Preservation by Freezing

Introduction

- The preservation of food by refrigeration is based on a very general principle in physical chemistry: molecular mobility is depressed and consequently chemical reactions and biological processes are slowed down at low temperature.
- In contrast to heat treatment, low temperature practically does not destroy microorganisms or enzymes but merely depresses their activity. Therefore:
- Refrigeration retards spoilage but it cannot improve the initial quality of the product, hence the importance of assuring particularly high microbial quality in the starting material
- Unlike thermal sterilization, refrigeration is not a method of 'permanent preservation.

Introduction

- Refrigerated and even frozen foods have a definite 'shelf life', the length of which depends on the storage temperature
- The preserving action of cold exists only as long as low temperature is maintained, hence the importance of maintaining a reliable 'cold chain' all along the commercial life of the product
- Refrigeration must often be combined with other preservation processes (the 'hurdle' principle).

History of mechanical refrigeration

- Natural ice, snow, cold nights and cool caves have been used for preserving food since pre-history.
- However, to become a large-scale industrial process, low temperature preservation had to await the development of mechanical refrigeration in the late 19th century.
- Frozen food made its appearance shortly before World War 2. Following are milestones in the history of mechanical refrigeration:
- 1748: W. Cullen demonstrates refrigeration by vacuum evaporation of ether

History of mechanical refrigeration

- 1805: O. Evans. First vapor compression system
- 1834: J. Perkins. Improved vapor compression machine
- 1842: J. Gorrie uses refrigeration to cool sick room
- 1856: A. Twinning. First commercial application of refrigeration
- 1859: F. Carre. First ammonia machine
- 1868: P. Tellier attempts refrigerated transatlantic maritime transport of meat
- 1873: C. von Linde. First industrial refrigeration systems in brewery

History of mechanical refrigeration

- 1918: First household refrigerators
- 1920: W. Carrier. Start of commercial air conditioning
- 1938: C. Birdseye. Start of the frozen food industry
- 1974: S. Rowland and M. Molino.
- Refrigerant gases in the atmosphere suspected of destroying the ozone layer.

History of mechanical refrigeration

- Food preservation at low temperature comprises two distinct processes: chilling and freezing.
- Chilling is the application of temperatures in the range of 0°C to 8°C, i.e. above the freezing point of the food, while freezing uses temperatures well below the freezing point, conventionally below 18°C.
- The difference between the two processes goes beyond the difference in temperature.
- The stronger preserving action of freezing is due not only to the lower temperature but also and mainly to the depression of water activity as a result of conversion of part of the water to ice.

History of mechanical refrigeration

- The use of refrigeration in the food industry is not limited to preservation.
- Refrigeration is applied for a number of other purposes such as hardening (butter, fats), freeze concentration, freeze drying, air conditioning including air dehumidification and cryo-milling.

Freezing

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- Freezing represents a point of sharp discontinuity in the relationship between temperature and the stability and sensory properties of foods.
- The exceptional efficiency of freezing as a method of food preservation is, to a large extent, due to the depression of water activity.

Freezing

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Freezing

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- On the other hand, the same phenomenon of ' freeze concentration ' may accelerate reactions, inducing irreversible changes such as protein denaturation, accelerated oxidation of lipids and destruction of the colloidal structure (gels, emulsions) of the food
- The rate of freezing has an important effect on the quality of frozen foods.
- Physical changes, such as the formation of large ice crystals with sharp edges, expansion, disruption of the osmotic equilibrium between the cells and their surroundings, may induce irreversible damage to the texture of vegetables, fruits and muscle foods.

Effect of freezing and frozen storage on product quality

- For a very large number of food products, freezing represents the best preservation method with respect to food quality.
- The nutritional value, the flavor and color of foods are affected very slightly, if at all, by the process of freezing itself.
- The main quality factor that may be adversely affected by freezing is the texture.
- On the other hand, unless appropriate measures are taken, the deleterious effect of long-term frozen storage and of thawing on every aspect of product quality may be significant.

