Canning

The basic process of canning consists of placing food in a sealable container, closing, heating and cooling. This method of food preservation has been in use since early the 1800s, though the understanding of the process came much later. Large quantities of foods are canned for preservation. In advanced countries, canned foods form a significant part of the diet of the people. Most fruits and vegetables, a wide variety of meats and meat products, fish products, soups, and many other items, are all canned. A typical canning process includes the following steps:

1. Receiving, cleaning, grading, and inspecting of raw commodity.
2. Blanching to inactivate enzymes.
3. Placing in the container with added brine or syrup, and deaeration of the product.
4. Heating in a retort, under 1.05 kg/cm^2 pressure, using steam for metal cans or pressurized water for glass containers.
5. Partial cooling under pressure in the retort.
6. Additional cooling by water sprays or in a cooling tank.
7. Labelling, racking, and distributing.

First, the raw commodity is inspected for any treatment required before canning. Many of them require special treatment, such as washing, trimming, shelling, size grading, and so on. In commercial canning, most of these operations are carried out mechanically. The food may then be blanched to reduce surface contamination and inactivate enzymes. The blanched food is placed in the containers. Brine (1.1 to 1.6 per cent salt concentration) is added in the case of vegetables, meat, and fish, and syrup in the case of fruits. In some cases, only water is added. Oils are commonly added to fish products.

The containers generally preferred for most heat-processed foods are tin cans. Glass jars are easy to clean, corrosion free, and transparent, but they have the disadvantage of requiring more processing time than cans of the same size. There is also the problem of breakage. As heating time is roughly proportional to volume of the container, larger containers must be heated for a longer time, and food canned in such containers will be of lower quality than those placed in smaller containers.

Heating time can be reduced by placing the food in a flexible, relatively thin pouch instead of a can or jar. It has been shown that foods processed in this manner are of comparable quality to frozen foods. The pouches can be heated for serving by simply placing them in hot water, and damage in distribution would be significantly less than with can or glass jar. Pouch canning is gradually gaining importance.

The container with the food has to be ready for deaeration. This can be done by heating the filled cans in steam or hot water or by the use of a vacuum closing machine, when the air is sucked out by a pump and the lid is sealed on while vacuum is maintained. Air and gas removal is necessary to prevent the bulging of the can due to internal pressure, oxidation of the contents, and inside corrosion of the tin plate.

The sealed containers are subjected to heating in a retort, a chamber in which canned foods are processed. Several types of retorts are used. Still retorts are the simplest type in which the cans remain still while they are being heated. In this case, the heating time to bring the cold point to the sterilizing temperature is relatively long. The time taken for sterilization can be markedly reduced by using agitating retorts. The cans are agitated during the heating process. The mixing inside the container helps the conduction and convection processes so that heating is achieved in significantly less time, and food quality is improved. Whether still or agitating retorts are used, the high temperature required for sterilization is commonly obtained from steam under pressure. The heating may be batch-wise or continuous. The heated containers are partially cooled under pressure in the retorts to decrease the internal pressure of the container. Next, the containers are cooled in water or under a spray. Finally, they are labelled and packed for distribution.

Canned food **UHT sterilised food**

Aseptic canning/ UHT sterilization

In normal canning, heat transfer from the outside of the container to the inside will require many minutes or even hours depending upon the container size to reach the sterilization temperature. The time of sterilization can be shortened to seconds or even a fraction of a second in aseptic canning. The basic principle of this method is that food is pumped continuously through a plate-type or tubular heat exchanger, which heats it very quickly to a high temperature, holding it at that temperature for the time required and then cooling. Food temperature employed may be as high as 150°C and sterilization takes place in 1 or 2 sees. Such a rapid sterilization at high temperature is referred to as ultra-high-temperature sterilization. The sterile food is quickly cooled, placed in aseptic containers, and the lids are sealed, while in a sterile environment. The food canned aseptically retains the nutrients and the sensory attributes will be good.

With acid foods, foods sterilized as in aseptic canning, while still hot, can be filled into clean but not necessarily aseptic containers. The heat of the food and some holding time before cooling the closed container renders the containers commercially sterile. This type of canning is known as "hot pack" or "hot fill."

With low-acid food (above pH 4.6), the conventional hot pack processing is not possible. In such cases, the *"flash 18"* process (pressure canning) is employed. Low-acid foods are heated above 100°C under pressure for sterility. If food at that temperature is poured into containers for sealing at atmospheric pressure, there will be violent boiling. This is eliminated by carrying out the canning process in a chamber under a pressure of 1.05 to 1.40 kg/cm^2. Thus, low-acid foods can be pre-sterilized by high temperature for a short time. They are then transferred to cans in a pressurized room and heated for an appropriate number of minutes so that commercial sterility of non-sterile cans is obtained, and finally the cans are sealed and cooled.

Food Preservation by use of low temperature

Preservation of food by freezing and cold storage was known to ancient people. Tribes and nations in the temperate and cooler climates froze their harvest, thawed it when necessary and consumed it. Frozen foods were even transported over short distances to consuming centres. With the development of mechanical refrigeration systems, cold preservation of food, food processing, storage, and distribution, have become widespread. Refrigeration has also influenced agricultural practices. It has become possible to transport perishable foods for long distances from production to consumption centres, and make available seasonal foods at all times of the year.

Effect of Cold on Micro-organisms

While most bacteria, yeasts, and moulds, grow best at temperatures of 16° to 38°C, some micro-organisms continue to grow even at low temperatures. These are known as psychrophilic (cryophilic) organisms. These grow even at 0°C, the freezing point of water. However, lowering the temperature of foods and food products decreases the growth-rate of micro-organisms and the growth and multiplicity completely stop when water freezes. In some foods, water does not freeze even at 10°C or lower temperatures, because of the lower freezing point due to dissolved salts, sugars, and other substances. The retardation of microbial and biochemical activities at low temperatures is the basis of preservation of food by cold. Cold temperature treatment, including severe freezing, only reduces the microbial activities and population, but does not kill all bacteria. Foods frozen, even for two years or more, when removed from cold storage have shown bacterial activity when thawed.

