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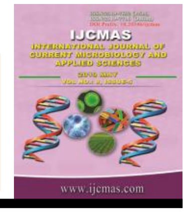

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An Analysis in Freezing Methods of Regular Shaped Meat Products

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A B S T R A C T

Freezing food preserves it from the time it is prepared to the time it is eaten. Freezing food slows decomposition by turning residual moisture into ice, inhibiting the growth of most bacterial species. The freezing kinetics is important to preserve the food quality and texture. Quicker freezing generates smaller ice crystals and maintains cellular structure. The freezing of food is one of the most important applications of refrigeration. The freezing time of food is calculated numerically by various scientist and they faced many challenges. In this paper, the semi-analytical/empirical food freezing time prediction methods applicable to regularly shaped food items is given in this paper. The performance of these various methods is evaluated by comparing their results to experimental freezing time data. Meat is mainly composed of water, protein, and fat. It is edible raw, but is normally eaten after it has been cooked and seasoned or processed in a variety of ways. Unprocessed meat will spoil or rot within hours or days as a result of infection with, and decomposition by, bacteria and fungi. Freezing process is the one of the most advantageous methods of food preservation techniques for high quality of food for long storage. The cold storage follows both chilling and freezing processes for the preservation of vegetables from between -18°C and -35°C to avoid the physical, microbiological and chemical activities that causes deterioration in foods. To preserve the food material various freezing equipment's are followed like blast freezer, plate freezer, contact freezer, immersion freezer, cryogenic freezer, individual quick freezer etc.

Introduction

Refrigeration reduced the temperature and support the chilling foods, preserving certain substances. Refrigeration defeats both bacterial growth and adverse enzymatic reactions in the normal atmosphere (Cipoletti, *et al*., 1977). The freezing technique itself, just like the frozen food market, is developing to become faster, more efficient and more cost-effective by mechanical freezing. Most frozen food is instead frozen using the vapor-compression refrigeration technology similar to ordinary freezers. Nevertheless, a wide variety of processes have been devised to achieve faster heat transfer from the food to the refrigerant. Salvadori *et al.*, (1987) coined graphical method to estimate freezing times of foods with a high-water content, which is applicable to simple regular shapes in 1987.

Air-blast freezing is the oldest and cheapest approach. Food is placed into freezing rooms where the air is cold. Air is either forced onto the food. This setup allows large chunks of food (meat) to be easily processed compared to other methods, but is quite slow. Belt freezers simply put a conveyor belt inside a cold room. Tunnel freezing is a variant of air-blast freezing where food is put onto trolley racks and sent into a tunnel where cold air is continuously circulated. Fluidized bed freezing is a variant of air-blast freezing where pelletized food is blown by fast-moving cold air from below, forming a fluidized bed. The small size of the food combined with the fast-flowing air provides good heat transfer and therefore quick freezing. Contact freezing uses physical contact other than air to transfer the heat. Direct contact freezing puts the product directly in contact with the refrigerant, while indirect contact freezing uses a plate in between. Plate freezing is the most common form of contact freezing. Food is put between cold metal plates and then lightly pressed to maintain contact. Immersion freezing dips the product into a cold refrigerant liquid to freeze it, usually on a conveyor belt. The product may be in direct contact with the liquid, or be separated by a membrane. It can be used for freezing the outer shell of large particles to reduce water loss. Individual Quick Freezing is a descriptive term that includes all forms of freezing that is individual and quick. It may correspond to cryogenic freezing, fluidized bed freezing, or any other technique that meets the definition. Hung (1990) stated that freezing time prediction methods into two major groups: simple equations and numerical methods. The freezing process is started in the point of chilling, the sensible heat is removed from the food. The initial freezing point is lower than the freezing point of pure water due to dissolved substances in the moisture within the food. During the decrease in temperature, the formation of ice crystals. During the freezing process, the ice and water fractions in the frozen food is based on temperature. The thermal properties of ice and liquid water are quite different. There is some complexities in deriving the freezing time of food. The regular shaped freezing of meat products is evaluated by plank's and pham equations and infinite slabs and cylinders the Cleland and Earle is explained. Pham also explained the spherical food items. The method of Lacroix and Castaigne made best for infinite cylinders of food and produced high prediction errors for infinite slabs and spheres and developed the food temperature and time curve.

