cans respectively. These solutions act as a preservating agent. Then the cans are evacuated by heating process or by mechanical means. Following this, the cans are sealed and are made airtight. The heating processes make the food sterile by killing the microorganisms which may spoil the fruits and vegetable in canned condition. To prevent the spoiling of canned, quite a number of methods are used: pasteurization, boiling (and other applications of high temperature over a period of time), pressure filler cooker process, sterilizing and closing process, steam injections, dehydrocanning, refrigeration, freezing, drying, vacuum treatment, antimicrobial agents, ionizing radiation, submersion in a strong saline solution, acid, base, providing extreme osmotic environments etc. however, no such method is perfectly dependable as a preservative. The heating processes are followed by rapid cooling of the cans. It is carried out by immersing the cans in the cold water tank or spraying cold water over them. Thus, canning can be accomplished and food can be preserved.

PICKLING (in brine, in vinegar, Indian pickles)

Pickling began as a way to preserve food for out-of-season use and for long journeys, especially by sea. Although the process was invented to preserve foods, pickles are also made and eaten because people enjoy the resulting flavors. Pickling is a method of preserving food in an edible anti-microbial liquid. Pickling can preserve perishable foods for months. The distinguishing characteristic of pickle is it's pH which is always less than 4.6 and therefore, is sufficient to kill most bacteria. The acidity or salinity of the solution, the temperature of fermentation and the exclusion of oxygen determine which microorganisms dominate and determine the flavor of the end product. Pickling may also improve the nutritious value of food by introducing B vitamins produced by bacteria. To enhance shelf life of the product further more, in commercial pickles, a preservative like sodium benzoate or EDTA may also be added.

Pickling can be broadly categorized as **fermentation pickling** and **chemical pickling**.

Fermentation pickling: In fermentation pickling, the food itself produces the preservation agent, typically by a process that produces lactic acid. Fermented pickles include sauerkraut, nukazuke, kimchi etc. Some chemically pickled cucumbers are also fermented.

Chemical pickling: In chemical pickling, the food is placed in an edible liquid that inhibits or kills bacteria and other micro-organisms. Typical pickling agents include brine (high in salt), vinegar, alcohol, and vegetable oil. Many chemical pickling processes also involve heating or boiling so that the food being preserved becomes saturated with the pickling agent. Common chemically pickled foods include cucumbers, peppers, mixed vegetables and achar. Depending upon the pickling agents, there are following types of chemical pickling:

- **Chemical pickling in brine:** Brining or corning is the process of preserving food by anaerobic fermentation in brine (a solution of salt in water) to produce lactic acid. Salting the vegetables helps to draw out excess water. If the food contains sufficient moisture, pickling-brine may be produced simply by adding dry salt. The jar and lid are first boiled in order to sterilize them. The fruits or vegetables to be pickled are then added to the jar along with brine solution or dry salt and are then allowed to ferment until the desired taste is obtained. This procedure gives the food a salty and sour taste.
- **Chemical pickling in vinegar:** It is the process of preserving food by anaerobic fermentation by marinating and storing it in an acid solution, usually vinegar (acetic acid). The jar and lid are first boiled in order to sterilize them. The fruits or vegetables to be pickled are then added to the jar along with vinegar and are then allowed to ferment until the desired taste is obtained. This procedure gives the pickle a sour taste.
- **Chemical pickling in vegetable oil (Indian pickles):** These involve use of edible vegetable oil as a main medium of preservation. India has a large variety of pickles (known as Achar in Hindi, Lonacha in Marathi, Oorukai in Tamil, Pachadi in Telugu) which is mainly made from Mango, Lime, Indian Goose Berry (Aawla), Chilli, vegetables, Ginger, Garlic and Citron. The jar and lid are first boiled in order to sterilize them. The

fruits or vegetables to be pickled are then added to the jar and are generally mixed with some other ingredients such as salt, antimicrobial herbs, spices, vegetable oils and is set to mature. The proper maturation imparts desired taste to the pickle. Besides, the addition of antimicrobial herbs and spices such as mustard seed, garlic, cinnamon or cloves, often help to add taste and flavor besides preserving.

