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| Freezing equipment |
| **Freezing equipment:** The equipment for freezing can be categorized in different ways, namely as equipment used for batch or in-line operation, heat transfer systems (air, contact, cryogenic), and product stability. Mechanical freezers use cooled air, liquid or cooled surfaces to remove heat from foods. On the basis of heat transfer system, freezers are categorised as:   **A. Mechanical Freezers**  **1) Cooled air freezer:** Mechanical refrigerator which evaporate and compress a refrigerant in a continuous cycle and use cooled air to remove heat from foods. It includes chest freezer, air blast freezer, fluidized bed freezer etc. Mechanical refrigeration generally refers to any system that uses electrical power to produce chilled air. The chilled air is passed over food continuously and it removes the heat.  **2) Cooled liquid freezer:** These are similar to cooled air freezers but they use cooled liquid to remove heat from foods and include Immersion freezers.  **3) Cooled surface freezer:** In this type, the surface of freezer is cooled by the refrigerant on which the food is placed for removal of heat. For example Plate freezer, Scraped surface freezer etc.  **Types of freezing:** On the basis of rate of formation of ice front, the freezers are classified into following types:  **1) Slow freezer and sharp freezer:** In this type, the rate of ice front formation is very slow i.e. 0.2 cm/h-1 (e.g., Still air freezers and cold stores) (Fig 13.5).  **Fig 13.5: Quick versus slow freezing**  **2) Quick freezers** having rate of ice front formation as 0.5-3 cm/h-1 (e.g., air blast and plate freezers).  **3) Rapid freezers** having rate of ice front formation as 5-10 cm/h-1 (e.g., fluidized bed freezer).  **4) Ultra rapid freezers** having rate of ice front formation as 10-100 cm/h-1 (e.g., cryogenic freezer).  All freezers are insulated with materials which have low thermal conductivity such as expanded polystyrene, polyurethane etc. Basic principle of operation of different freezers is discussed as under:   **A. Cooled air freezers**  **1. Chest freezer:** In chest freezer, the food is frozen in naturally circulated stationery air at temperature between -20oC to -30oC. Chest freezer takes longer time (3-72 h) for freezing; resulting in loss of product quality. These are not used as such for commercial freezing owing to low freezing rates. Cold stores can be regulated as large chest freezers. These are used to store foods that are frozen by other methods and as hardening rooms for ice cream. Air is circulated by fans for uniform distribution of temperature; however the heat transfer coefficients are low. The major problem in cold stores is the formation of ice on the floor, walls and evaporator coils, caused by moisture from the air or from unpackaged products in the store.  **2. Air blast freezer:** Air blast freezing refers to freezing of products in a powerful blast of circulating cold air at a temperature from -18 to -400C under forced circulation. The air blast freezer is one of the oldest and commonly used freezing equipment due to its temperature stability and versatility for several product types. Air is used as the freezing medium in the freezing design, either as still air or forced air. The air is re-circulated over food at a velocity of 1.5-6.0 m/s. The high air velocity reduces the thickness of boundary films surrounding food and thus improves the surface heat transfer co-efficient. For freezing in batch system the foods is stacked on trays in rooms or cabinets. While continuous system consists of trolleys stacked with trays of food or on conveyor belts which carry the food through an insulated tunnel. Multi-pass tunnels contain a number of belts and products falls from one to another. This action breaks up any clumps of foods and allows control over the product depth (for example a 25-50 mm bed is initially frozen for 5-10 minutes and then repiled to 100-125 mm on second belt). Air flow is either parallel or perpendicular to the food and is directed to pass evenly over all food pieces. Blast freezing is economical and highly flexible for different shapes and sizes of the food. The equipment is compact and has a relatively low capital cost and high throughput (200-1500 kg h-1).  **3. Tunnel freezer:** In tunnel freezers, the products on trays are placed in racks or trolleys and frozen with cold air circulation inside the tunnel. In order to allow air circulation, optimum space is provided between layers of trolley, which can be moved continuously in and out of the freezer manually or by forklift trucks. This freezing system is suitable for all types of products, although there are some mechanical constraints including the requirement of high manpower for handling, cleaning, and transportation of trays. A trolley for a tunnel freezer is shown in Figure 13.6.  The freezer is generally used for the individual quick freezing (IQF) of small products with particle size of 0.5 to 5cm in diameter like peas, beans, mushrooms, small fruits etc. It has low operation costs as compare to other liquid nitrogen freezers.  **4. Belt freezers:** Belt freezers were first designed to provide continuous product flow with the help of a wire mesh conveyor inside the blast rooms. These are also called as spiral freezer as they have a continuous flexible mesh belt which is formed into spiral tiers. The food is carried up through a refrigerated chamber on the belt. Cold air or sprays of liquid nitrogen is directed down through the belt stack in a counter current flow, which reduces weight losses due to evaporation of moisture. Airflow has good contact with the product only when the entire product is evenly distributed over the conveyor belt. Belt freezers require relatively small floor space and have high capacity. Other features include automatic loading and unloading, low maintenance cost and flexibility to freeze different products. Both packed and unpacked products with variable freezing times (10 min to 3 hr) can be frozen in spiral belt freezers due to the flexibility of the equipment.  **5. Fluidized bed freezer:** These are modified blast freezers in which air between -25oC and -35oC is passed at a high velocity (2-6m/s) through a 2-13 cm bed of food, contained on a perforated tray or conveyor belt. The shape and size of food pieces determines thickness of fluidized bed and air velocity needed for fluidization. The foodstuff is fluidized to form a bed of particle followed by freezing. Air is forced upward through belt o suspend the particles. In fluidized bed freezer, the food comes in to greater contact with the air than in blast freezer and thus all surfaces are frozen simultaneously and uniformly. The use of high air velocity is very effective for freezing unpacked foods, especially when they can be completely surrounded by flowing air, as in the case of fluidized bed freezers. The product zone in the freezer is constructed with stainless steel and food grade plastic for easier maintenance. In some cases, the freezing is done in two stages; firstly the initial rapid freezing to produce ice glaze on food surface, followed by freezing on second belt in beds 10-15cm deep. Small vegetables, french-fried potatoes and fruits like strawberries are some of the products now frozen with this technology. A typical fluidized-bed freezer is shown in Figure 13.7.  **B. Cooled liquid freezer** **Immersion freezer:** In immersion freezer, the food comes in direct contact with the refrigerant. For freezing, the food is passed through a bath of refrigerated propylene glycol, brine, glycerol or calcium chloride solution on a submerged mesh conveyor. In contrast with cryogenic freezing, the liquid in immersions freezer remains fluid throughout the freezing operation and change of state does not occur. Immersion freezer involves less capital cost and offers high rates of heat transfer. They are used commercially for concentrated orange juice in laminated polyethylene cans. Freezing of orange juice in cans and peas to -180C in immersion freezing generally takes 10-15 minutes and 30 seconds respectively. Direct immersion of a product into a liquid refrigerant is the most rapid way of freezing since liquids have better heat conducting properties than air. The solute used in the freezing system should be safe without taste, odour, colour or flavour and for successful freezing; products should be greater in density than the solution. A simple illustration of the immersion freezer is shown in Figure 13.8.  **C. Cooled surface freezer:** These include plate freezer and scraped-surface freezer. **1. Plate freezer:** These freezers consist of a vertical or horizontal series of hollow plates, through which refrigerant is pumped at -40oC temperature. In this case, the product is pressed between hallow metal plates, either horizontally or vertically, with a refrigerant circulating inside the plates. Vertical plate freezers are suitable for the viscous products like orange juice whereas, horizontal plate freezers are suitable for packaged products like vegetable or fish fillets. For freezing, flat and relatively thin foods are placed in single layers between plates and a slight pressure is applied by moving plates together. This improves contact between the food and plates and thus increases the rate of heat transfer.   **Advantages:** Plate freezers include advantages like good economy and space utilization, low operating costs, minimum defrosting of condenser and high rate of heat transfer.   **Disadvantages:** High capital costs and suitability only for flat and thin foods are the major disadvantages.  A typical plate freezer is shown in Figure 13.9. Plate freezers may be batch, semi-continuous or continuous in operation.  **Fig 13.9: Plate freezer with a two-stage compressor and sea water condenser**  **2. Scraped surface freezer:** These are used for liquid as well as for semi-solid foods like ice cream. They consist of a jacket (freezer barrel) surrounding a high speed rotor, fitted with short blades. In ice-cream manufacture, the rotor scrapes frozen food from the wall of the freezer barrel and incorporates air. In scraped surface freezers, the freezing is very fast and up to 50% of the water is frozen within a few seconds. This results in very small crystals which are not detectable in the mouth and thus given a smooth creamy consistency to the product. The temperature is reduced between -4oC and -7oC. The frozen aerated mixture is then pumped into containers and finally the freezing is completed in hardening room.   **3. Contact freezers:** Contact freezing is one of the most efficient ways of freezing in terms of heat transfer mechanism. In contact freezing process, the product can be directly or indirectly contact with the freezing medium.  **a) For direct** contact freezers, the product being frozen is fully surrounded by the freezing medium, the refrigerant, maximizing the heat transfer efficiency. A schematic illustration is given in Figure-13.10.  **b) In case o**f indirect contact freezers, the product is indirectly exposed to the freezing medium while in contact freezers; the product is directly in contact with the belt or plate, which is in contact with the freezing medium. The material is being frozen is separated from the refrigerant by a conducting material, usually a steel plate. The mechanism of indirect contact freezer is shown in Figure 13.11. Indirect contact freezers generally provide an efficient medium for heat transfer, although the system has some limitations, especially when used for packaged foods due to resistance of package to heat transfer.  **Fig 13.10: Direct contact freezer. Fig 13.11: Indirect contact freezer.**  **B. Cryogenic Freezers** The Cryogenic freezers use solid or liquid carbon dioxide, liquid nitrogen directly in contact with the food and refrigeration is obtained as a pre-cooled substances. Cryogenic freezers used are carbon dioxide, liquid nitrogen or Freon. Cryogenic freezers are characterized by a change of state in the refrigerant (Cryogen) as heat is absorbed from the freezing food. The food is exposed to an atmosphere below -60°C through direct contact with liquefied gases such as nitrogen or carbon dioxide. The heat from the food provides the latent heat of vaporization or sublimation of the cryogen. The cryogen is in intimate contact with the food and rapidly removes heat from all surfaces co-efficient and rapid freezing. Liquid nitrogen and solid on liquid carbon dioxide are the commonly used refrigerants. Low initial investment and rather high operating costs are typical for cryogenic freezers. The limitation cryogenic freezer is the rate of excess cryogen residue in foods.  **1. Liquid nitrogen freezers:** Liquid nitrogen refrigerants are colourless and odourless. In these freezers, the packaged or unpackaged food travels on a perforated belt through a tunnel where product is cooled by gaseous nitrogen and frozen by liquid nitrogen spray. Liquid nitrogen, with a boiling temperature of -196°C at atmospheric pressure, is a by-product of oxygen manufacture. The refrigerant is sprayed into the freezer and evaporates both on leaving the spray nozzles and on contact with the products. Typical food products used in this system are fish fillets, seafood and fruits like berries. The temperature is either allowed to equilibrate at the required storage temperature (18-30oC) before the food is removed from the freezers or alternatively food is passed to a mechanical freezer to complete the freezing process. The use of gaseous nitrogen reduces the thermal shock to the food and recirculation fans increases the rate of heat transfer.   **2. Liquid carbon dioxide freezers:** Liquid carbon dioxide exists either as a solid or gas when stored at an atmospheric pressure. When the gas is released to the atmosphere at -70°C, half of the gas becomes dry-ice snow and the other half stays in the form of vapour. This unusual property of liquid carbon dioxide is used in a variety of freezing systems, one of which is a pre-freezing treatment before the product is exposed to nitrogen spray.   **C. Dehydro-Freezing** In this method of freezing, the freezing of food is preceded by the partial dehydration. The moisture of fruits and vegetables is removed up to 50% by dehydration, prior to freezing. The products which are dehydro-frozen are more stable and are better in quality.  **D. Freeze-drying** Freeze drying is also known as sublimation-drying or lyophilisation. The method involves freezing of the material by exposing to cold air followed by sublimation of ice in vacuum from frozen state to produce a dried product. The food is firstly frozen at -18oC on trays in lower chamber of the freeze drier and the frozen material is then dried initially at 30oC for 24 hours and then at 20oC under high vacuum of 0.1mm Hg in the upper chamber. In freeze drying process, the food material is composed of a frozen core and as the ice sublimes the plane of sublimation recedes from outer surface leaving a porous shell of the foodstuff. The heat supplied for latent heat of sublimation of about 2838 kJ/kg ice is conducted inward through layer of dried material. Water vapour also transferred through dried material and heat or mass transfer occurs simultaneously during freeze drying. |