Types of Cold Preservation

Cold preservation of food may be categorized into two groups: refrigeration, and freezing. Household and commercial refrigerators usually run at 4.4°-7.2°C. Commercial refrigeration (cold or chill storage) may use a slightly lower temperature, depending upon the nature of food refrigerated. Freezing refers to foods maintained in a frozen condition. For good freezing, a temperature of-18°C or below is required. Chill storage will preserve perishable foods for days or weeks depending upon the food. Frozen storage (deep freezing) will preserve foods for months or even years.

Refrigeration has certain advantages over freezing. It takes less energy to cool a food to just above its freezing point than to freeze it. Refrigeration storage requires less insulation and refrigeration capacity, and refrigerated products do not suffer from texture and flavour losses caused by freezing. Finally, refrigerated products do not have to be thawed before use—a process that may take as much as 48 hours with large frozen foods.

A further distinction between refrigeration and freezing temperatures relates to microbial activity. Most spoilage organisms grow above 10°C. Some food poisoning organisms grow slowly up to 3.3°C. Cryophilic organisms grow slowly from -4.4°C to -9.4°C, provided the food is not frozen. These organisms, however, do not produce toxins or disease but cause food deterioration. There is no growth of organisms below -9.4°C, though there may not be a total destruction at that temperature.

Chill Storage

Chill storage is useful as the principal method of preservation and as an adjunct to other methods of preservation. The shelf-life of food is directly linked with the microbial rate of growth as influenced by temperature. Storage at - 1° and - 4°C can provide stability, particularly in the presence of food preservatives or a modified atmosphere.

Production of Low Temperature

Chill storage requires controlled low temperature. This is achieved by taking heat away from the storage area. Heat is transferred from the storage area by the principle of latent heat of vaporization. If the state is changed from liquid to gas, or from gas to liquid, without affecting its temperature, an amount of heat must be added or removed. Liquids like ammonia and freon ($C1_2F_2$) are used as refrigerants. Liquid refrigerant is circulated through an expansion valve or a capillary tube and then through a heat exchanger, called an evaporator, within the storage area. In passing through the capillary tube, the refrigerant goes from a relatively high pressure to a relatively low one, causing the liquid refrigerant to evaporate, thus reducing the temperature of the liquid-gas phase of the refrigerant. In the evaporator, the remaining liquid evaporates, absorbing heat from the storage area. The temperature of vaporization of the refrigerant is some 5°-6°C below the storage temperature. A compressor then pumps the refrigerant from the low-pressure cold condition to a high-pressure hot one. The hot gas flows through a condenser where heat is extracted from the refrigerant, and transforms it back to a room temperature, high-pressure liquid ready to flow again to the expansion or capillary tube. Air, water, or a combination of air and evaporating water, is used to cool the condenser.

For the construction of commercial chill storage rooms, the "refrigeration load" is to be taken into consideration. This is the quantity of heat that must be removed from the product and the storage area, in order to go from an initial temperature to the selected final temperature, and then maintain this temperature for a specific time. This depends on the storage area and other factors that may generate heat within the storage area or influence the removal of heat from the area. These include the light and electrical installations, number of people working, how often the doors, which permit entrance of warm air, are opened, and the amount and nature of the food product stored in the refrigerated area. Also, the specific heat of food and the rate of respiration of such foods as fruits and vegetables have a bearing on the extent of refrigeration required. The heats produced from the respiration of fruits and vegetables vary considerably. Products like green beans, peas, spinach, sweet corn, and strawberries have a high respiration rate even at 0°C.

Air Circulation and Humidity

The heat produced due to respiration in the vicinity of the food surface in cold storage is to be transferred towards the refrigerator. This is achieved by air circulation. The humidity of the circulated air is to be controlled. If it is too moist, moisture will condense on the cold food and moulds will grow on food surfaces at the common refrigeration temperature. On the other hand, if the air is too dry there will be desiccation of food. The optimum relative humidity of the circulated air depends upon the moisture content of the foods and the ease with which they dry out. Most foods store best at a refrigeration temperature, when the relative humidity of air is between 80 and 95 per cent. Dry and granular foods store well at about 50 per cent relative humidity. When foods are to be chill stored for a long time, they are protected by packing to prevent loss of moisture. Plastic sacks or moisture-resistant coating are used for this purpose. Cheese ripened for a long time in cold storage are wax coated. Loss of moisture from stored eggs is prevented by dipping the eggs in some oil, to seal the minute pores of the eggshell. If packing is not possible, as in the case of tenderizing beef by ageing in cool rooms, ultraviolet light is employed to retard mould growth.

Deep Freezing

Tremendous advances have been made in freezing food for preservation, storage, and distribution. Many foods can be frozen for twelve months or more without major changes in size, shape, texture, colour, and flavour. Frozen foods have thus attained wide acceptance by the public. At present, no form of food preservation is as well suited to provide maximum convenience as freezing. Complete meals on individual plates can be frozen and are ready for use with a single thawing-heated operation. An unlimited number of items may now be frozen in their final serving forms.

Changes during Freezing and Thawing

Uncontrolled freezing of food can result in the disruption of texture, breaking up of emulsion, denaturation of proteins, and many other physical and chemical changes.

Substances like sugar, salt, and proteins dissolved in water lower the freezing point of water. Thus, when food is kept at a freezing temperature, where the temperature is considerably below the freezing point of water, the water component freezes first and leaves the dissolved solids in a more concentrated solution, which requires a still lower temperature to freeze it. Thus, different foods, with varying levels of water as well as the amount and nature of dissolved substances, will have different freezing points, and under a given freezing condition will require different times to reach a solidly frozen state.

