What is freezing?

A method of food preservation whereby:

- ✓ the heat is removed (heat of fusion)
- ✓ temperature of the food is reduced below its freezing point ($T<T_f$)
- ✓ and a portion of water in food undergoes a change in state to form ice crystals (a_w lowered)

OR

Freezing is a phase transition in which a liquid turns into a solid when its temperature is lowered below its freezing point.

Goal of freezing:

- ➢ To prevent growth of microorganisms by
  - –Killing some bacteria (little effect)
  - –Reducing water activity
  - –Mechanical formation of ice crystals
  - –Osmotic changes in cell fluids
  - –Tying up some free water
- ➢ To lower temperature enough to slow down chemical reactions
  - – (every 10°C decrease in temperature halves the reaction rate)

Freezing point/Freezing temperature depression

The freezing point of pure water is 0^0C; at this temperature, the formation of ice crystals within the water phase results in a concentration of water molecules. Thus the ice crystals of pure water are in the solid phase.

Since all food products contain relatively large amounts of moisture or water in which various solutes are present, the actual or initial freezing point of the water in the product will be depressed to some level below that expected for pure water. The magnitude of this freezing point depression is due to the molecular weight and concentration of the solute in the food product and in solution in the water.

The freezing point/ freezing temperature depression equation for an ideal solution can be expressed as-

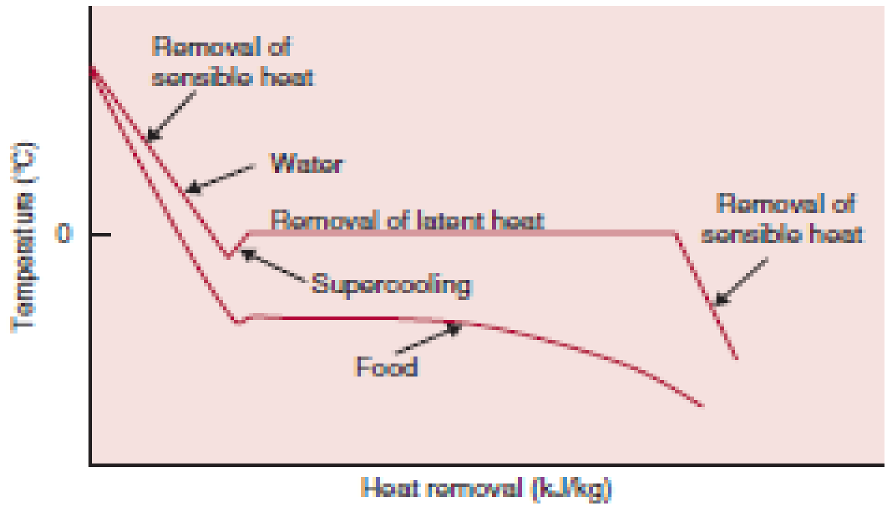
$$\frac{\lambda}{R_g}\left[\frac{1}{T_{A_0}} - \frac{1}{T_A}\right] = \ln X_A$$

Where, λ= molar latent heat of fusion, T_{Ao} = is the equilibrium freezing temp. Depression; T_A = Absolute temperature; X_A = mole fraction of water in solution.

when expressing the mole fraction of solute in terms of molality (m), the commonly used freezing point depression equation in dilute solution is-

$$\Delta T_F = R_g T_{Ao}^2 m /(L\times1000)$$

where L= latent heat of fusion, m= molality of that solutes



Methods of freezing:

There are various methods of freezing:

1. Sharp freezing (Slow freezing)

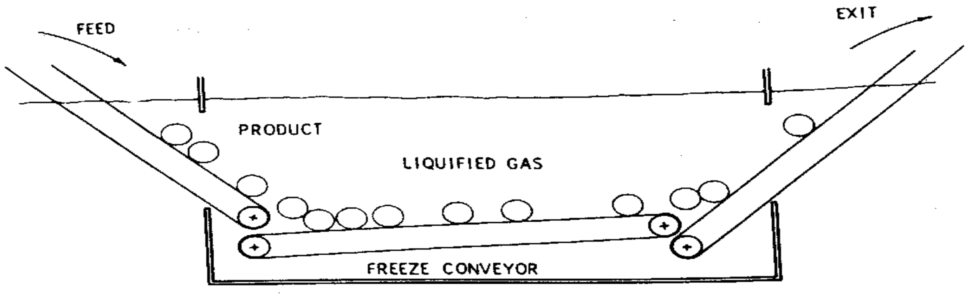
This technique, first used in 1861, involves freezing by circulation of air, either naturally or with the aid of fans. The temperature may vary from -15 to -29° C and freezing may take from 3 to 72 hours. The ice crystals formed are large and rupture the cells. The thawed tissue cannot regain its original water content. The first products to be sharp frozen were meat and butter. Nowadays freezer rooms are maintained at -23 to -29° C or even lower, in contrast to the earlier temperature of -18° C.

2. Quick freezing

In this process the food attains the temperature of maximum ice crystal formation (0 to -4° C) in 30 minutes or less. Such a speed results in formation of very small ice crystals and hence minimum disturbance of cell structure. Most foods are quick frozen by one the following three methods:

A. By direct immersion

Since liquids are good heat conductors, food can be frozen rapidly by direct immersion in a liquid such as brine or sugar solution at low temperature. Berries in sugar solution, packed fruit juices and concentrates are frozen in this manner. The refrigeration medium must be edible and capable of remaining unfrozen at -18° C and slightly below.



6.11 figure A continuous immersion freezing system.

Advantages:

i. There is perfect contact between the refrigeration medium and the product, hence the rate of heat transfer is very high.

ii. Fruits are frozen with a coating of syrup which preserves the colour and flavor during storage.

iii. The frozen product is not a solid block because each piece is separate.

Disadvantages:

i. Brine is a good refrigerating medium but it cannot be used for fruits.

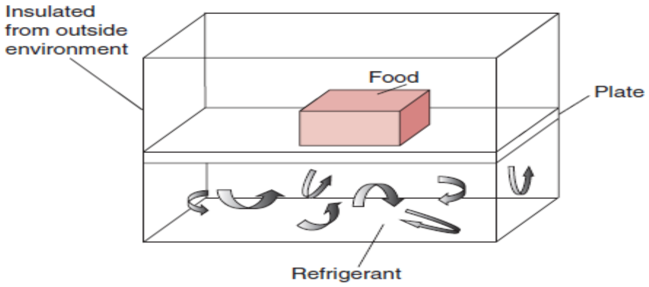
ii. It is difficult to make a syrup that will not become viscous at low temperature

iii. The refrigeration temperature must be carefully controlled, as at high temperature the medium will enter the product by osmosis and at low temperature the medium may freeze solid.

iv. It is very difficult to maintain at a definite concentration and also to keep it free from dirt and contamination.

B. By indirect contact with refrigerant

Indirect freezing may be defined as freezing by contact of the product with a metal surface which is itself cooled by freezing brine or other refrigerating media. This is an old method of freezing in which the refrigerant at -18 to 46° C flows.



C. By air fast (Air blast freezing)

This refers to vigorous circulation of cold air in order to freeze the product. Freezing is done by placing the foodstuffs on trays or on a belt which are then passed slowly through an insulated tunnel containing air in it. Here the air temperature is approximately -18 to -34° C or even lower. This process is economical and a variety of sizes and shapes can be accommodated.