SUGAR CONCENTRATES (Jams, Jellies, Fruit juices)

Sugar is used to preserve fruits, either in syrup with fruit such as apples, pears, peaches, apricots, plums or in crystallized form where the preserved material is cooked in sugar to the point of crystallisation and the resultant product is then stored dry. This method is used for the skins of citrus fruit (candied peel) and ginger. A modification of this process produces glace fruit such as glace cherries where the fruit is preserved in sugar but is then extracted from the syrup and sold, the preservation being maintained by the sugar content of the fruit and the superficial coating of syrup. The main types of fruit preservations in sugar concentrates are as follows:

Jam

Jam is a type of fruit preserve which involves preservation of fruits by boiling them in sugar syrup. The proportions vary according to the type of fruit and its ripeness. When the mixture reaches a temperature of 104°C, the acid and the pectin in the fruit react with the sugar and the jam will set on cooling. Some of the popular jams are pineapple, apple, mango, strawberry, orange and mixed fruit.

The setting of the jam depends on the pectin content of the fruit. Some fruits, such as guava, apple, plum, grapes, jackfruit, papaya, gooseberries, blackcurrants and raspberries have high pectin contents hence they set very well. However, others such as strawberries, blackberries and over ripe fruits have less pectin, hence, need to have pectin added. There are proprietary pectin products in the market and most industrially-produced jams use them. Home jam-makers generally rely on adding a pectin-rich fruit to poor setters. Other tricks include extracting juice from redcurrants or gooseberries. Good jam should have a good colour, taste, flavor and the characteristics of fruit from which it is prepared. The jam contains 45% fruit-pulp, 65% sugar, 0.4% to 0.6% citric acid and preservative 675mg/kg of fruit pieces. The preparation of jam at industrial level involves following steps:

- **Selection of fruits**: The best products are made from the best quality fruit. Mature, undamaged fruits should be selected. The selected fruits are washed thoroughly, dried and then should be used. The fruit peel and seeds are removed and the fruits are chopped into fine pieces. To avoid browning of the fruits, the fruit pieces can be placed in water that contains lemon juice (250ml lemon juice per litre of water).
- **Preparation of the fruit-pulp:** The fruit pieces are measured using measuring glass and are transferred into a vessel. To it water is added until all the pieces get covered thoroughly. The fruit pieces are cooked fully on low flame. After cooking, the pieces are ground into the grinder to get a pulp having fine paste like consistency.
- **Checking the pectin content:** The setting of the jam requires enough amount of pectin. Therefore, the pectin content of the pulp is checked using pectin-meter and if required pectin powder is added. Home-makers avoid addition of artificial pectin.
- **Rolling boil and reducing the volume:** To the fruit pulp, sugar is added (for 500gm of fruit pieces, 375gm of sugar is added) and the mixture is placed on the low flame. When the sugar has been dissolved, the heat under the pan can be raised and stirring can be continued until the fruit comes to a rolling boil. The mixture should not be boiled too much, otherwise sugar stars again crystallization. Constant stirring is necessary in the final stages otherwise the jam will start sticking at the bottom of the pan.
- **Setting the sheet test:** The time taken to reach the setting point is dependent primarily on the quantity of pectin contained in the fruit and the rate of evaporation. Using the wooden spoon, a small amount of jam is poured into the pan. If it falls in the form of solution or drops then still it requires boiling. If it falls easily, in

the form of sheet form the edge of the spoon then the jam is ready and will set perfectly after cooling. When the jam answers sheet test positively then the pan is removed from the flame and is allowed to cool a little.

- **Addition of preservative:** To increase the shelf life of jam, preservatives like sodium metabisuphite or potassium metabisulphite is added.
- **Jar and bottle preparation:** Jars and bottles need to be scrupulously clean and rinsed before storing upside down. They should be sterilized at 185^{0}C for 20 minutes and then should be used.
- **Bottling and sealing:** The bottles should be filled fully almost to the top with the jam when it is still hot. The jam will shrink back as it cools. After filling all the bottles or jar, the lids are applied and are sealed firmly.