When food containing water is placed in a freezer, it does not freeze uniformly. The portion of food nearest to the container freezes first and the first ice crystals are pure water. As water continues to be frozen, the concentration of dissolved solids increases, and finally a central core of highly concentrated unfrozen liquid remains. If the temperature is sufficiently low, this central core also freezes solid ultimately. In the case of solid foods, like a piece of meat at about -4°C, they appear to be solidly frozen, but they still contain about 3 per cent water in an unfrozen condition. Even at -18°C, not all of the water is completely frozen.

Small quantities of unfrozen water in frozen foods result in the deterioration of food with respect to texture, colour, flavour, and other properties. The high concentration of dissolved substances in the remaining water can cause effects of various kinds. The dissolved substances may precipitate or crystallize, imparting a gritty, sandy texture to the food; if they remain in solution, the high salt concentration or drop in pH (if the solutes are acidic) might result in protein denaturation. The disturbances in anionic and cationic concentration can disturb colloidal substances, and finally the concentration effects can cause the dehydration of adjacent tissues, resulting in loss of tissue turgor. Other effects of unfrozen water are the possibilities of the growth of psychrophilic micro-organisms, and the greater action of enzymes.

Formation of ice crystals during freezing can affect the texture of many frozen foods. There is water within and between the cells of food. When water freezes rapidly, it forms minute ice crystals and clusters of crystals. In slow freezing, water within and between the cells freezes, causing physical rupture and separation of cells. If freezing is rapid, the minute crystals formed are only within the cells but not between the cells, and physical damage of the cells is less severe. Rapid cooling also minimizes concentration effects by decreasing the time of contact of solutes with food tissues during the transition from the unfrozen to the fully frozen state. For these reasons, rapid freezing is desirable for better product quality.

From the point of view of quality and economic aspects, it is best to freeze foods to -18°C or lower, and maintain them at that temperature during storage and transport. In order to achieve the best advantage of rapid freezing, many foods are frozen to temperatures somewhat below -26°C, but this increases the cost. A freezing temperature of-18°C is very safe from attack by micro-organisms as no pathogenic organisms grow below about 3.3°C and spoilage organisms below about -9.4°C. At -9.4°C, most foods retain considerable frozen water, and long storage at this temperature can result in the enzymatic deterioration of food. Even at -18°C some enzymes retain activity. However, the rates of reactions they catalyze will be extremely slow. In the case of fruits and vegetables, the enzyme activity even at -18°C is sufficient to bring about spoilage. In these cases, the enzymes are inactivated by blanching before freezing. Properly packed foods, frozen and stored at -18°C, have high-quality storage life of the order of 12 months and longer.

The kind of damages that occur to food during slow freezing also occur during thawing. Repeated freezing and thawing is, therefore very detrimental to the quality of food. Even a fluctuation of 3°C in freezing temperature above and below -18°C, at which the food is frozen and stored, can damage many foods. Upon refreezing, water melted from small ice crystals tends to bathe un-melted crystals, causing them to grow in size. Also, if thawing of frozen foods is slow, there is loss of quality due to concentration effects. In slow thawing, there is more time for food constituents to be in contact with concentrated solution, thus intensifying their damaging effect. Quick thawing is also desirable from the point of keeping the microbial population in check. Large volumes of frozen food can take from 20-60 hours for thawing, Since bacteria survive the thawing process, long periods and rise in temperature of products will be opportunity for bacterial multiplication. Use of microwave heating reduces the thawing time.

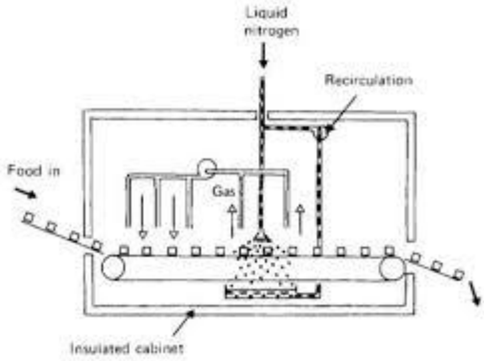
Methods of Food Freezing

There are three basic methods of freezing in commercial use. These are freezing in air, freezing by indirect contact with a refrigerant, and freezing by direct contact with the freezing medium. Air freezing may be by the use of still air ("sharp freezing") or an air blast. Indirect contact freezing consists of keeping food or food packages on a surface cooled by a refrigerant. In direct-contact freezing, the food or package is submerged in a cold liquid or the cold liquid is sprayed on the food or package.

Air freezing: Still-air freezing is the oldest and least expensive method of freezing. This is the type of freezing carried out in home freezers. In this method, food packs are placed in the freezer in such a way that air can circulate between the packages. The freezer is maintained in the range of-23° to -29°C. There is some air movement due to convection, and in some cases gentle air movement may also be promoted.

In air-blast freezing, food packages are carried on an open mesh belt through a tunnel, through which air at temperatures of-29°C to -46°C is forced at velocities of 10 to 15 m/s over, under, or through, the product. Under these conditions, a food packet that takes 72 hours to freeze in still-air can be frozen in about 12-18 hours. A drawback of air-blast freezing is the dehydration of food in an unwrapped condition, which is known as freezer burn. This occurs due to ice changing directly to water vapour molecules without going through the liquid state. Freezer burn results in discolouration, changes in texture, and off-flavour. Freezer burn can be minimized by pre-chilling food with air at high humidity at about -4°C, and the pre-chilled food is then moved into the colder zone where it is quickly frozen.

Blast freezer



Cryogenic freezing

Frozen vegetables

Frozen Ready to cook foods

Indirect contact freezing: Solid foods in consumer size flat packets are placed on shallow metal plates chilled by the circulating refrigerant, so that the food is in direct contact with the cold metal wall but in indirect contact with the refrigerant. The efficiency of freezing depends upon the extent of contact between the plates and the food. For this reason, the packages should be well filled or slightly overfilled to make good pressure contact with the plates. The freezing of liquids and purees by indirect freezing is carried out by pumping them through tubes on the outside of which the refrigerant flows. Through appropriate mechanical devices, the frozen food is scrapped to keep the mass in motion thus enabling the continuous bringing of new portions of food into contact with the cold wall. In this method, freezing occurs in a matter of seconds.