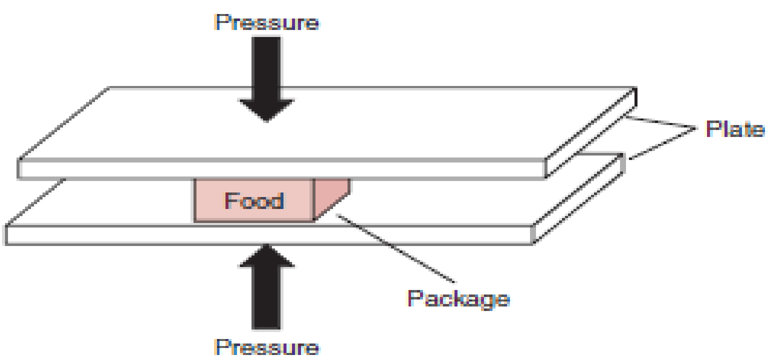
a) Fluidized bed freezing

This is a modification of air blast freezing. The foodstuff is fluidized to form a bed of particles, and then frozen. Air is forced upward through the belt to partially lift or suspend the particles. If the air is appropriately cooled, drying can be done quite speedily. The depth of the bed of particles varies with the product. Fluidized bed freezing has certain advantages:

- ✓ it gives more sufficient heat transfer and more rapid rates of freezing
- ✓ extent to which the product gets dehydrated is less, and
- ✓ defrosting of equipment is required less frequently

b) Plate freezing

In this method, food products are placed in contact with a cold surface. The cooling temperature of the metal surface is accomplished by using cold brine or vaporizing refrigerants. This is suitable for packaged food products which may rest on/ slide against or be pressed between cold metal plates. The process is also suitable for unpacked foodstuffs, e.g., shrimps, which can be frozen in cylindrical scraped-surface heat exchangers. Contact plate freezing is quite economical. It minimizes problems of dehydration, defrosting of equipment and packet bulging.



The advantages claimed for quick freezing over slow freezing are:

i. Smaller ice crystals are formed, hence there is less mechanical destruction of intact cells of the food,

ii. Period of ice formation is shorter, therefore, there is less time for diffusion of soluble material and for separation of ice,
iii. More rapid prevention of microbial growth, and
iv. More rapid slowing down of enzyme action.

D. **Cabinet freezing system**

The product is placed in a package prior to freezing, and the packages are placed on trays before they are moved into the freezing system. These types of freezing systems operate as batch systems, with ti1e freezing time established by the length of time that the product remains in the cabinet. The environment in the room is maintained at a low temperature, and air movement is established by fans within the cabinet.

E. **Scrapped surface freezing system**

These types of freezing systems utilize a scraped surface heat exchanger as a primary component of the continuous system used to convert liquid product into a frozen slurry. In these systems, the outer wall of the heat exchanger barrel represents the barrier between the product and the low-temperature refrigerant used for product freezing.

For freezing liquid foods, the residence time in the freezing compartment is sufficient to decrease the product temperature by several degrees below the temperature of initial ice-crystal formation. At these temperatures, between 60 and 80% of the latent heat has been removed from the product, and the product is in the form of a frozen slurry. In this condition, the product flows quite readily and can be placed in a package for final freezing in a low-temperature refrigerated space. The scraped-surface heat exchanger ensures efficient heat exchange between the slurry and the cold surface.
for example: scrapped surface heat exchanger used in ice-cream hardening.

F. **Individual quick freezing (IQF) system**

Individual Quick Freezing (I.Q.F.) is the latest technology available in freezing and with the advent of the same, it is now possible to preserve and store raw fruit and vegetables in the same farm-fresh condition for more than a year, with the colour, flavour and texture of produce remaining as good as fresh from the farm. In individual quick freezing, very low temperatures (-30°C to - 40°C) is maintained to halt the activities of the microorganisms that cause decay and deteriorate foodstuffs.

3. Cryogenic freezing

Although most foods retain their quality when quick frozen by the above methods, a few (mushrooms, sliced tomatoes, whole strawberries and raspberries) require ultrafast freezing.

