Novel Technologies for Food Processing and Shelf Life Extension

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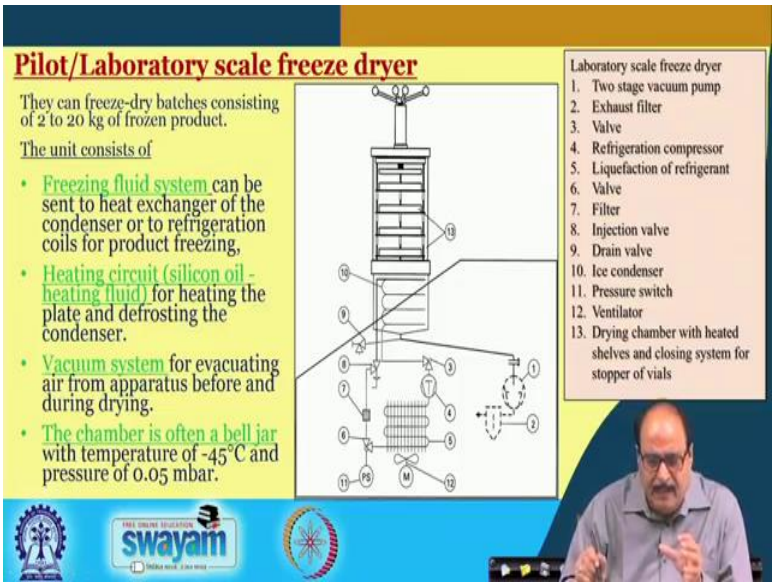
Lecture – 22
Freeze Drying (Part 2)

In the first part, the fundamental aspects of the freeze drying process were discussed. Now, in the second part of the freeze drying, the equipment(s), systems and product applications are elaborated.

Freeze dryers

The freeze dyers /freeze drying systems may be classified as pilot or laboratory scale and industrial or large scale freeze dryer. The industrial or large scale freeze dryers may be of multi batch type, continuous freeze dryer or tunnel freeze dryers. The continuous freeze dryers are again classified into two groups, continuous tray freeze dryer or continuous tray-less freeze dryer. The tray-less freeze dryers are different vibrational freeze dryer, circular plate dryers, vacuum spray freeze dryer, belt freeze dryers and atmospheric freeze dryers.

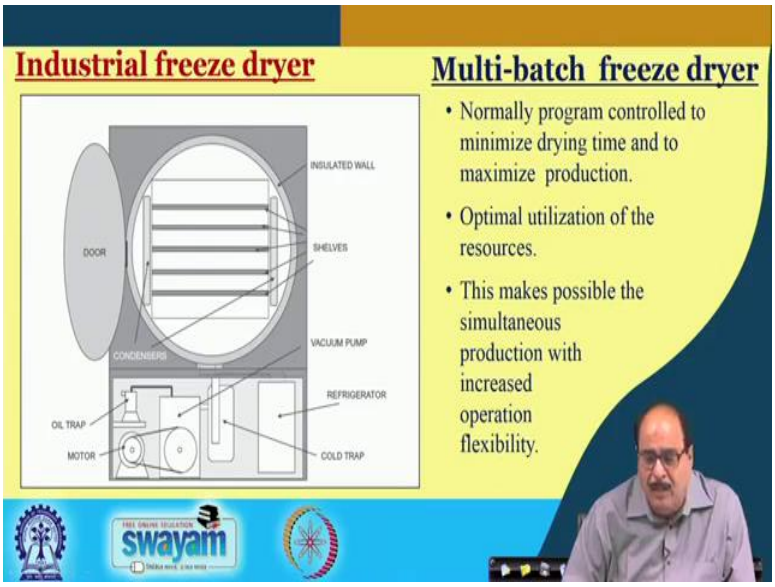


Pilot/Laboratory scale freeze dryer

The schematic of the laboratory scale or pilot scale freeze dryer is shown in figure. They can freeze-dry batches consisting of 2 to 20 kg of frozen product.

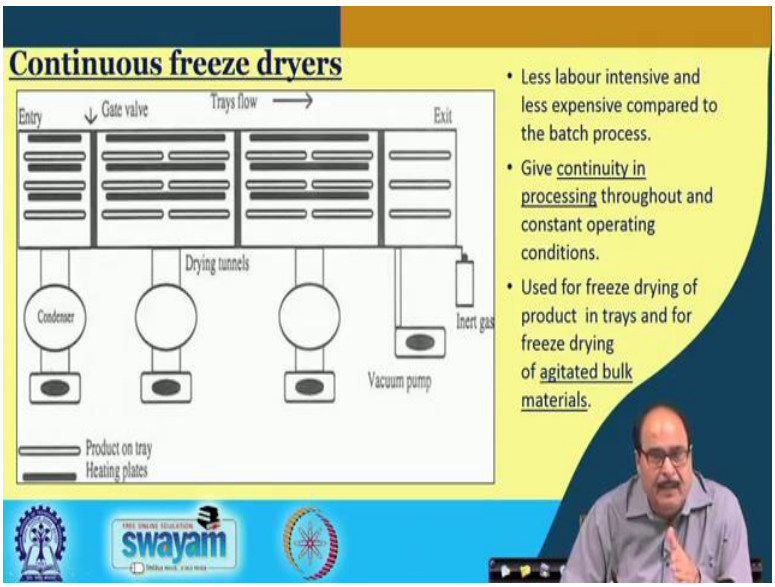
The unit consists of

- Freezing fluid system can be sent to heat exchanger of the condenser or to refrigeration coils for product freezing,
- Heating circuit (silicon oil -heating fluid) for heating the plate and defrosting the condenser.
- Vacuum system for evacuating air from apparatus before and during drying.
- The chamber is often a bell jar with temperature of -45°C and pressure of 0.05 mbar.