Effect of freezing on texture

- In a vegetal or animal tissue, the cells are surrounded by a medium known as the extracellular fluid.
- The extracellular fluid is less concentrated than the protoplasm inside the cells.
- The concentration difference results in a difference in osmotic pressure which is compensated by the tension of the cell wall.
- This phenomenon, known as turgor, is the reason for solid appearance of meat and the crispiness of fruits and vegetables.

Effect of freezing on texture

- Its concentration rises and the osmotic balance is disrupted. Fluid flows from the cell to the extracellular space.
- Turgor is lost and the tissue is softened. When the food is thawed, the liquid that was lost to the extracellular space is not reabsorbed into the cell, but is released as free juice in the case of fruits or 'drip' in the case of meat.
- It is generally believed that freezing damage to the texture of cellular foods is greatly reduced by accelerating the rate of freezing.
- This is explained by the fact that the condition of osmotic imbalance, created at the onset of freezing, disappears when the entire mass is frozen.
- Furthermore, rapid freezing results in the formation of smaller ice crystals, presumably less harmful to the texture of cellular systems.

Effect of freezing on texture

- Another probable reason for the deterioration of the texture is the volumetric expansion caused by freezing.
- The specific volume of ice is 9% higher than that of pure water. Because cellular tissues are not homogeneous with respect to water content, parts of the tissue expand more than the others.
- This creates mechanical stress that may result in cracks. Obviously, this effect is particularly strong in foods with high water content such as cucumbers, lettuce and tomatoes.
- This kind of texture damage is partially prevented by adding solutes. Adding sugar to fruits and berries before freezing was a widespread practice before the development of ultra-rapid freezing methods.

Effect of frozen storage on food quality

- Frozen storage, even at fairly low temperature, does not mean the absence of deteriorative processes.
- On the contrary, frozen foods may undergo profound quality changes during frozen storage.
- While the rate of reactions is generally (but not always) slower in frozen foods, the expected shelf life, and therefore the time available for the reactions to take place, is long.
- Some of the frequent types of deterioration in frozen foods are protein denaturation resulting in toughening of muscle foods, protein–lipid interaction, lipid oxidation and oxidative changes in general (e.g. loss of some vitamins and pigments).

Freezing Methods

- There are three major methods of freezing foods:
- Air Freezing
- Indirect Contact Freezing
- Immersion and Cryogenic Freezing

Air Freezing

- Still-air 'sharp' freezer
- Air blast freezer
- Fluidized-bed freezer (IQF)

Indirect Contact Freezing

- Single plate freezing
- Double plate freezing
- Pressure plate freezing
- Slush freezing

Immersion and Cryogenic Freezing

- Heat exchange fluid freezing
- Compressed gas freezing
- Refrigerant spray freezing

Aseptic Packaging

- **Air Blast Freezing:** Air freezing is the oldest and most common type of freezing used.
- The freezer section of household refrigerator and the deep freezer are examples of still air freezers or low air velocity systems.
- **Air blast freezing** is a moderately fast freeze because of vigorous circulation of cold air.
- The product is placed on trays or mesh belts and passed slowly through an insulated tunnel.
- In different systems the temperature may range from -18°C to -34°C, with an air velocity of 100-3500 lineal feet per minute, with a counter current air flow.

Aseptic Packaging

- Air blast freezers operate at lower temperatures than still air freezers and rely on movement of the cold air at high velocity over the food in order to achieve rapid removal of heat and to maximize the freezing rate.
- **Fluidized-bed Freezer:** In this type of air freezing, solid particles ranging in size from peas to strawberries are being exposed through a movement of the cold air (-18°C to -34°C) at high velocity as they pass along a conveyor belt.
- This will impart a vibratory motion to food particles, accelerating the freezing rate.
- The cold air being forced upward through the bed lifts and suspends the food particles, thus fluidization occurs.