Such materials are subjected to cryogenic freezing which is defined as freezing are liquid nitrogen and liquid carbon dioxide. In the former case, freezing may be achieved by

i. Immersion in the liquid
ii. Spraying of liquid, or
iii. Circulation of its vapour over the product to be frozen.

4. Dehydro-freezing

This is a process where freezing is preceded by partial dehydration. In case of some fruits and vegetables about 50 per cent of the moisture is removed by dehydration prior to freezing. This has been found to improve the quality of the food. Dehydration does not cause deterioration and dehydro-frozen foods are relatively more stable.

5. Freeze drying

In this process food is first frozen at -18° C on trays in the lower chamber of a freeze drier and the frozen material dried (initially at 30° C for 24 hours and then at 20° C) under high vacuum (0.1 mm Hg) in the upper chamber. Direct sublimation of the ice takes place without passing through the intermediate liquid stage. The product is highly hygroscopic, excellent in taste and flavor and can be reconstituted readily. Mango pulp, orange juice concentrate, passion fruit juice and guava pulp are dehydrated by this method.

Chemical changes during freezing

Fresh fruits and vegetables, when harvested, continue to undergo chemical changes, which can cause spoilage and deterioration of the product. This is why these products should be frozen as soon after harvest as possible and at their peak degree of ripeness. Fresh produce contains chemical compounds called enzymes, which cause the loss of color, loss of nutrients, flavor changes, and color changes in frozen fruits and vegetables. These enzymes must be inactivated to prevent such reactions from taking place.

The blanching process inactivates enzymes in vegetables. Blanching is the exposure of the vegetables to boiling water or steamfor a brief period of time. The vegetable must then be rapidly cooled in ice water to prevent it from cooking. Contrary to statements in some publications on home freezing, in most cases blanching is absolutely essential for producing quality frozen vegetables. Blanching also helps to destroy microorganisms on the surface of the vegetable and to make some vegetables, such as broccoli and spinach, more compact. The major problem associated with enzymes in fruits is the development of brown colors and loss of vitamin C. Because fruits are usually served raw, they are not blanched like vegetables. Instead, enzymes in frozen fruit are controlled by using chemical compounds, which interfere with deteriorative chemical reactions. The most common control chemical is ascorbic acid (vitamin C). Ascorbic acid may be used in its pure form or in commercial mixtures with sugars. Some directions for freezing fruits also include temporary measures to control enzyme-activated browning. Such temporary measures include soaking the fruit in dilute vinegar solutions or coating the fruit with sugar and lemon juice. However, these latter methods do not prevent browning as effectively as treatment with ascorbic acid. Another group of chemical changes that can take place in frozen products is the development of rancid oxidative flavors through contact of the frozen product with air. Using a wrapping material, which does not permit air to pass into the product, can control this problem. It is also advisable to remove as much air as possible from the freezer bag or container to reduce the amount of air in contact with the product.

Textural changes during freezing

County extension offices frequently receive questions about whether certain fruits, vegetables, or mixtures of either may be successfully frozen. Such questions can be answered by knowing the effect of freezing on various plant tissues.

Water makes up over 90 percent of the weight of most fruits and vegetables. This water and other chemical substances are held within the fairly rigid cell walls, which give support structure, and texture to the fruit or vegetable. Freezing fruits and vegetables actually consists of freezing the water contained in the plant cells.

When the water freezes, it expands and the ice crystals cause the cell walls to rupture. Consequently, the texture of the produce, when thawed, will be much softer than it was when raw. This textural difference is especially noticeable in products, which are usually consumed raw. For example, when a frozen tomato is thawed, it becomes mushy and watery. This explains why celery, lettuce, and tomatoes are not usually frozen (Table 1) and is the reason for the suggestion that frozen fruits, usually consumed raw, be served before they have completely thawed. In the partially thawed state, the effect of freezing on the fruit tissue is less noticeable.