Industrial freeze dryer

These are normally program controlled to minimize drying time and to maximize production. Optimal utilization of the resources makes possible the simultaneous production with increased operation flexibility. The multi batch freeze dryer is shown in the figure. It consists of insulated chamber with condensers on both sides of the shelves which are used to keep products. The system is provided with the vacuum pump, refrigeration unit, oil and cold traps, etc.



Continuous freeze dryers

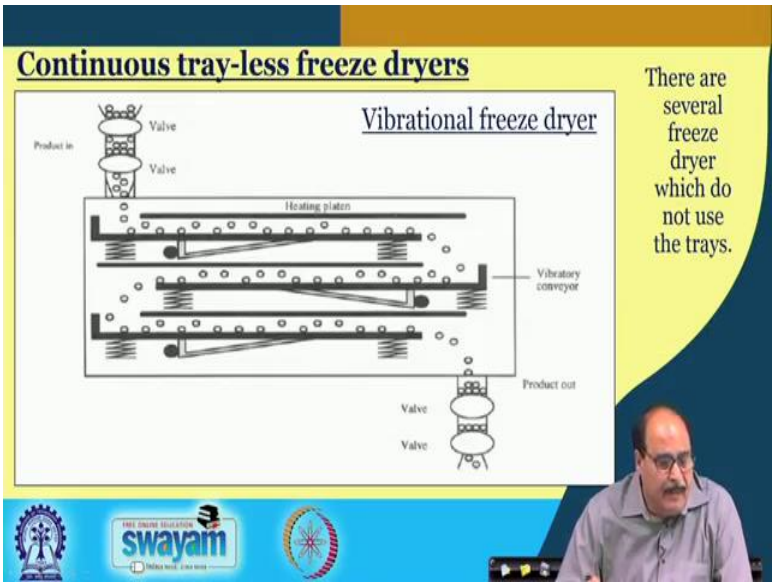
The other type of dryer is a continuous freeze dryer (see figure). Obviously, since it is a continuous system, it involves less labour and is also less expensive process as compared to that of the batch process. It gives continuity in processing throughout and the constant operating conditions can be maintained. It is generally used for freeze drying of product in trays as well as for agitated bulk materials. It has a drying tunnel with entry and exit lock which is divided into different sections. Every section is provided with the heating plates and condenser systems. The product is loaded in the tray and trays are moved through different chambers using the conveyor belt. The inert gas is used to open and close the lock.

Continuous tray freeze dryers

Similarly, the continuous tray freeze dryer is shown in figure. The product is placed on trays and moves along the dryer in a continuous manner. There are two main types depending on the type of the condenser used.

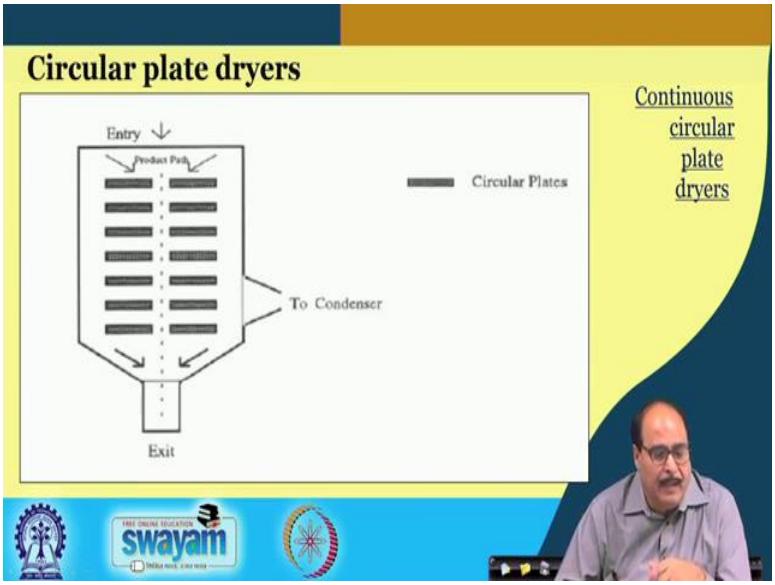
(i) Continuous tray freeze dryer where the condenser plates are alongside the tray heater assembly.

(ii) Continuous tray freeze dryer where the condenser plates are placed separately. The condenser joined to the first by a butterfly valve. Generally used in pharmaceutical industries as well as in freeze drying of foods.