Jelly

Fruit preserved by jellying is known as jelly, marmalade, or fruit preserves. The juices of pulpy fruits, when fresh, contain an active principle known as pectin, which is the coagulating substance that forms the basis of fruit jellies. Fruits may be preserved by cooking them in a material that solidifies to form a gel. Such materials include gelatin, pectin, agar, maize flour and arrowroot flour. In this case, the jellying agent is usually pectin, either added during cooking or arising naturally from the fruit. Most preserved fruit is also sugared in jars. Heating, packaging and acid and sugar provide the preservation. The preparation of jelly at industrial level involves following steps:

- **Selection of fruits**: The best products are made from the best quality fruit. Mature, undamaged fruits should be selected. The selected fruits are washed thoroughly, dried and then should be used. The fruit peel and seeds are removed and the fruits are chopped into fine pieces. To avoid browning of the fruits, the fruit pieces can be placed in water that contains lemon juice (250ml lemon juice per litre of water).
- **Preparation of fruit broth:** The fruit pieces are measured using measuring glass and are transferred into a vessel. To it water is added until all the pieces get covered thoroughly. The fruit pieces are cooked fully on low flame. After cooking, the mixer is strained and the clear solution is separated and used further.
- **Checking the pectin content:** The setting of the jelly requires enough amount of pectin. Therefore, the pectin content of the pulp is checked using pectin-meter and if required pectin powder is added.
- **Rolling boil and reducing the volume:** To the clear solution collected after straining, sugar is added (for 500gm of fruit pieces, 375gm of sugar is added) and the mixture is placed on the low flame. When the sugar has been dissolved, the heat under the pan can be raised and stirring can be continued until the fruit comes to a rolling boil. The mixture should not be boiled too much, otherwise sugar stars again crystallization. Constant stirring is necessary in the final stages otherwise the jelly will start sticking at the bottom of the pan.
- **Setting test:** The time taken to reach the setting point is dependent primarily on the quantity of pectin contained in the fruit and the rate of evaporation. Using the wooden spoon, a small amount of jam is placed on a cold saucer. It is left as it is for 2 to3 minutes and then tested by pushing it with the finger. If a translucent skin has formed on the top of the drop and the drop falls easily from the saucer back into the pan in a clot, then jelly point has been reached.
- **Addition of preservative:** To increase the shelf life of jelly, preservatives like sodium metabisuphite or potassium metabisulphite is added.
- **Jar and bottle preparation:** Jars and bottles need to be scrupulously clean and rinsed before storing upside down. They should be sterilized at 185^{0}C for 20 minutes and then should be used.
- **Bottling and sealing:** The bottles should be filled fully almost to the top with the jelly when it is still hot. The jelly will shrink back as it cools. After filling all the bottles or jar, the lids are applied and are sealed firmly.

Fruit Juices

A wide range of fruit drinks can be prepared using fruit juice or fruit pulp as the base material. Many of the fruit drinks are consumed as a pure juice without the addition of any other ingredients; however, some are diluted with sugar syrup. The fruit are drunk straight after opening the can. Generally, these do not require preservatives, if they are processed and packaged properly. However, sometimes, certain amount of permitted preservatives may be added to have a better shelf-life after opening.

Method of preparation

Any fruit can be used to make fruit juice, but the most common ones include apple, pineapple, lemon, melon, orange, grapes, mango, blackcurrant and passion fruit. Some juices, such as guava, papaya, strawberry, cranberry, mulberry etc. are not filtered after extraction and are sold as fruit nectars. The fruit juice preparation involves following key steps:

1. **Selection and preparation of raw material**

   Mature, undamaged fruits should be selected. Any fruits that are moldy or unriped should be sorted and rejected. The selected fruits are washed with clean or chlorinate water. The fruit peel and seeds are removed and the fruits are chopped into fine pieces. There are chances that the fruit pieces may get oxidized and start turning brown which will lead to discolouration of the fruit juice. To avoid browning of the fruits, the fruit pieces can be placed in water that contains lemon juice (250ml lemon juice per litre of water).

2. **Juice extraction**

   Depending on the type of fruit, there are several methods of extracting juice. For citrus fruits which are naturally juicy, the best option is to use a hand presser. Some fruits such as melon and papaya are steamed to release their juices. Apples are pressed or crushed to get the juice while the fruits such as mango, guava, pineapple, strawberry must be pulped to extract the juice. Such fruit pieces are pushed through a perforated metal plate that crushes and turns them into a pulp. Some fruits can be pulped in a grinder and then filtered to remove the left-over ungrounded fruit pieces.