Immersion freezing: Immersion freezing has a number of advantages. There is intimate contact between the food or package and the refrigerant. This is particularly important in freezing irregularly shaped food pieces, and immersion freezing minimizes the contact of food with air during freezing, which is desirable for foods sensitive to oxidation.

The refrigerants used for immersion freezing should be non-toxic, pure, clear, free from taste, odour, colour, or bleaching action. Low-freezing-point liquids cooled by indirect contact with another refrigerant or cryogenic liquids like liquid nitrogen, carbon dioxide, or freon, are used as refrigerants.

The low-freezing-point liquids used are solutions of sugar, salt, or glycerol. A temperature as low as -21°C can be reached with a 23 per cent sodium chloride or 62 per cent sucrose solution. With a 67 per cent glycerol-water solution, one could go down to -47°C.

Cryogenic liquids are liquefied gases of extremely low boiling point, such as liquid nitrogen (Boiling Point (BP), -196°C), liquid carbon dioxide (BP, -79°C), and freon 12 (BP, -30°C). The most commonly used cryogenic liquid is liquid nitrogen. Its low boiling point helps very quick freezing of even large food pieces and it can give a quality unattainable by other non-cryogenic freezing methods. Further, since the cold temperature results from evaporation of liquid nitrogen, freezing by liquid nitrogen does not require a primary refrigerant to cool this medium, and liquid nitrogen is non-toxic and inert to food constituents. The operating cost of liquid-nitrogen freezing, however, is high. With liquid nitrogen, it is possible to freeze food down to -196°C, but it is seldom frozen to a temperature below -46°C. Generally, liquid-nitrogen freezing produces less dehydration loss during freezing and less drip loss during thawing than other freezing methods.

Freezing with liquid carbon dioxide is carried out in a manner similar to freezing with liquid nitrogen. Some foods frozen with this refrigerant are equal in quality to those by liquid nitrogen freezing. In such cases, use of liquid carbon dioxide for freezing is very economical. Of late, freon freezing is coming into use. The installation and operational costs of freon freezing are high, but this can be overcome by the efficient recovery of freon, which becomes vapour on contact with food, for reuse.

Packaging for freezing: Choice of packaging material is of special concern in the manufacture of high-quality frozen foods. The material should be moisture-proof and impermeable to oxygen and flavour compounds, both at freezing temperature and after thawing. It should be resistant to chemical attack from the constituents of foods. Most foods expand on freezing. Therefore, the packaging material in which the food is frozen should have good mechanical strength, have a degree of flexibility, and should not be completely filled. Many packaging materials, such as cans, metal foils, waxed papers, plastic-coated cardboards and plastic foils, cellophane, parchment paper, etc., are all satisfactory for frozen foods. Glass is not generally satisfactory for frozen foods, due to the possibility of breakage from expansion and thermal shocks.

Preservation by drying, dehydration and concentration

Food preservation by drying is one of the methods practised from ancient times. Drying is the method nature resorts to, preserve foods. Grains in the field dry sufficiently on the stalk by exposure to the sun, which requires no further drying for preservation. This is also true of legumes, innumerable seeds, and some spices. The observation of natural drying was adopted by early man to dry fruits, fish, and meat, by exposing them to the sun. Sun drying is still in use in many parts of the world for preserving certain foods, such as fruits and nuts. However, it is limited by the fact that it is feasible only under climatic conditions of high heat and low humidity.

Drying of food involves complete removal of water under controlled conditions in such a way that the food is not altered and results in minimum changes by the drying process. Dried foods contain moisture to the extent of 1-5 per cent, and they have storage stability at room temperature of a year or longer. On reconstitution with water, dried foods are very close to and virtually indistinguishable from the original foods used in their preparation. Removal of moisture from a solid with minimum change in food material is not an easy problem. Removal of only a part of the water of foods, perhaps 1/3 to 2/3 of the water, as in the preparation of syrups, evaporated milk, tomato paste, condensed soups, etc., is not considered as drying. Partial removal of water is known as concentration.

Advantages of Drying

Micro-organisms require water for growth, and when they are growing on food, they get water from the food. If water is removed from the food, the multiplication of micro-organisms will stop. The highest water contents at which microbial spoilage does not occur in the case of traditional dried foods are: dehydrated whole egg, 10-11 per cent; wheat flour, 13-15 per cent; dehydrated fat-free meat, 15 per cent; dehydrated vegetables, 14-20 per cent; and dehydrated fruits, 18-25 per cent. Drying of foods, thus, is primarily carried out to preserve food by controlling micro-organisms. Partial drying, as in concentration, will be less effective than total drying in food preservation. However, concentration is quite sufficient to arrest the growth and multiplication of micro-organisms in some foods.

Drying, in addition to preservation, helps decrease the weight and bulk of food, e.g., 237 ml of orange juice on dehydration yields just 28 g of solids. In some cases, the drying process may be chosen to retain the original shape and size. However, in such a case, the volume may not be affected but there is reduction in weight. Drying thus results in great economy in storage, packaging, and transport, of food. Drying also results in the production of convenience foods, such as instant coffee, instant rice, etc. In these cases, cooking steps are completed before the products are dried.

Drying Rate

The amount of water removed from a given weight of material during a given time interval is called the drying rate. The most important stages in dehydration are penetration of heat into the product and removal of moisture out of the product. Various factors contribute to these two stages.

A large surface area of the food to be dehydrated provides more surface area for contact with the heating medium and for moisture to escape. Therefore, generally foods are divided into small pieces of thin layers for dehydration. This also helps reduce the distances heat must travel to reach the centre of the food and moisture must travel to reach the surface to escape.