Continuous tray-less freeze dryers

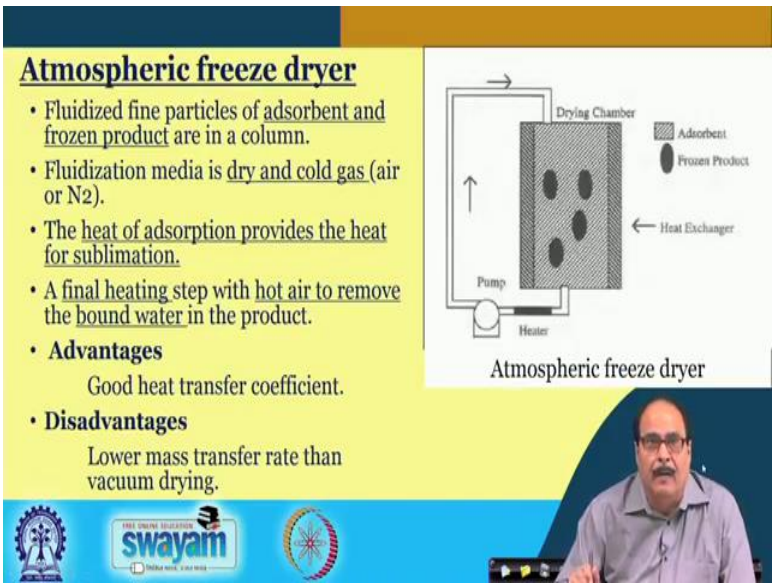
Continuous tray less freeze dryer is shown in the figure. In this system, the vibrational conveyor is used instead of the trays and the heating plates are used to maintain temperature. The vibration of the conveyor causes the movement of material from the inside to product end.



Circular plate dryers

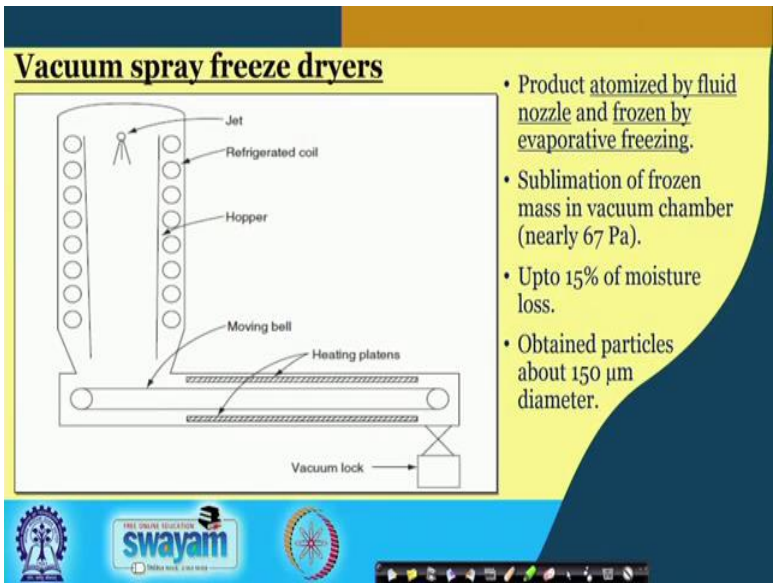
The other type is the circular plate dryer, where the circular plates, heating platens and the assembly to condenser, etc. are provided. The material moves from one plate to other

plate, and finally, comes to the bottom in dried state. The pictorial or schematic presentation of a circular plate dryer is shown in figure.



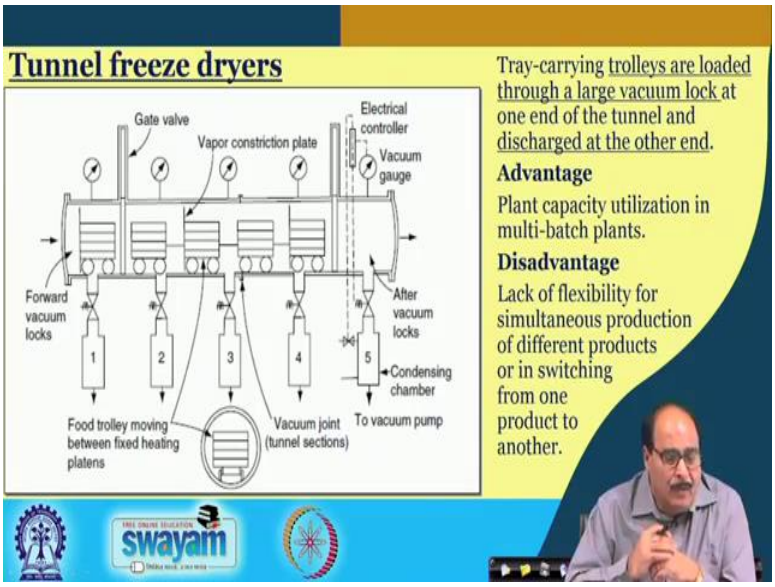
Atmospheric freeze dryer

The schematic presentation of atmospheric freeze dryer is shown in figure. Fluidized fine particles of adsorbent and frozen product are put inside a column or drying chamber. Fluidization media is dry and cold gas (air or N_2). The heat of adsorption provides the heat for sublimation. A final heating step with hot air is adopted to remove the bound water in the product. The advantage of the system is that it provides good heat transfer coefficient, but the disadvantage is the lower mass transfer rate than vacuum drying.



