ZERO LEARNING ACADEMY
MOVING TOWARDS AI BASED LEARNING

Freezing time, freezing rate and thawing time

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Freezing time

- The freezing time is the time taken to lower the temperature of the product from its initial temperature to a given temperature at its thermal centre.
- The final temperature at the thermal centre is therefore selected to ensure that the average product temperature has been reduced to this storage value.
- The recommended storage temperature for frozen fish in the UK for a period of 1 year is -30°C and, to ensure that the fish are frozen quickly, the temperature of the freezer must be lower than this.
- The surface of the fish in a freezer will be quickly reduced to near the freezer temperature of say -36°C.
- Thus when the warmest part at the thermal centre is reduced to -20°C, the average temperature of the fish will be close to the required storage temperature of -30°C.
- The freezing time, in this particular case, will therefore be defined as the time taken for the warmest part of the fish, at the thermal centre, to be reduced to -20°C.

What is thermal centre ?

- The **thermal centre** of a product is the point within the product which has the warmest temperature **at** the end of the **freezing** process.

Factors affecting freezing time

1. Freezer type
2. Freezer operating temperature
3. Refrigeration system and operating condition
4. Air speed in an air blast freezer
5. Product temperature
6. Product thickness
7. Product shape
8. Product contact area and density
9. Product packaging
10. Type of product

Note: The above factors will determine the overall heat transfer coefficient and hence the freezing time.

1. Freezer type

- The type of freezer will greatly influence the freezing time.
- For example, due to improved surface heat transfer, a product will normally freeze faster in an immersion freezer than in an air blast freezer operating at the same temperature.

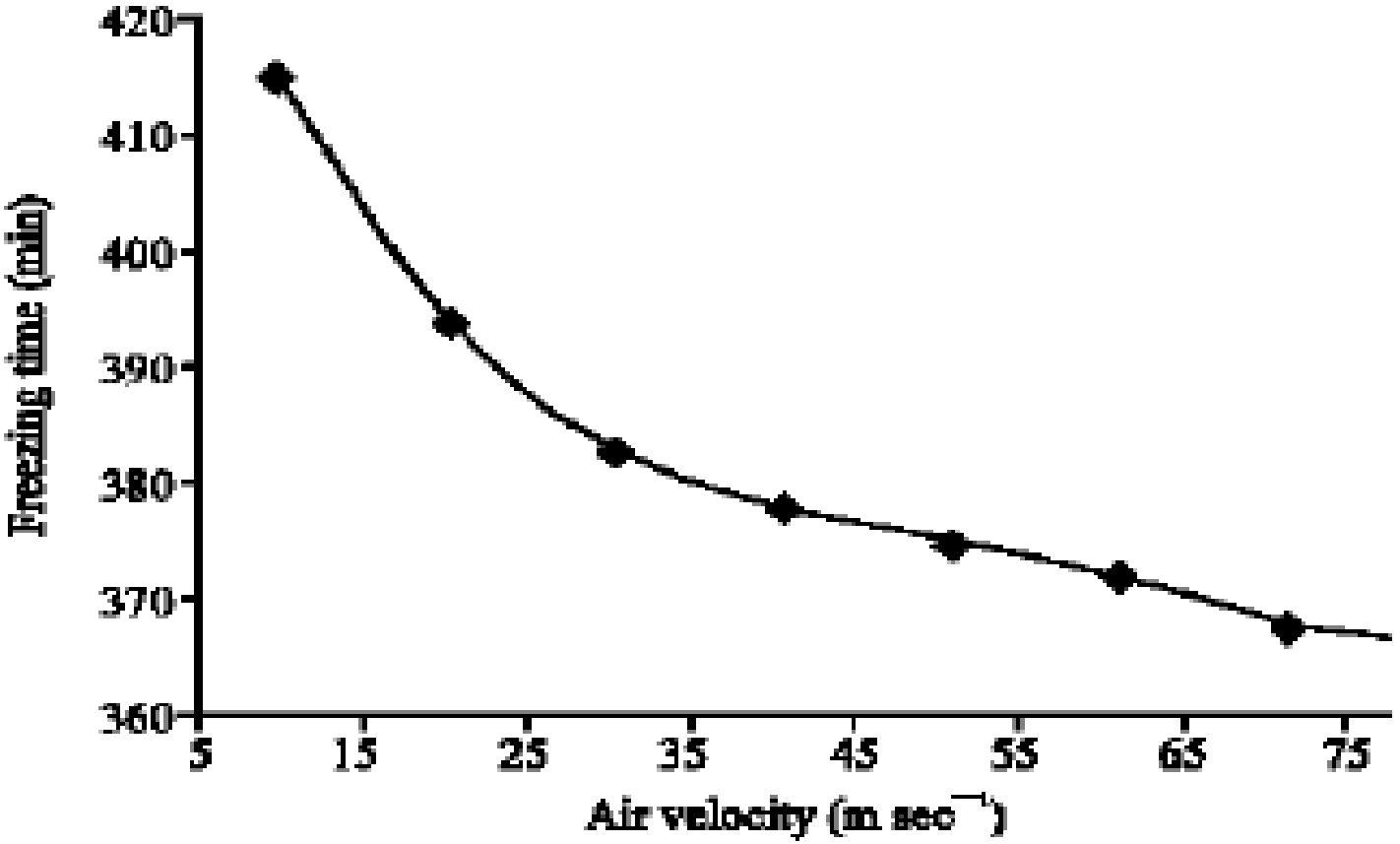
2. Operating temperature

- The colder the freezer, the faster the fish will freeze.
- However, the cost of freezing increases as the freezer temperature is reduced, and in practice, most freezers are designed to operate only a few degrees below the required storage temperature of the product.
- For example, plate freezers usually operate at about -40°C and blast freezers at about -35°C when the storage temperature is -30°C.