   There is a range of equipment available that varies in size and in the type of power supply. Some are operated manual while the larger ones require electricity. For the small scale processor, hand-powered pulper/sieve which forces the fruit pulp down through interchangeable metal strainers is sufficient. At slightly higher production levels, it is necessary to use a power source having pulper like mixer to achieve a higher throughput of juice. For large-scale production, an industrial pulper-sieving machine is necessary.

3. **Filtering**

   To make a clear juice, the extracted juice or pulp is filtered through a muslin cloth or a stainless steel filter. Although juice is naturally cloudy, some consumers prefer a clear product. It may be achieved by adding pectic enzymes. These enzymes act on pectins, break down them and thereby make the juice a clear solution. However, the pectic enzymes may be difficult to find and expensive and therefore should only be used, if really necessary and readily available.

4. **Batch preparation**

   When the juice or pulp has been collected, it is necessary to prepare the batch according to the chosen recipe. This is very much a matter of choice and judgment and must be done carefully to suit local tastes. Juices are sold either pure or sweetened. Fruit squashes would normally contain about 25% fruit material mixed with sugar syrup to give a final sugar concentration of about 40%. Squashes are diluted with water prior to use and as the bottle is opened, partly used and then stored, it is necessary to add a preservative. Another popular product is fruit nectar, which is a sweet mixture of fruit pulp, sugar and water which is consumed on a 'one shot' basis. Essentially, these consist of a 30% mix of fruit pulp and sugar syrup to give a final sugar level of about 12-14%. All fruits contain sugar, usually around 8-10%. The actual levels vary from fruit to fruit and with the stage of ripeness of the fruit. The addition of sugar to the fruit pulp to achieve the recommended levels for preservation must take into account the amount of sugar already present in the juice. It is important to achieve the minimum level that will prevent the growth of bacteria, however, once that level has been achieved; it is possible to add more if the consumers require a sweeter product. The amount of sugar added in practice is usually decided by what the purchasers actually want. In all cases, sugar should be added to the fruit juice as sugar syrup. The syrup should be filtered through a muslin cloth prior to mixing to remove particles of dirt which are always present. This gives a clearer, higher quality product.

5. **Pasteurization**

All the products mentioned above need to be pasteurized at 80-95°C for 1-10 minutes prior to hot-filling into bottles. At the simplest level, this may be carried out in a stainless steel, enameled or aluminum sauce-pan over a gas flame but this can result in localized overheating at the base of the pan, with consequent flavour changes.

It is best to use stainless steel pans to heat fruit juice as the acidity of the juice can react with aluminium in aluminium pans during prolonged heating. However, large stainless steel pans are very expensive and may not be affordable by the small scale processors. To get round this problem, it is possible to use a large aluminium pan to boil the sugar syrup. The boiling syrup can then be added to a given amount of fruit juice in a small stainless steel pan. This increases the temperature of the juice to 60°-70°C. The juice is then quickly heated to pasteurizing temperature. The pasteurization time for 0.5 liters of juice at 80 0C is 15 minutes.

Another option is to pasteurize the juices, once they have been bottled. The bottles are placed in a hot water bath which is heated to 80°C. The bottles are held in the hot water for the given amount of time until the contents reach the desired temperature. The length of time required in the water bath depends on the size and volume of the bottles. A thermometer should be placed in one of the bottles, which is used as a test bottle per batch, to monitor the temperature and to ensure that the correct temperature has been reached. This method of pasteurisation has benefits but also has problems which are as follows:

- **Benefits**
    - Juice is pasteurised within the bottle so the chance for re-contamination of the juice is reduced.
    - No need for large stainless steel pans for pasteurisation
- **Problems**
    - Difficult to ensure the internal temperature of the bottles reaches the desired pasteurising temperature.
    - Require glass bottles for pasteurising

6. Filling and bottling

In all cases, the products should be hot-filled into clean, sterilized bottles. A stainless steel bucket, drilled to accept a small outlet tap, is very effective bottle filler. The output can be doubled quite simply by fitting a second tap on the other side of the bucket. This system has been used to produce 500-600 bottles of fruit juice per day. After filling hot, the bottles are capped and laid on their sides to cool prior to labelling.