Textural changes due to freezing are not as apparent in products which are cooked before eating because cooking also softens cell walls. These changes are also less noticeable in high starch vegetables, such as peas, corn, and lima beans.

Changes caused by fluctuating temperatures

To maintain top quality, frozen fruits and vegetables should be stored at 0° F or lower. This temperature is attainable in separate freezer units and in some combination refrigerator-freezers. A freezer thermometer can help you determine the actual temperature of your freezer. If your freezer has number temperature settings, such as from 1 to 9, check the manual to see what settings are recommended for different uses.

Storing frozen foods at temperatures higher than 0° F increases the rate at which deteriorative reactions can take place and can shorten the shelf life of frozen foods. Do not attempt to save energy in your home by raising the temperature of frozen food storage above 0° F.

Fluctuating temperatures in the freezer can cause the migration of water vapor from the product to the surface of the container. This defect is sometimes found in commercially frozen foods, which have been improperly handled.

Moisture loss

Dehydration is of particular interest because it is less obvious, harder to quantify and often has a large economic impact. It is the result of the inevitable loss of water vapor that occurs when a product is exposed to air or another gaseous medium. Frost accumulating on the coil surfaces provides a gross indicator of the rate of dehydration moisture loss.

Fast cooling and freezing greatly reduce dehydration for two reasons. First, the temperature of the product is reduced quickly, which minimizes the evaporation rate (the rate at which water moves from the product into the air). Second, fast freezing minimizes the length of time the product is evaporating water at a higher rate. To achieve fast cooling and freezing, cold air is not enough. It needs to be distributed efficiently over the product surface by an effective airflow design.

Freezer burn

Freezer burn is a condition that occurs when frozen food has been damaged by dehydration and oxidation, due to air reaching the food. It is generally caused by food not being securely wrapped in air-tight packaging. Freezer burn appears as grayish-brown leathery spots on frozen food, and occurs when air reaches the food's surface and dries the product. Color changes result from chemical changes in the food's pigment. Freezer burn does not make the food unsafe; it merely causes dry spots in foods. Provided that the freezer burns are removed before cooking, the food remains usable and edible.

Microbial growth in the freezer

The freezing process does not actually destroy the microorganisms, which may be present on fruits and vegetables. While blanching destroys some microorganisms and there is a gradual decline in the number of these microorganisms during freezer storage, sufficient populations are still present to multiply in numbers and cause spoilage of the product when it thaws. For this reason it is necessary to carefully inspect any frozen products which have accidentally thawed by the freezer going off or the freezer door being left open.

Nutrient value of frozen foods

Freezing, when properly done, is the method of food preservation, which may potentially preserve the greatest quantity of nutrients. To maintain top nutritional quality in frozen fruits and vegetables, it is essential to follow directions contained in this leaflet for pretreatment of the vegetables, to store the frozen product at 0° F and to use it within suggested storage times.

Factor Affecting the Quality of Frozen Food

5 factors are importance in the maintenance of the quality of foods in frozen storage

- **Solute concentration effects:**
    - ✓ Maintaining the quality of most food
    - ✓ Food must be frozen to a solid/nearly so to maintain good quality during frozen storage
    - ✓ A partially unfrozen are will deteriorate with respect to texture, colour, flavour and other properties
- **Ice-Crystal Size:**
    - ✓ Freeze rapidly it forms small crystal of ice
    - ✓ Rate of freezing is slow, the ice crystal size is large and clusters are also formed leading to physical rupture of cells
- **Rate of freezing:**

  Freezing produce as quickly as possible can control the extent of cell wall rupture. In rapid freezing, a large number of small ice crystals are formed. These small ice crystals produce less cell wall rupture than slow freezing which produces only a few large ice crystals.
- **Final Temperature:** Maintain of final temperature to an accuracy of ± 1.0° C is important.
- **Intermittent thawing:** Quick final thawing is better than slow thawing

Thawing: the process whereby heat changes something from a solid to a liquid