Also, the greater the temperature differences between the heating medium and the food to be dried, greater is the drying rate. For any given temperature, the rate of water removal from the food is greater in vacuum than under atmospheric pressure. When the heating medium is air, it gets saturated with the moisture from the water driven from the food and this slows down subsequent moisture removal. Air in motion sweeps away moist air from the drying food surface. Thus, air velocity is also a factor that determines the drying rate.

There is also a time and temperature relationship in food preservation by drying. As food constituents are heat-sensitive, a high temperature for a short time does less damage to food than a low temperature for a long time. Also, when foods are dried, they do not lose water at a constant rate all the way down to dryness. At the beginning of drying, and for some time thereafter, water generally evaporates from the food at a rather constant rate, and then leaves with a falling-rate period of dryness. For example, 90 per cent of water from diced carrot can be removed in four hours, and the removal of the remaining 10 per cent requires another four hours.

Thus, varying conditions, such as temperature, humidity, air velocity, direction of the air, thickness of the food, and other factors affect the drying of food. Removal of water below 2 per cent, without damage to the product, is exceedingly difficult.

Most foods are not homogeneous at the molecular level. The escape of water from food depends upon the condition in which it is present. Free water easily evaporates. Water loosely held, by force of adsorption to food solids, evaporates slowly. Removal of water which enters into colloidal gels, such as when starch, pectin or other gums are present, is more difficult. It is also more difficult to remove chemically bound water as in hydrates of salts. In many cases, foods are pre-treated before drying, with a view to making the structure more porous so as to facilitate transfer of moisture and thereby speed the drying rate. The cells of blanched or cooked foods are more permeable to moisture and dry more easily than their fresh counterparts, provided cooking does not cause excessive toughening or shrinking. Food porosity has the advantages of quick solubility on reconstitution, but suffers from the disadvantages of increased bulk and shorter storage stability.

Changes during Drying

Drying brings about changes in the final product quality. One of the most obvious changes during drying of cellular as well as non-cellular foods is shrinkage. The type and extent of shrinkage depend upon the rate of drying. For example, on the slow drying of a vegetable dice, first there is surface shrinkage. With continued drying, water is removed from the deeper layers and finally from the center, causing continuous shrinkage towards the centre with a concave appearance, and the product is dense. With quick high-temperature drying of food, the surface becomes dry and rigid long before the centre dries out. Thus, when the centre dries and shrinks it pulls away from the rigid surface layer causing internal splits, voids and honeycomb effects, and the product is less dense. Such a product absorbs water, reconstitutes quicker, more closely resembles the original material, and is thus favoured by consumers.

With foods that contain dissolved sugar and other solutes in high concentration, drying can result in the shrinkage and sealing off of the surface pores and cracks. This results in trapping much of the remaining water with the food and drying rate dropping off severely. Dried food pieces may also contain voids, cracks and pores of various diameters. The shrinking and pore clogging by the solutes is known as core hardening. Gradual drying with low surface temperature can minimize core hardening.

Methods of Drying

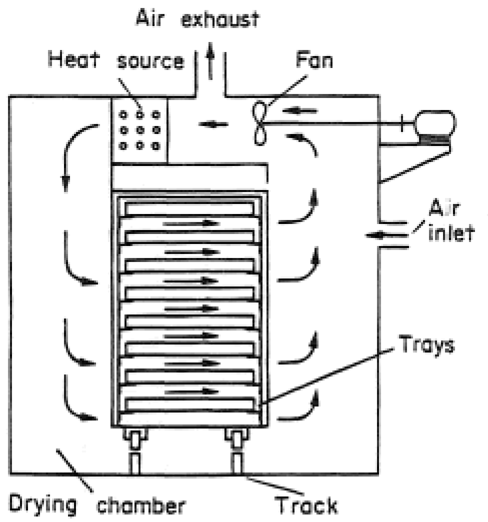
Methods used for food preservation by drying should produce a maximum drying rate with minimum product damage and economic drying costs. A number of drying methods are available; some are particularly suited for liquids, others for solid foods, or mixtures containing food pieces. The common drier types used for liquid and solid foods may be categorized as the air-convection drier, drum or roller drier, and vacuum drier. In the air-convection method, hot air supplies the heat for evaporation. If liquid, the food may be sprayed, or poured, into pans or on belts. Drum or roller driers are limited to their use with liquid foods, pure'es and mashes, that can be applied as thin films. Vacuum driers are employed to lower the temperature of drying. Freeze driers are vacuum driers where, at an extremely low temperature, water vapour directly forms ice without going through the liquid state. The above division of driers is not rigid since many driers are combinations, e.g., a drum drier can be operated in vacuum or by blowing high-velocity healed air.

Air-convection driers: There are some common aspects of the different types of air-convection driers. They all have an insulated enclosure, a means of circulating air through the enclosure, and a means of heating this air. They also have means of supporting foods to be dried, and devices to collect dried food.

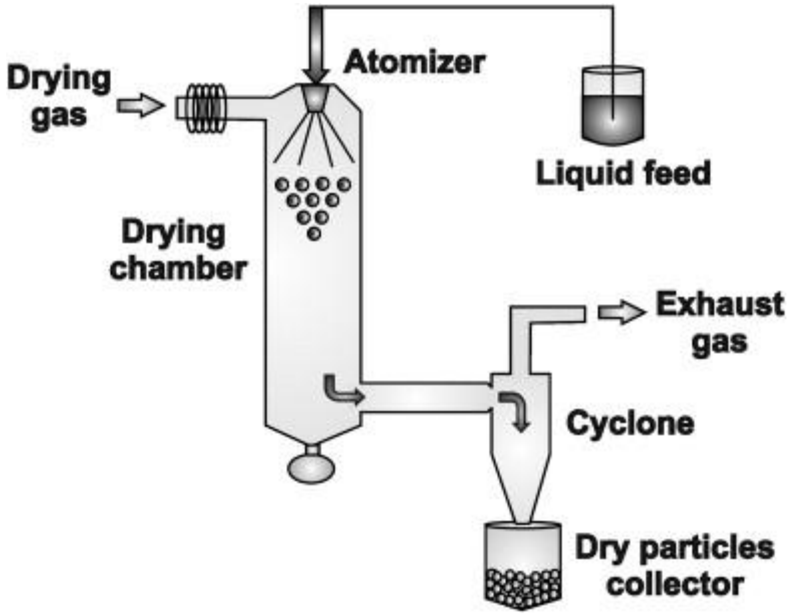
Air may be heated directly or indirectly. In the former method, air is in direct contact with combustion gases. In indirect heating, the air is heated in contact with a hot surface, which is heated by a convenient method. A direct heating method may contaminate the food product, which is not the case with indirect heating.