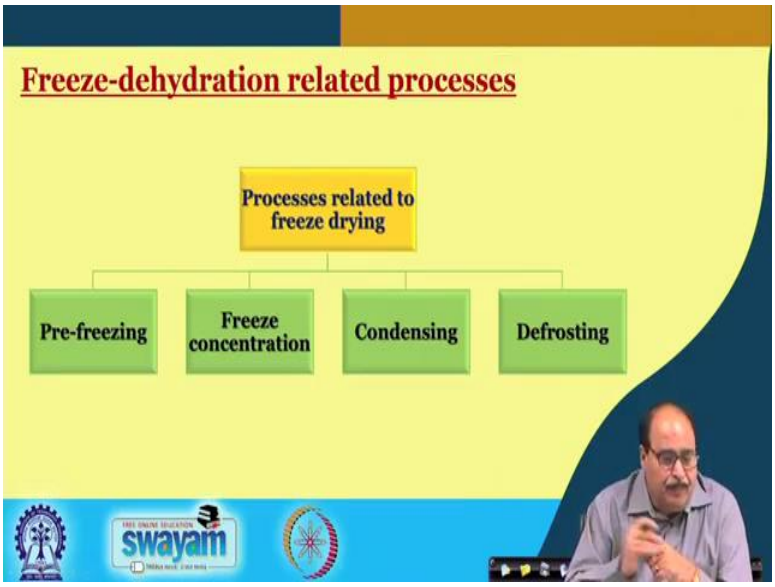
Vacuum spray freeze dryers

The schematic of vacuum spray freeze dryers is shown in figure which contain refrigerated coil, atomizers (spray jet), moving belt, heating platens and hopper. Product is atomized by fluid nozzle in the form of droplets and gets frozen by evaporative freezing. The frozen mass is allowed to fall on the moving belt which comes in contact with the heating platens in a vacuum chamber. The heat of sublimation is provided to the frozen mass in vacuum chamber (nearly 67 Pa). In this process, upto 15% of moisture loss in the product is reported in the literature and the size of obtained particles were about 150 µm diameter.



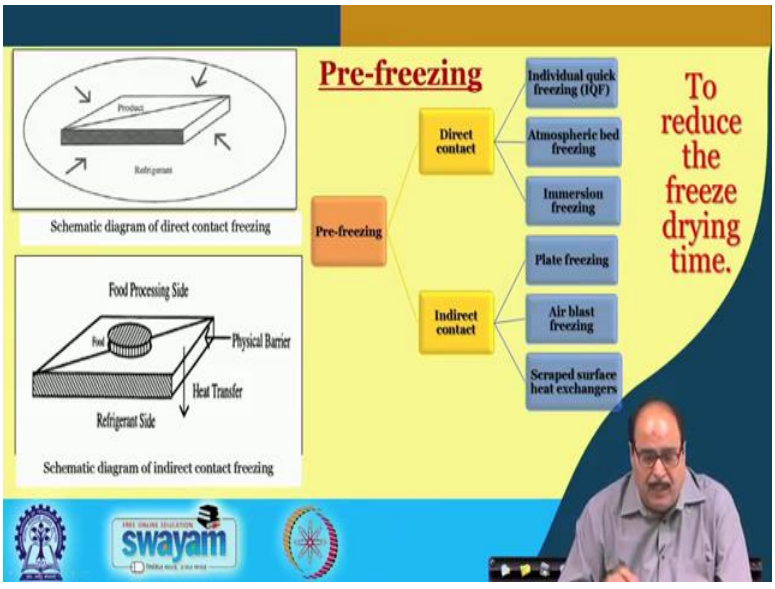
Tunnel freeze dryers

Tunnel freeze dryer are similar to the continuous tray freeze dryer. The frozen food products are loaded in the trolleys which are passed through the vacuum chambers. The chamber is provided with entry gate and exit gate valves, forward vacuum locks, condenser, etc. Tray-carrying trolleys are loaded through a large vacuum lock at one end of the tunnel and discharged at the other end. The plant capacity utilization is an advantage in multi batch plants, but lack of the flexibility for simultaneous production of different products or in switching from one product to other, is generally difficult.



Freeze-dehydration related processes

There are four important processes related to freeze drying. Those are pre freezing, freeze concentration, condensing and defrosting. These require meticulous control to ensure the process economy and quality of the final processed product.



Pre-freezing

Pre-freezing is done to reduce the freeze drying time during freezing process. It is classified as direct contact freezing or indirect contact freezing.