Aseptic Packaging

- In this way, a rapid freezing rate is accomplished and an IQF (individually quick frozen) product is produced.
- In other words, food items are frozen as individual pieces and are not stuck together.
- **Advantages and Disadvantages of Air blast freezing; Fluidize-bed freezing (IQF)**
  Advantages:
- Economical
- Can freeze various sizes and shapes of food
- IQF has more efficient heat transfer, increased rate of freezing

Aseptic Packaging

- **Disadvantages:**
- Possible excess dehydration (freezer burn)
- Undesirable bulging of the packages (by expansion of the product) may occur
- Non-uniform products can not be fluidized (IQF) easily

Indirect Contact Freezers

- Indirect Contact freezers are used in the production of various frozen food commodities.
- In these freezers, food is placed on belts or trays and a refrigerant circulates through a wall beside the food.
- As the food comes into "contact" with the cold wall, it quickly cools down and freezes.
- **Plate** and **slush freezers** are some examples of indirect contact freezers.

Indirect Contact Freezers

- During plate freezing food products are placed in contact with a metal surface which is cooled by a cold brine, or a vaporizer refrigerant such as ammonia.
- The packaged food either rests on, slides against or is pressed between the cold metal plates.
- These plates maintain firm contact with two major surfaces of packages to facilitate heat transfer and prevent bulging of the packages during the freezing process.
- Fish sticks and frozen fish fillets are commonly frozen in plate contact freezers.

Indirect Contact Freezers

- Another type of indirect contact freezer is the slush freezers or scraped surface heat exchangers.
- These freezers can be used only for fluid food products. A common example of a scraped surface freezer is the machine used to convert ice cream mix to soft ice cream in restaurants and ice cream shops.
- The same principle is used in the commercial production of ice cream that is sold as hard ice cream.
- In the case of ice cream, the rotator not only aids in promoting rapid freezing and the development of small ice crystals, but it also aids in the incorporation of air bubbles into the freezing mix which results in the formation of a solid foam.

Advantages and Disadvantages of Indirect Contact Freezing

- **Advantages:**
- Economical
- Minimal dehydration
- Minimal package bulging
- Disadvantages:
- Slow freezing process
- Products must be of uniform thickness

Immersion and Cryogenic Freezing

- **Immersion freezing** involves the immersion of packaged or un-packaged food products directly in a non-toxic refrigerant fluid.
- The refrigerant fluids commonly used are propylene glycol, glycerol, sodium chloride, calcium chloride, and mixtures of salt and sugar.
- Canned citrus juice, turkeys and chickens are often frozen in immersion freezing units. Ice cream popsicles can also be frozen using this method.
- **Cryogenic freezing** is accomplished with cryogenic liquids, with liquid nitrogen being the most commonly used.
- This is a very rapid freezing method in which un-packaged or thinly packaged foods are exposed to extremely cold freezant.

Immersion and Cryogenic Freezing

- In contrast to the liquid immersion freezing, heat removal is accomplished during a change of state by the freezant.
- Products such as TV dinners, preformed patties and other high value food products are frozen in cryogenic freezers because of the excellent retention of quality imparted by the rapid rate of freezing and small ice crystal formation. The figure on the right illustrates a cryogenic process.
- **Liquid nitrogen cryogenic freezing** : The product is first placed on a conveyor belt and is moved into the pre-cooling part of the freezing unit.
- Once the food is cooled, the food is sprayed by liquid nitrogen as it is being moved through the conveyor belt; here is where the freezing process takes place, by the nitrogen boiling as it contacts the food.

Immersion and Cryogenic Freezing

- Finally, the food is allowed to equilibrate to the desired final temperature (between -18°C to -30°C).
- **Advantages and Disadvantages of Immersion/ Cryogenic Freezing**
- Rapid freezing process
- Almost no dehydration
- Oxygen is excluded, decreasing oxidative spoilage
- Individual freezing pieces have less freezing damage

Conclusion

- Freezing and low temperature preservation provides longer shelf life of food.
- It is carried out at temperatures well below 0°C.
- Freezing slows/stops microbial growth.

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- It is carried out at temperatures well below 0°C.
- Freezing slows/stops microbial growth.
- Once the food is thawed, the surviving microorganisms can resume their growth and function, causing disease or spoilage if the proper conditions for microbial growth prevail.
- When freezing of food is properly done, it can preserve the quality of the food without causing major changes in appearance, texture and flavour.
- Frozen foods are generally of higher nutritional and aesthetic quality than thermally processed foods.

Conclusion

- The faster the rate of freezing, the better the retention of quality, both sensory and nutritional.

THANK YOU

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