The simplest type of air-convection drier is the kiln drier. In this case, there is direct heating of air. This kind of drier does not generally reduce moisture to below 10 per cent. A step more advanced drier is the cabinet drier. Food loaded in trays or pans in thin layers are placed in the cabinet, and air heated by an indirect method is blown across food trays. This method is used for small-scale operations. Foods commonly dried by this method are fruits and vegetables. The drying time is of the order of 10-20 hours. For larger operations, a tunnel drier is used. Wet food carts are moved through the tunnel on a continuous belt. Drying air is blown in a direction opposite to the movement of food carts (counter-current principle). The conveyer belt itself in some cases may form a trough (belt trough drier). The belt is usually of metal mesh and heated air is blown through the mesh. Another type of air-convection drier is the fluidized bed drier. In this case, heated air is blown through food particles with just enough force to suspend the particle in a gentle boiling motion.

The most important kind of air-convection drier is the spray drier. More food is dehydrated by using this using this drier than all other kinds of driers put together. Spray drying is limited to liquids, low-viscosity pastes, or purees. Food in the form of a fine spray or mist is introduced into a tower or chamber along with heated air. The small droplets make intimate contact with hot air, blast off their moisture, become small particles, and drop to the bottom of the tower, from where they are removed. Drying takes place in a matter of seconds. The air temperature will be 204°C, but the food particles, never reach a temperature above 82°C as evaporation cools the food. This method of dehydration can produce a high-quality product even with heat-sensitive materials like milk, eggs and coffee.



Tray dryer



Spray dryer

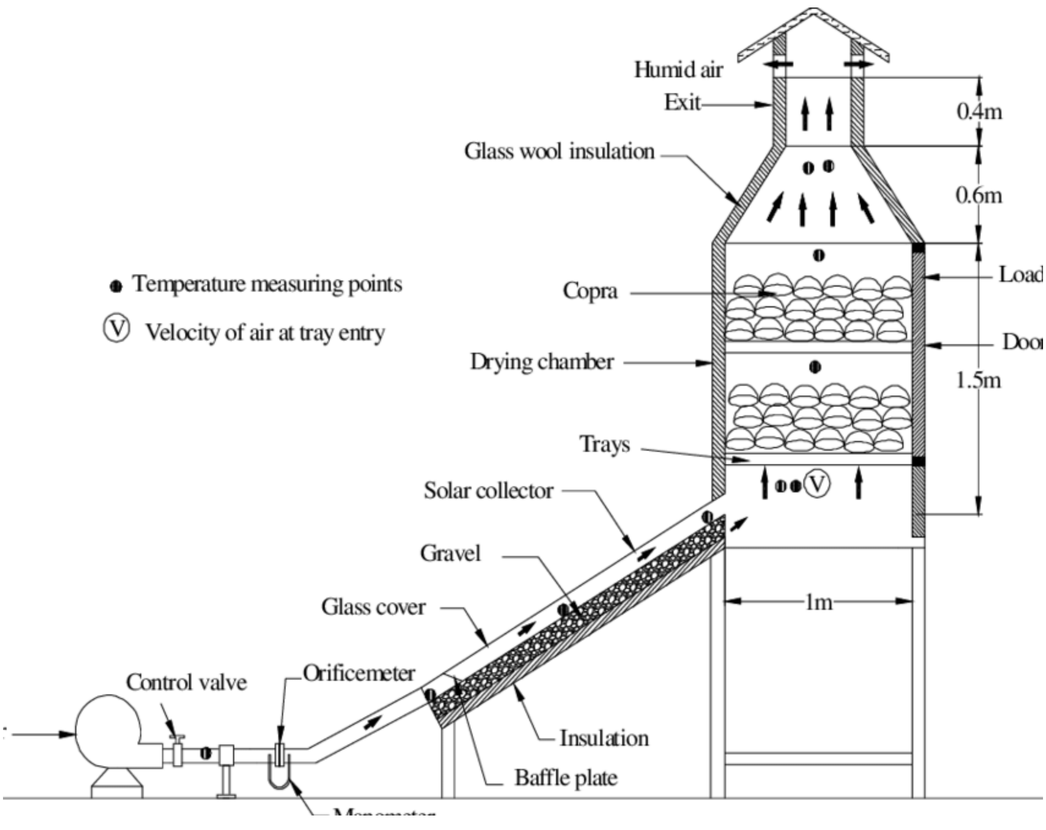
Drum or roller drier: Liquid foods, pure'es, and mashes, are dried by this method. The food to be dried is applied, as a continuous thin layer, on to the surface of a revolving drum or between a pair of drums moving in opposite directions, generally heated by steam. The dried thin layer of food on the drum is scraped by a scraper blade positioned at a point on the drum. Some foods when dry are sticky and cannot be scraped off from the drum when hot. Such a sticky food becomes brittle when cold, which facilitates scraping. Providing a cold zone on a drum thus helps the drying of such foods. The drum temperature may be kept above 100°C by using steam under pressure. Generally, the drum is kept at 150°C when a film of food 1.6 mm in thickness gets dried in one minute or less. For heat resistant food products, drum drying is one of the least expensive dehydration methods. Drum-dried foods generally will have a somewhat more "cooked" character than the same material spray-dried.