(a) Direct contact freezing

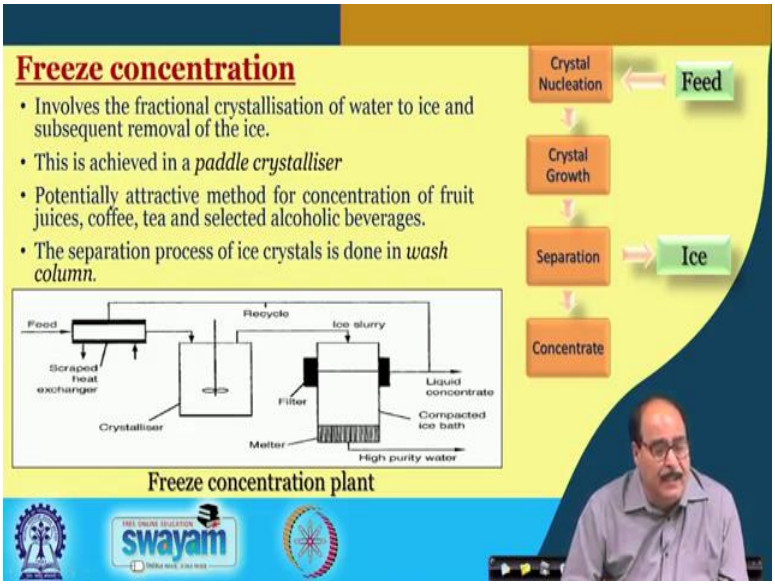
Food material in any form which is to be frozen comes in direct contact with the freezing media.

i. Individual quick freezing (IQF)
ii. Atmospheric bed freezing
iii. Immersion freezing

(b) Indirect contact freezing

There is no contact between the food material and freezing medium.

i. Plate freezing
ii. Air blast freezing
iii. Scraped surface heat exchanger



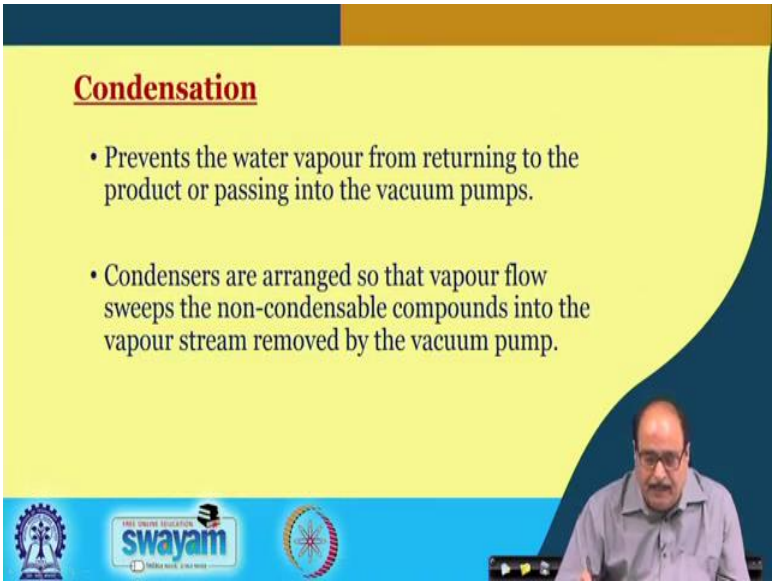
Freeze concentration

Freeze concentration is another important aspect in the freeze drying processes particularly required to reduce the cost of the product and to improve the process economy otherwise it becomes a very costly process to remove the moisture from the food material.

Freeze concentration involves the fractional crystallisation of water to ice and subsequent removal of the ice. It includes the process of crystal nucleation, crystal growth during freezing process and then ice separated from the system, either through centrifugation process or by other system. This is achieved in a paddle crystalliser. It is a potentially

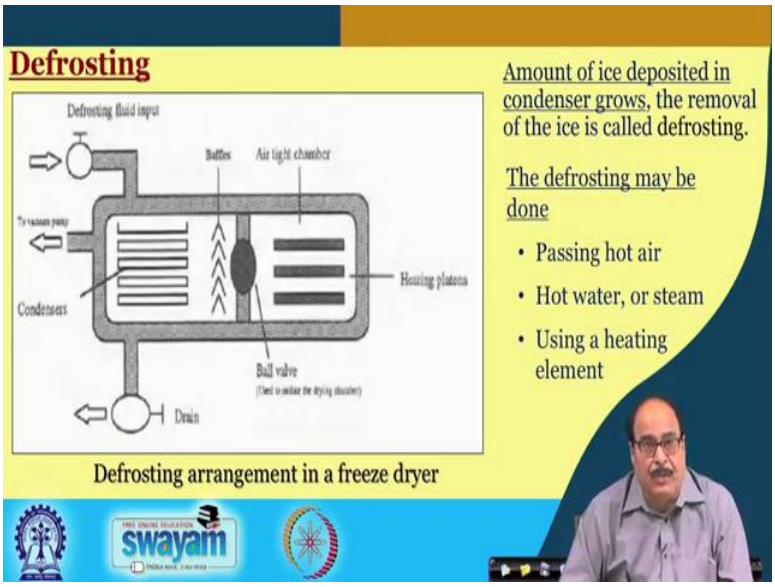
attractive method for concentration of fruit juices, coffee, tea and selected alcoholic beverages. The separation of ice crystals is done in wash column.

The freeze concentration process is shown in the figure which consists of the scraped heat exchanger, crystalliser, filter and melter. The food material is fed to the crystalliser through the scraped heat exchanger after precooling where crystallisation takes place. When the desired final concentration is achieved, the concentrate is used for the next process of the freeze drying. The centrifugal system may be used to remove the ice crystals.