Another method adopted is to fill the freshly prepared cold juice into bottles until it reaches the necks and on the top of this fruit juice, a little quantity of glycerin is placed. Fruit juices thus preserved will keep in an unchanged condition in any season.

Preservation of fruit juices

As the name suggests, pure fruit juice is solely the extracted juice of fruit and should not have any preservative or any other ingredients (such as sugar) added. However, the fruit drinks that are not consumed in one go can have preservatives added to help prolong the shelf life once they have been opened. There are several chemical preservatives that can be added to fruit juices. They are as follows:

Compound	Comments	Amount
Sulphites and Sulphur dioxide	Sulphur dioxide gas and the sodium or potassium salts of sulphite, bisulphite or metabisulphite are the most commonly used forms. Sulphurous acid inhibits yeasts, moulds and bacteria. Sulphur dioxide is mainly used to preserve the colour of fruits during drying.	0.005 to 0.2%
Sorbic acid	Sorbic acid and sodium and potassium sorbate are widely used to inhibit the growth of moulds and yeasts. The activity of sorbic acid increases as the pH decreases. Sorbic acid and its salts are practically tasteless and odourless in foods when used at levels less than 0.3%.	0.05 to 0.2%
Benzoic acid	Benzoic acid, in the form of sodium benzoate is a widely used preservative. It occurs naturally in cranberries, cinnamon and cloves	0.03 to

	and is well suited for used in acid foods. It is often used in combination with sorbic acid at levels from 0.05-0.1% b y weight.	0.2%
Citric acid	Citric acid is the main acid found naturally in citrus fruits. It is widely used in carbonated beverages and as an acidifier of foods. It is a less effective anti-microbial agent than other acids.	No limit

FOOD PRESERVATIVES AND USE OF ANTIOXIDENTS IN PRESERVATION

Food preservation has become an increasingly important component of the food industry as fewer people eat foods produced on their own lands and as consumers expect to be able to purchase and consume foods that are out of season. Another major reason why food preservation is in demand is that there is a long gap between production and the actual consumption of food commodities.

Basically, the food preservation industry has to fight against several factors such as non-enzymatic chemical reactions, enzymatic chemical reactions, insects and rodents, microbial decomposition. However, the vast majority of instances of food spoilage can be attributed to one of two major causes: (1) Attack by pathogens (disease-causing microorganisms) such as bacteria and molds. (2) Oxidation that causes the destruction of essential biochemical compounds and/or the destruction of plant and animal cells. There are various methods which have been devised for preserving foods. The most effective and common methods of food preservation are use of **chemical preservatives** (antimicrobials) and use of **antioxidants**.

A. Chemical preservatives and their uses

Food additive is a substance which is added to the food during production, processing, packaging or storage to increase the shelf life of the food. The chemical food additives which are added to the food to prevent deterioration or decomposition of food are called chemical preservatives. Chemical preservatives cannot take the place of stronger preservation methods, like commercial sterilisation, which kills most bacteria and enzymes, but they can be used effectively to delay spoiling and to stop the growth of harmful micro-organisms. However, majority of food preservation operations used today employ chemical preservatives. A chemical preservative exhibit following useful properties:

- Chemical preservatives kill or at least inhibit the growth of the microorganisms. Most of the preservatives are bacteriostatic or fungistatic.
- They are also effective against both spoilage and pathogenic microorganisms.
- They maintain the good microbiological quality of food.
- They should not react with the food.
- They have long persistence and do not get inactivated by microorganisms or other agents present in the food.
- They are effective over a wide pH range.
- They should be tasteless, colourless, water soluble, economic and practical.