Vacuum driers: This method of drying of foods is expensive but gives high-quality foods. The drying system consists of a vacuum chamber that can withstand external air pressure, and contains shelves or other supports to hold food. This kind of vacuum drier is for batch-type operation. For continuous operation a belt drier is used. The shelves are heated electrically or by circulating a heated fluid. The food gets heated by conduction and also by radiated heat from shelves above and below. The drying chamber is evacuated by a suitable device maintained outside the vacuum chamber. The water that evaporates from the food is suitably condensed. The temperature of the food and the rate of water removal are controlled by controlling the degree of vacuum and the intensity of heat output. Liquid foods dehydrated by vacuum drying have a puffed structure and are easily dissolved in water. Because of the low temperature used, there is minimal flavour change and other kinds of heat damage in this method of drying.

Freeze-drying is used to dehydrate sensitive high-quality liquid foods, such as coffee and juices, and also solids of high value, like strawberries, shrimps, etc., having delicate flavour, colour and textural attributes, which cannot be preserved by any other drying method. In freeze-drying, water evaporates from ice without passing through the liquid stage, i.e., water from ice directly becomes water vapour. This happens at a temperature of 0°C or below, and at a low pressure of 4.7 mm of mercury or less. Frozen food is dried by keeping it in a vacuum chamber maintained at a pressure of 0.1 to 2 mm of mercury and maintaining the temperature of the chamber just below the melting point of ice. Under such conditions, water from the frozen food evaporates at the maximum rate. Since the frozen food remains rigid, the evaporation of water leaves voids behind it, resulting in a porous sponge-like dried material. After the food is dried, the vacuum is broken with inert nitrogen gas, and it is packed under nitrogen. If the vacuum is broken by admitting air, the dried product absorbs the air into its pores, resulting in impaired storage stability.

Foam-drying (puff dry) at atmospheric pressure can be employed to dehydrate foods and obtain products with qualities approaching vacuum-dried ones. This method of drying is very economical compared to the vacuum drying method, and can be applied to liquid foods and pure'es which can be pre-foamed before drying. As foaming exposes an enormous surface area for quick moisture escape, drying of foams can be rapid at atmospheric pressure at a reduced temperature. With foods that do not whip readily, some whipping agents (vegetable proteins, gums, monoglycerides) are added prior to being whipped. Stable foams are cast in thin layers into trays or belts and dried by various heating schemes.

Solar food drying is an ideal application for solar energy. Solar radiation passes through the clear glass top of a wooden dehydrator box, then the heat trapped by the box dries the food. The dehydrator also may have an absorber plate inside, which indirectly heats food and creates a convection current of air that enters a vent at the bottom of the dryer. As the food dries, moisture is carried away with the hot air. The easiest solar food dryer to build is a "hot box." One type of solar food dryer integrates the solar collector and food drying cabinet into a compact configuration, which uses both direct heating (like the solar hot-box dryer) and indirect heating from the absorber plate. In a solar food dehydrator, foods are dried quicker on par with an electric food drier. It is relatively compact and lightweight for portability. A simple solar dehydrator can be used at the household level as it is easy to load, unload, and clean.



Solar dryer

Concentration

Foods are concentrated for the same reasons that they are dried—preservation and reduction in weight and bulk. Nearly all liquid foods are first concentrated before drying, because of the technical and economical advantages of such processing. Many foods are better recognized as concentrates than dried ones; examples are fruit-juice concentrates, canned soups, condensed milk, etc.

Concentration may not be effective in all cases as a means of food preservation The levels of water in most concentrated foods are sufficient for microbial growth. Concentrated non-acid fruit juice and vegetable purees undergo spoilage, unless they are further processed. On the other hand, concentrated sugar syrups, sauces, and jellies, are relatively free from spoilage. The solutions of sugar and salt dissolved in the remaining water give concentrates which exert high osmotic pressure and draw water from the microbial cells or prevent normal diffusion.of water into the cells, and thus prevent microbial contamination. Solutions containing 70 per cent of sugar or 18-25 per cent salt prevent the growth of all micro-organisms.

Methods of Concentration

As in food drying, one of the simplest methods of concentration is by utilizing solar energy. Salt has been manufactured by the concentration of seawater by this method from the earliest times.

Kettle evaporators: A simple method of concentration is by the use of open kettles and pans, which may be heated by direct flame or steam. High temperature and long concentration times damage most foods. However, kettle or pan concentration is used in the manufacture.of syrups, as high heat is desirable to produce the colour from caramelized sugar and develop typical flavour.

Flash evaporation: Purees are concentrated by flash evaporation. Superheated steam (150°C) is injected into the food pumped into a vertical tubular steam-jacketed evaporator, where boiling occurs. The boiling mix then enters a separator from which the concentrated food is drained off.