Condensation

It prevents the water vapour from returning to the product or passing into the vacuum pump. Condensers are arranged so that the vapour flow sweeps the non-condensable compounds into the vapour stream removed by the vacuum pump.

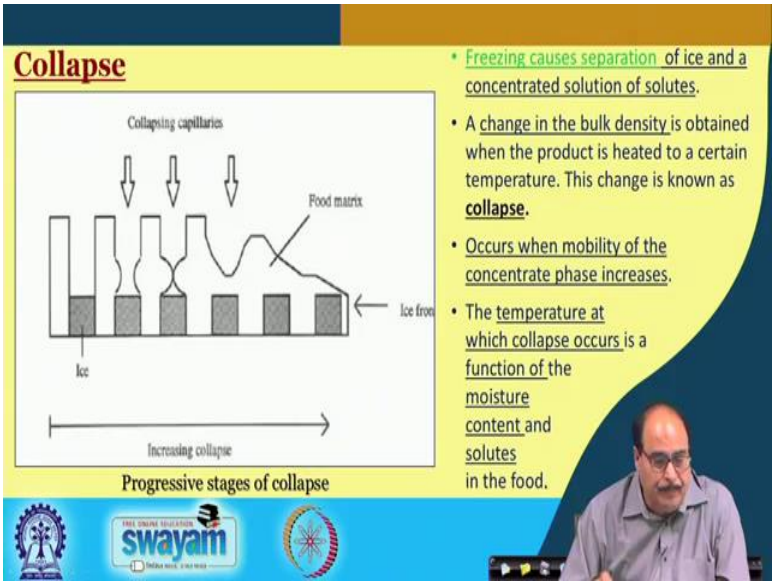


Defrosting

Defrosting is the removal of ice deposited in the condenser during the progress of the freeze drying process. It should be continuously removed to get the process efficiency.

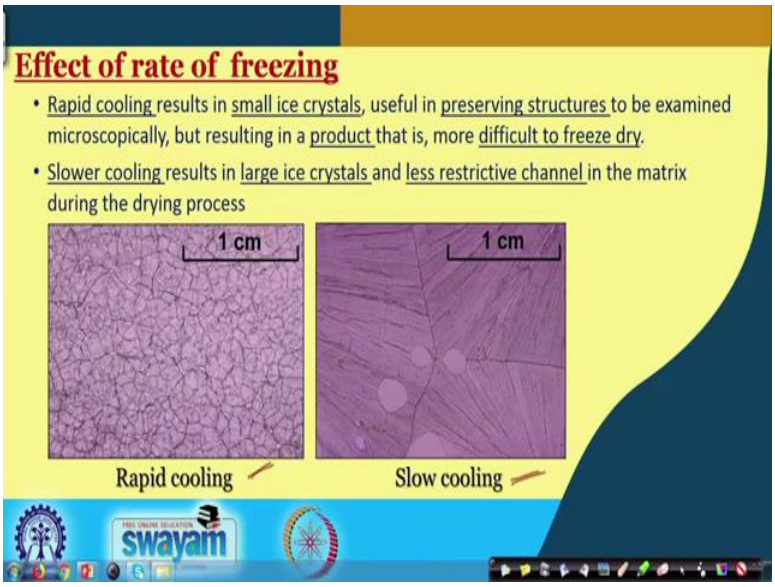
The defrosting may be done by

- Passing hot air
- Hot water, or steam
- Using a heating element



Collapse

Freezing causes separation of ice and a concentrated solution of solutes. A change in the bulk density is obtained when the product is heated to a certain temperature. This change is known as collapse. It occurs when mobility of the concentrate phase increases. The temperature at which collapse occurs is a function of the moisture content and solutes in the food.



Effect of rate of freezing

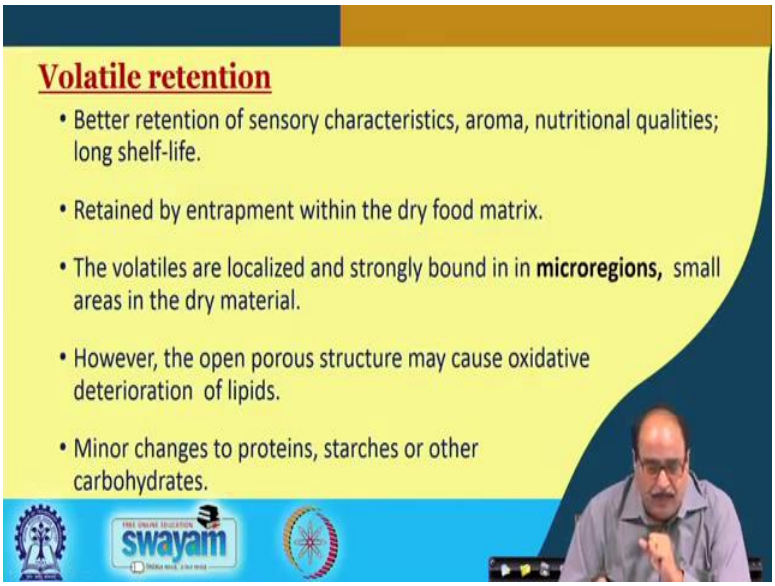
Another factor affecting the quality of the product is the rate of freezing i.e. use of freezing process such as rapid or slow freezing. It affects the structure and texture of the dried material.