The commonly used chemical preservatives in fruit and vegetable industry and their uses or role are as follows:

a. **Propionic acid and Propionates:** Propionic acid, sodium propionate and calcium propionate (salts of propionic acid) are effective antimicrobials that help to keep the horticultural produce fresh. Propionic acid occurs naturally in apples, strawberries, and in grains. It works at pH range 5 to 6 and prevents the growth of bread moulds and bacteria. It mainly affects the cell membrane permeability of the microorganisms.

b. **Benzoic acid and Benzoates:** Benzoic acid, sodium benzoate and potassium benzoate (salts of benzoic acid) are the antimicrobials that fight only against fungi. They work best at pH between 2.5 and 4.0. Due to this particular pH range, they can control only acidophilus microorganism. Benzoates are found naturally in cranberries. Sodium benzoate and potassium benzoates are widely used in jam, jelly, juice, fruit beverages and in pickle preservation.

c. **Sorbic acid and Sorbates:** Sorbic acid, sodium sorbate, calcium sorbate and potassium sorbate (salts of sorbic acid) are mainly controls mold growth than bacterial growth. It is effective in pH range of 4.0 to 6.5. It is widely used in coating of the packaging material.
d. **Acetic acid and Acetates:** Acetic acid, sodium acetate, calcium acetate and potassium acetate (salts of acetic acid) are effective against bacteria and yeast but not against mold. It is commonly used to preserve pickles, squash, syrups and fruit juices.
e. **Citric acid and Citrates:** Citric acid, sodium citrate and potassium citrates (salts of citric acid) are effective antimicrobials. It is commonly used in preservation of squash, syrups, fruit juices, jam and jellies.
f. **Boric acid and borate:** Boric acid and borates (salts of boric acid) are used in storage of pulses and grains at home level. These are not only effective against bacteria and mold but also effective against insect pests.
g. **Nitrites and nitrates**: Sodium and potassium nitrates and nitrites are rarely used in fruit and vegetable preservation. It is used to preserve meat and protect it from botulism bacteria. These preservatives also give cured meat its fresh pink colour because without nitrates or nitrites meat turns brown. However, its frequent use is risky because it is observed that they react with amino acids from the meat to form nitrosamines which is a cancer-causing agent.
h. **Sulphur dioxide and sulphites:** Sulphur dioxide, sodium sulphite and potassium sulphites work in preservation of variety of foods. They show good antimicrobial activity at low pH level. Some fruit juices and dried fruits contain sulphites. Sulphites block the growth of microbes by interrupting the normal functioning of their cells. Both of these are also used in wine industry for sanitation of the equipments.

B. Antioxidants and their uses

The preservatives which slow the oxidation of fats and lipids that lead to rancidity are called antioxidants. Oxidation-reduction reactions are common in fresh fruits and vegetables. Similarly, almost all free and packaged foods and drinks undergo gradual changes during storage. The typical cause of such spoilage is the presence of oxygen and the products of chemical oxidation. Heat, light, presence of heavy metals, alkaline conditions, degree of unsaturation, pigments and availability of oxygen are the factors which catalyze oxidation of food. In the process of oxidation, the molecules in chemically unsaturated fats and oils from food react with oxygen to form free radicals. Other byproducts formed are aldehydes, ketones, acids and alcohols, which result in the harsh flavors, odours, changes in texture and loss of nutritional value associated with rancidity. In addition, lipid quality deteriorates under photo oxidative conditions or oxidation under thermal conditions such as frying of food. Most of these reactions lead to detrimental effects such as degradation of vitamins, pigments and lipids with loss of nutritional value and development of off-flavours. Therefore, to maintain attractive flavor, odour and texture of the fruits and vegetables, the post-harvest industry has to add food-grade antioxidants to packaged foods for many years.

Types of antioxidants

Antioxidants are of two types' viz., synthetic and natural antioxidants. Their brief account is as follows:

- **Synthetic antioxidants:** These are the first preservatives which are designed for their widespread industrial use. Since their introduction in the 1940s, four have been widely approved by Food and Drug Administration (FDA) as food preservatives. These are Butylated hydroxyanisole (BHA), Butylated hydroxytoluane (BHT), Propyl gallate (PG) and Tertiary butylhydroquinone (TBHQ), Sodium sulfite, Potassium sulfite and Sulfur dioxide. They are fat soluble and impart no flavors, colors or aroma to the final products.
- **Natural antioxidants:** Natural antioxidants are called biopreservatives. In the 1980s, natural antioxidants gained popularity as a preservation option. The most commonly used natural antioxidants are tocopherols, which are found in plant tissues as a blend of alpha, beta, gamma and delta homolog. Trocopherols are the natural source of vitamin E and is mainly used to protect freshness of the processed food. Tocopherols are fat soluble and like BHA and BHT, have almost worldwide acceptance for use in food preservation. Tocopherols have GRAS (Generally Recognized As Safe) status and are the only natural food grade antioxidants currently regulated as such by the FDA. The natural antioxidants present in fruits, vegetables and other dietary supplements include vitamin E, beta carotene, Ascorbic acid (vitamin C), salts of Ascorbic acid such as calcium ascorbate and sodium ascorbate, Citric acid and salts of Citric acid such as calcium citrate and