3. Air speed in blast freezers

- The general relationship between air speed and freezing time is shown below and this shows that freezing time is reduced as the air speed is increased.

Relation between freezing time and air velocity



- This, however, is a rather complicated relationship and it depends on a number of factors.
- If the resistance to heat transfer of the stagnant boundary layer of air is important, changes in air speed will make a significant difference to the freezing time.
- If, however, the package is large and the resistance of the product itself is the important factor then changes in air speed will be less significant.
- Air temperature, air density, air humidity and air turbulence are other factors that have to be taken into account when the effect of air condition on freezing time is considered.
- Some of these factors however, may only have a minor effect.

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4. Product temperature before freezing

- The warmer the product, the longer it will take to freeze.
- Product should therefore be kept chilled before freezing both to maintain quality and reduce freezing time and refrigeration requirement.
- For example, a single tuna 150 mm in diameter frozen in an air blast freezer will take 7h to freeze when the initial temperature is 35°C but, only 5h when the temperature is 5°C.
- The initial temperature of the product must therefore be given when quoting a freezing time.

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5. Product thickness

- The thicker the product, the longer is the freezing time.
- For products less than 50 mm thick, doubling the thickness may more than double the freezing time whereas doubling a thickness of 100 mm or more may increase the freezing time fourfold.
- The rate of change of freezing time with thickness therefore, depends on the relative importance of the resistance of the fish to heat transfer.

6. Product shape The shape of the product or package can have a considerable effect on its freezing time and this is dependent on the ratio of surface area to volume.

7. Product contact area and density

- In a plate freezer, poor contact between product and plate results in increased freezing time.
- Poor contact may be due to ice on the plates, packs of unequal thickness, partially filled packs or voids at the surface of the block.
- Surface voids are often accompanied by internal voids and this also results in poor heat transfer.
- Apart from increasing freezing time, internal voids also reduce the density of the block.

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8. Product packaging

- The method of wrapping and the type and thickness of the wrapping material can greatly influence the freezing time of a product.
- Air trapped between wrapper and product has often a greater influence on the freezing time than the resistance of the wrapping material itself.
- The following example illustrates the point.

1. Smoked fish in a cardboard box with the lid on take 15h to freeze in an air blast freezer.
2. Smoked fish in an aluminium box of the same shape and size and with the lid on take 12h, but if the lid is taken off the cardboard box, the freezing time is only 8h because there is no trapped air acting as an insulation.

9. Species of product

- The higher the oil content of the fish the lower is the water content.
- Most of the heat extracted during freezing is to change the water to ice; therefore, if there is less water, then less heat will require to be extracted to freeze the fish.
- Since the fat content of oily fish is subject to seasonal variations, it is safer to assume the same heat content figure used for lean fish in any calculation.
- This also ensures that the freezer capacity is adequate whatever the species of fish being frozen.

Calculating freezing time

$$Freezing \cdot time = \frac{L}{V\Delta}\left(\frac{PD}{f} + \frac{RD^2}{k}\right)$$

L = Heat to be extracted between the initial freezing point and final temperature (kcal/kg)
V = Specific volume of fish (m3/kg)
Λ = temperature difference between the initial freezing point of the fish and the refrigeration medium (°C)
D = Thickness of product in direction of prevailing heat transfer (m)
k = Thermal conductivity of frozen fish (kcal/h m °C)
P and R = Constants which depend on shape