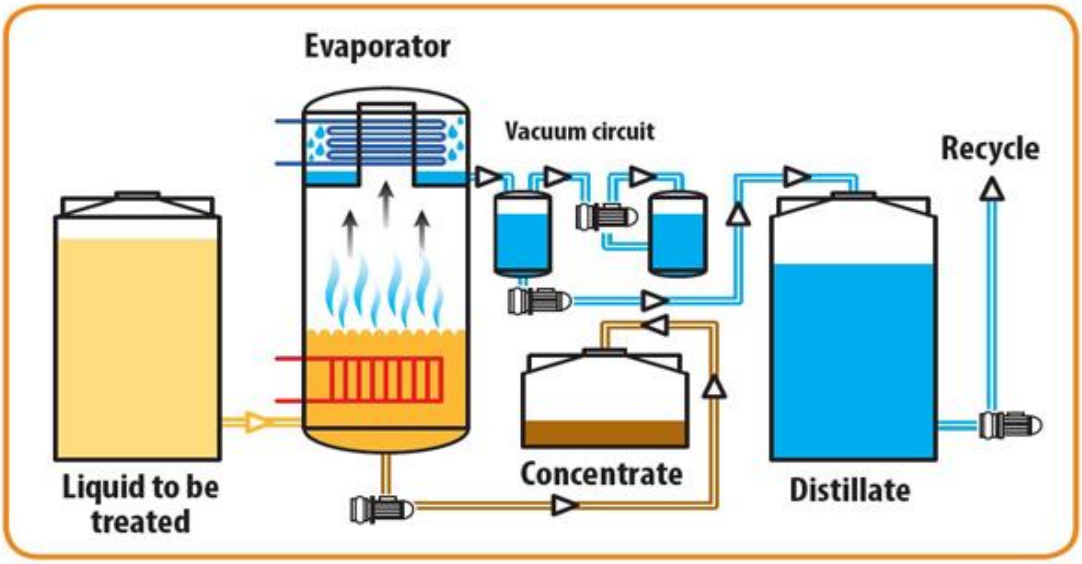
Film evaporators: Foods are also concentrated using tfyin film evaporators. In this case, food is pumped into a vertical cylinder which has a rotating element that spreads the food into a thin layer on the cylindrical wall. The cylinder wall is usually heated by steam. Water quickly flashes from the thin food layer, and the concentrated food is simultaneously wiped from the cylinder wall. The product temperature may reach 83°C, but since the concentrated food will be in contact with the heated cylinder for less than a minute, the damage is minimal.

Vacuum evaporators: Heat-sensitive liquid foods are commonly concentrated at low temperatures in vacuum evaporators. Evaporation systems can be made that operate many times more effectively than single-effect evaporation. Several vacuumized vessels in series constitute multiple effect evaporators. In this process, the first evaporator under vacuum is heated with steam. The water vapour boiled off from the food is sent to the next evaporator kept at a higher vacuum than the first. The water vapour acts as a heat source to evaporate food in the second evaporator. The water vapour from the second can next be passed to a third evaporator, having a higher vacuum than the second, and so on. Grape juice and tomato juice are concentrated in this way. This method results in energy conservation.

Freeze concentration: Concentration by freezing has been used to concentrate fruit juice. When liquid food is frozen, not all the water is converted into ice at the same time. Before the food freezes, the initially formed ice crystals are separated. By repeating this process several times on the concentrated unfrozen food, a high percentage of water can be removed. The disadvantage of this method is the unavoidable entrainment loss.

Ultraflltration and reverse osmosis: Another method of concentration of liquid food is by ultra-filtration and reverse osmosis. The process consists of pumping liquid foods at a high pressure against selective membranes that allow water molecules to pass through them, while retaining macromolecules, salts, sugar, and other organic molecules. Membranes used in ultra-filtration are "less light" and may allow small molecules to pass through them under moderate pressure, while in reverse osmosis, the membranes are "tighter" and permeability does not allow even these molecules to pass through. In osmosis, there is the movement of water through membranes from a region of lower concentration to a region of higher concentration. In reverse osmosis, this is reversed; under pressure, there is flow of water through the membranes from a region of higher concentration to that of a lower.

The concentration of foods results in a cooked flavour and darkening of colour. Concentration also causes changes in organoleptic and nutritional properties of foods. Some foods cannot be concentrated beyond a certain point. When foods containing sugar are concentrated, sugar crystallizes out as concentration increases. Concentration also causes an increase in the level of salts and minerals, which results in the precipitation of proteins. This is the cause of gel formation of evaporated milk after a few weeks' or months' storage.



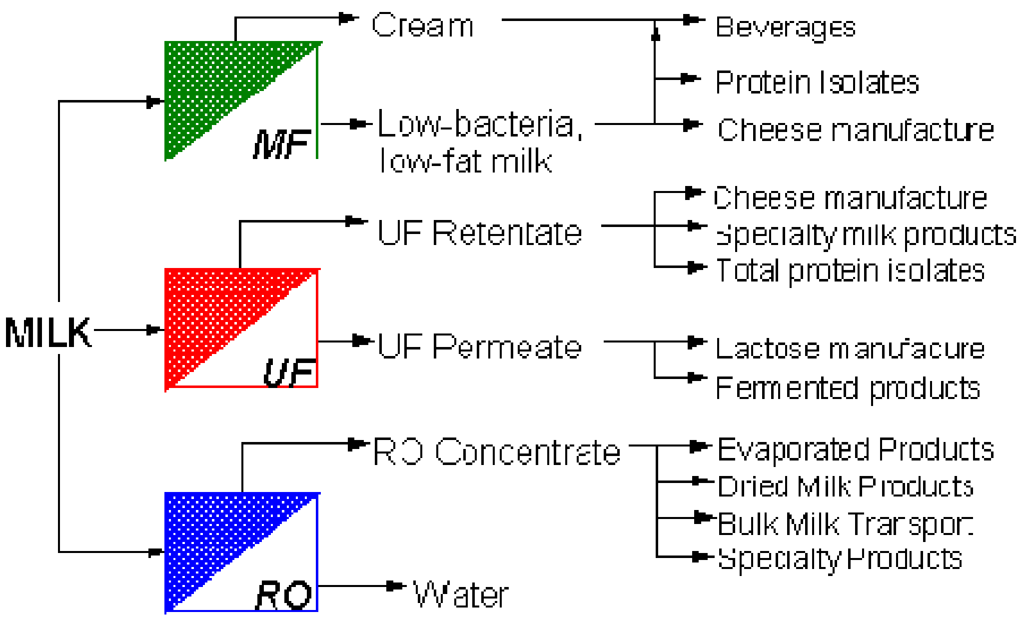


Figure 1. Milk processing with membranes
(From: UF and MF Handbook, 1998)