sodium citrate. Food fortified with vitamin C or E may enjoy enhanced preservation and a longer shelf life due to the extra presence antioxidant. All these antioxidants impart no flavor in preserved foods but contribute significant nutrient intake. Although water-soluble vitamin C has little antioxidant function alone, it serves to enhance other antioxidants by recycling their oxidized states.

Selection of an antioxidant

Choosing the best antioxidant depends upon its compatibility with the fat. For preservation of a fat with a high rancidity level, certainly require a high performance antioxidant. However, a palm or hydrogenated vegetable oils, which are much more stable, require lower levels of antioxidants. The antioxidants re-form the fat molecule and prevent breakdown by donating a hydrogen atom. Although both types of antioxidants exhibit the same chemical properties, the naturals may exhibit a greater reluctance to donate hydrogen atom, which results in their lower performance value compared with synthetics. Natural antioxidants are generally priced closer to the more expensive synthetics, like TBHQ.

Addition of antioxidants

The most practical food preservation method with antioxidants is usually through their addition to the fats and oils used in food production. Antioxidant effectiveness is measured by the amount of peroxides formed in the fat or oil, over the time. The antioxidant must also be added at the proper time and in adequate quantities in accordance with manufacturing laws. Levels of synthetic antioxidant combinations in the fat content of final food products may not exceed 0.02%. In animal fats, the levels of natural antioxidants are permitted up to 0.03%. In certain situations, such as for nuts and cereals, the antioxidant carrier may be a food grade solvent, which can be sprayed on. The antioxidants can also be added to food packaging materials such as wax paper, polyethylene and paperboard. This protects the material, which may be subject to rancidity itself and provides another source of antioxidants for the wrapped food inside. According to the FDA, antioxidants, added alone or in a carrier substance for food preservation, must be declared on the product label.

Role of antioxidants

Unsaturated fatty acids in oils and lipids are especially susceptible to oxidation and will take on a rancid flavour and odour as a result. Antioxidant preservatives stop the chemical breakdown of food when products are exposed to the air. The antioxidants block the formation of free radicals in food by stabilizing the molecular structure of oils and fats. Thus, natural and synthetic antioxidants play major role in preservation of processed food.

Paper IV/Unit II/ Postharvest Technology
Question Bank

1. What is drying? Give an illustrated account of sun drying.
2. Write an essay on hot air drying.
3. What is drying? Explain in brief, vacuum drying.
4. What is osmotic drying? Add a note on candied fruits.
5. What is fruit leather? How is it produced commercially?
6. Explain in brief, freeze drying.
7. What is freezing? Explain in brief, cold air blast system.
8. What is freezing? Give the important features of liquid immersion system.
9. What is freezing? Explain construction and working of plate freezer. Add a note on advantages and disadvantages of plate freezer.
10. What is freezing? Describe the process of dehydrofreezing.
11. Give an illustrated account of Canning.
12. What is pickling? Explain the different types of pickling.
13. What is jam? How is it produced commercially?

14. What is jelly? How is it produced commercially?
15. What is fruit juice? How is it produced commercially?
16. What is chemical preservative? What are the properties, which a chemical preservative must posses?
17. Give the significance of chemical preservatives in food preservation.
18. Enlist the commonly used chemical preservatives in fruit and vegetable industry along with their significance.
19. What are antioxidants? Explain their importance in food preservation.
20. Short notes:
    - Sun drying
    - Crystallized fruit
    - Candied fruit
    - Grace fruit
    - Fruit leather
    - Canning
    - Pickling
    - Indian pickles
    - Jam
    - Jelly
    - Fruit juice
    - Chemical preservatives
    - Antioxidants