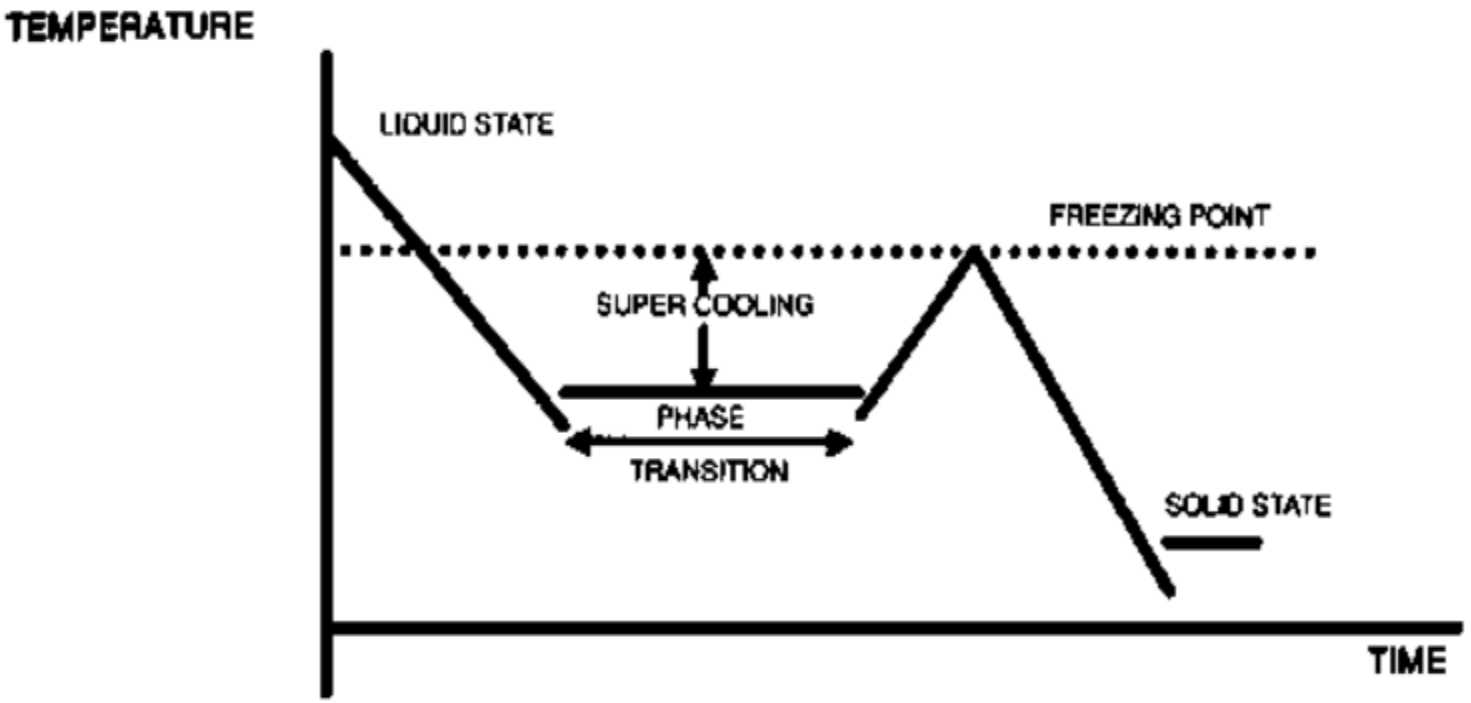
Values for shape constants P and R

Shape	P	R
Sphere	0.167	0.042
Infinite Cylinder	0.167	0.042
Infinite Slab	0.500	0.250

Freezing rate

- The freezing rate (°C/h) for a product or package is defined as the ratio of difference between initial and final temperature of product to freezing time.
- At a particular location within the product, a local freezing rate can be defined as the ratio of the difference between the initial temperature and desired temperature to the time elapsed in reaching the given final temperature (Persson and Lohndal, 1993).
- The quality of frozen products is largely dependent on the rate of freezing (Ramaswamy and Tung, 1984).
- Generally, rapid freezing results in better quality frozen products when compared with slow freezing.
- In contrast, if freezing is slow, the crystal growth will be slower with few nucleation sites resulting in larger ice crystals.
- Large ice crystals are known to cause mechanical damage to cell walls in addition to cell dehydration.
- Thus, the rate of freezing for plant tissues is extremely important due to the effect of freezing rate on the size of ice crystals, cell hydration, and damage to cell walls (Rahman, 1999).

Time-Temperature Relationship



Thawing time

- **Thawing** is the **process** of taking a frozen product from frozen to a temperature (usually above 0°C) where there is no residual ice, i.e. "**defrosting**".
- **Thawing** is often considered as simply the reversal of the freezing **process**.
- The thawing time is the time required to bring the product at temperature above 0 °C.
- It usually takes an entire day to **thaw** even a small amount of frozen food, such as a pound of ground meat or boneless chicken breasts.
- For large items, like a whole turkey or ham, it'll take about 24 hours of **defrosting time** for every 5 pounds of food.

- Determining thawing times of frozen foods is a challenging problem as the thermophysical properties of the product change during thawing.
- A number of calculation models and solutions have been developed.
- Several analytical, empirical and graphical models are used for the calculation of thawing time.
- The graphical and semi--graphical models are derived from numerical methods.
- Using the numerical methods is not always possible as running calculations takes time, whereas the specialized software and equipment are not always cheap.
- For these reasons, the application of analytical-empirical models is more useful for engineering.
- It is demonstrated that there is no simple, accurate and feasible analytical method for thawing time prediction.

Importance and method of thawing

- Thawing frozen food correctly is important for keeping food safe to eat.
- The FDA Food Code states that the temperature of food should not exceed 41 °F or 5 °C during the thawing process.
- If the final temp. of product will be more that 5 °C, the microorganisms will start to grow.
- There are four acceptable methods for thawing food:

1. Thawing in a refrigerator: safest method
2. Thawing under cold running water (T< or = 21 °C)
3. Thawing in a microwave: if food is immediately cooked.
4. Thawing as a part of cooking process: frozen vegetables and ground meat. In this method, allow more time than normal to cook.