- Rapid cooling results in small ice crystals, useful in preserving structures to be examined microscopically, but resulting in a product that is, more difficult to freeze dry.

- Slower cooling results in large ice crystals and less restrictive channel in the matrix during the drying process

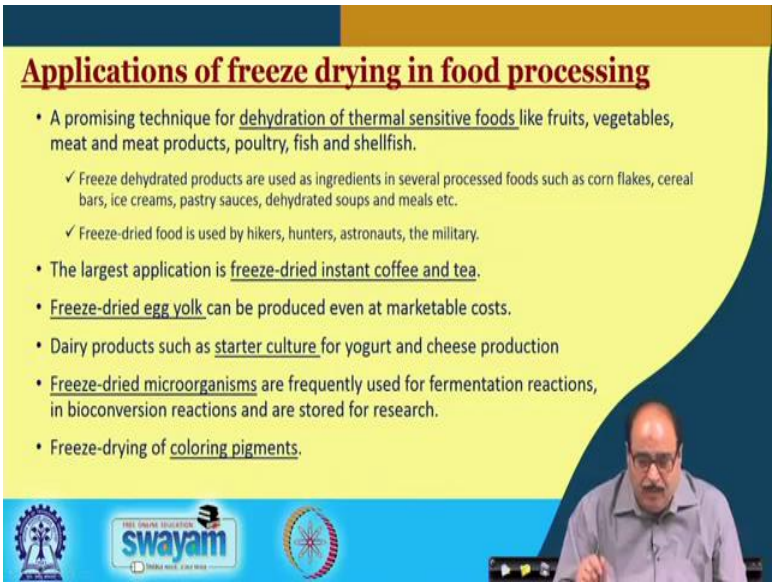
The effects of the rapid cooling and slow cooling can be seen in the figures.

These two phenomena i.e. the collapse and the freezing rate are the important factors which contribute to the product quality during freeze drying process and these should be properly analysed and considered.



Volatile retention

Freeze drying imparts better retention of sensory characteristics, aroma, nutritional qualities, and offers long shelf life to the products. The volatiles are retained by entrapment within the dry food matrix. The volatiles are localized and strongly bound in in microregions, small areas in the dry material. However, the open porous structure may cause oxidative deterioration of lipids. Minor changes to proteins, starches or carbohydrates may take place.



Applications of freeze drying in food processing

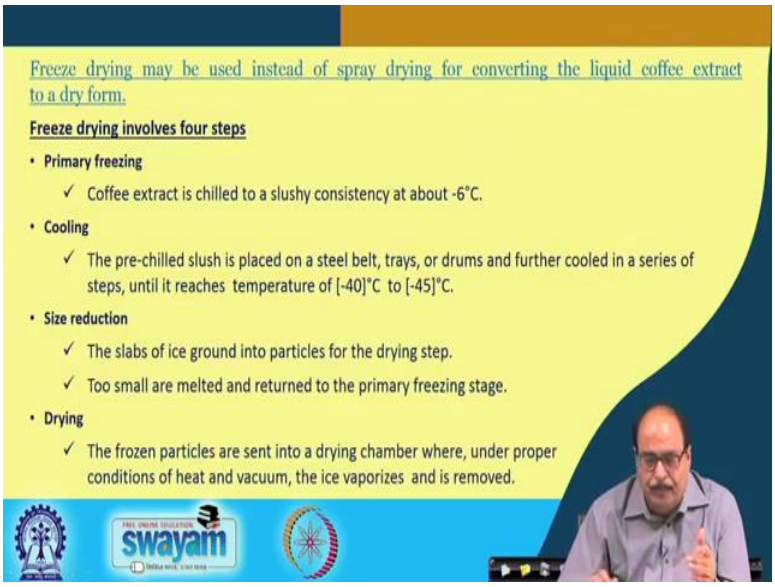
As far as the application of freeze drying in food processing is concerned, although it is considered to be a costlier process, but still it is recommended or rather it is being used for large scale processing of the various products. The applications of the freeze drying are listed below:

- It is a promising technique for dehydration of thermal sensitive foods like fruits, vegetables, meat and meat products, poultry, fish and shellfish.
- Freeze dehydrated products are used as ingredients in several processed foods such as corn flakes, cereal bars, ice creams, pastry sauces, dehydrated soups and meals etc.
- Also, freeze-dried food is used by hikers, hunters, astronauts, and military. The largest application is freeze-dried instant coffee and tea.
- Freeze-dried egg yolk can be produced even at marketable costs. Dairy products such as starter culture for yogurt and cheese production.
- Freeze-dried microorganisms are frequently used for fermentation reactions, in bioconversion reactions and are stored for research.
- Freeze-drying of coloring pigments.

Freeze dried instant coffee

In the market, freeze dried coffee are available because the quality obtained after the freeze drying is much better but little more cost is involved in the process. The steps involved in the process are extraction, filtration and concentration, recovery of aromatics, reserving the aroma and flavour, primary freezing, cooling, size reduction, drying, aromatization and packaging.

This is the flow diagram for the manufacture of freeze dried instant tea and coffee is shown. In the making of coffee or even instant tea, first a brew is made which is filtered and concentrated using suitable equipment. The volatile aromas are recovered and they are kept aside. The de-aromatized concentrated coffee or tea extracts is frozen. The frozen mass is then cooled and ground for size reduction. The ground mass is subjected to the sublimation by using appropriate freeze drying equipment. After sublimation, the aroma recovered earlier again is added into the dried material and finally, the product is packaged.



Freeze drying may be used instead of spray drying for converting the liquid coffee extract to a dry form.

Freeze drying involves four steps

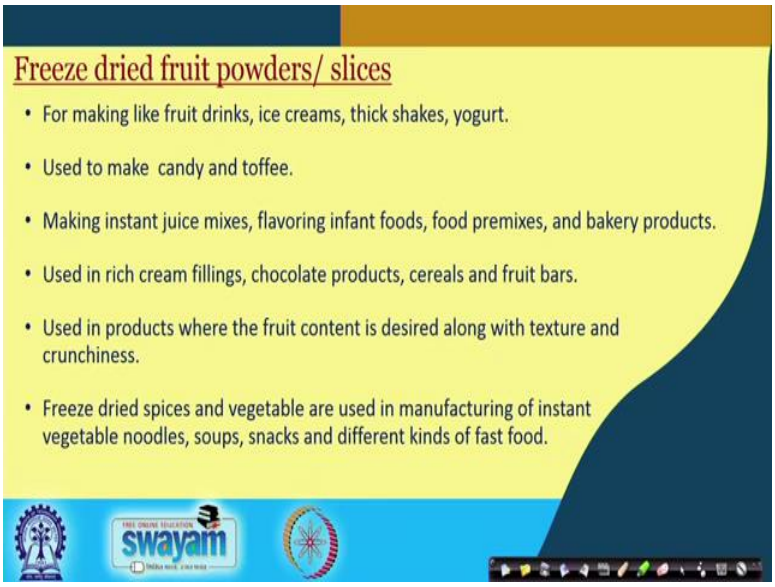
- **Primary freezing**

  Coffee extract is chilled to a slushy consistency at about -6°C.
- **Cooling**

  The pre-chilled slush is placed on a steel belt, trays, or drums and further cooled in a series of steps, until it reaches temperature of -40°C to -45°C.
- **Size reduction**

  The slabs of ice ground into particles for the drying step. Too small are melted and returned to the primary freezing stage.
- **Drying**

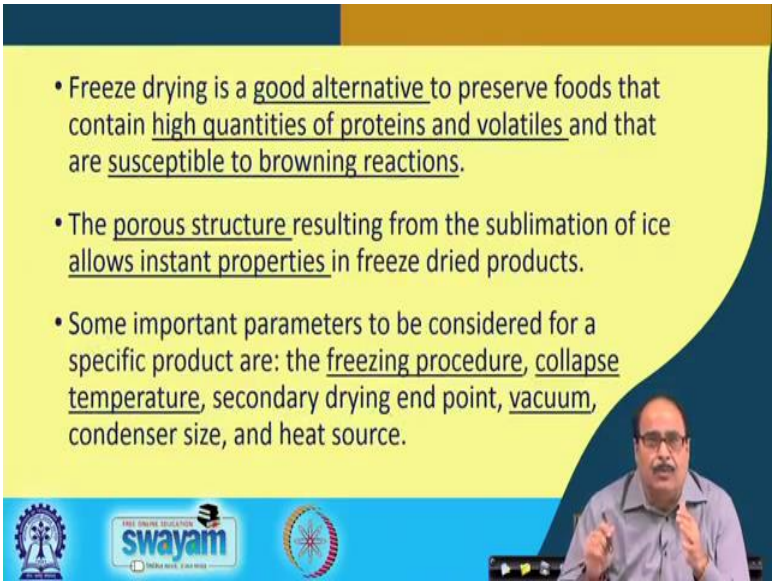
  The frozen particles are sent into a drying chamber where, under proper conditions of heat and vacuum, the ice vaporizes and is removed.



Freeze dried fruit powders/ slices

The freeze drying technology can utilized -

- For making like fruit drinks, ice creams, thick shakes, yogurt.
- For making candy and toffee.
- For making instant juice mixes, flavoring infant foods, food premixes, and bakery products.
- In rich cream fillings, chocolate products, cereals and fruit bars.
- In products where the fruit content is desired along with texture and crunchiness.
- For making freeze dried spices and vegetable are used in manufacturing of instant vegetable noodles, soups, snacks and different kinds of fast food.



Freeze drying is a good alternative to preserve foods that contain high quantities of proteins and volatiles and that are susceptible to browning reactions. The porous structure resulting from the sublimation of ice allows instant properties in freeze dried products. Some important parameters to be considered for a specific product are: the freezing procedure, collapse temperature, secondary drying end point, vacuum, condenser size, and heat source.