Air Blast Freezer

In this method of quick freezing, the food products are freezed by the contact with cold air by convection process. The air blast freezing is widely used because it provides excellent quality of the food among all other types. In this method, a very low temperature air is circulated with a very high velocity around the various parts of the products kept in insulated tunnel type storages. The temperature of – 20°C to – 40°C are commonly used for this method of freezing. The velocity of air varies from 30m/min to 120m/min according to the type of food to be freeze. It may be noted that dehydration of the product may occur in freezing unpacked whole or dressed fish in blast freezer unless the velocity of air is kept to about 160m/min and the period of exposure of air is controlled. The blast freezer are provided with blower to circulate the air towards the food at rapid rate and produce ice crystals over the surface. The micro-organism are not able to survive in the extremely cold condition of blast freezer**.** The air blast freezer are extensively used throughout the world to freeze the various products of packaged or un packaged of any shape and size. Hence, this type of freezer's are mostly used to preserve the meat products.

In air blast freezer the temperature to be maintained at -35°C with varying freezing time up to 48hrs (Dempsey, 2010). In quick freezing, the ice crystals are formed at the higher nucleation points to maintain the quality (Dempsey *et al.,* 2012). The air blast freezing is mainly used for freezing fishery products like meat, shrimp, fish fillets steaks, scallops or pre cooled products packed in small packages.

Immersion Freezer

In this method of quick freezing, the food products are immersed into low temperature liquids. Since the liquids are good conductors of heat and in good thermal contact with all the products, therefore the heat transfer is rapid and the product is completely frozen in a very short time. The liquid medium, used for freezing the foods should be non-toxic and should not produce any bad effect on the immersed foods. The liquids used for this purpose are sodium chloride, brine (Robertson *et al.,* 1976), sugar brine and propylene glycol. The fish and shrimp are the two animal products which are most frequently frozen by immersion. This freezing method produces a thin coating of ice on the surface of the product resulting in prevention of dehydration of unpackaged products during the storage period. The only disadvantage of this system is the extraction of the juices from the products by osmosis resulting into contamination and weakening of the freezing solution. This defect can be avoided by freezing the products in canned or packaged forms.

Immersion freezing systems are extensively used in on the ship freezing of fish but its industrial use on other products has been limited. There are two advantages of immersion freezing over air blast freezing. Overall, energy consumption is reduced by 25% in immersion freezing. It is one of the fastest freezing techniques, because heat transfer coefficient is higher in the liquid phase than in air (Robertson *et al.,* 1976). Immersion freezing causes less product dehydration and a higher quality final product is obtained (Lucas *et al.,* 1996). In this type of freezing system, using a liquid coolant as a heat-transfer medium (Lucas *et al.,* 1998), can radically increase freezing speed (Pham *et al.,* 1986; Ribero *et al.,* 2009; Sun *et al.,* 2003) due to the high thermal coefficient of liquid medium. This results in an immediate and even nucleation throughout foods achieved and small ice crystals are formed (Zhu *et al.,* 2004; Elansari *et al.,* 2019).

Individual Quick Freezer

Individual quick-freezing technique is designed to freeze each and every piece of food products. Generally, smaller pieces of food products, such as meat, poultry, shrimps, small fish etc., (Hung, 1983). There is no formation of swellings in product, creates smaller ice crystals and less mechanical damage of whole cells of the food. Quick frozen products have better taste, flavour, aroma, colour appearance and freshness than slow frozen products (Salvadori, 1996). Darke *et al.,* (1981) compared the Individual quick freezing and air blast freezing for vegetables and found that vegetables in individually quick frozen were higher quality compare to common blast frozen vegetables, particularly with regard to reduced drip loss.

Packaging

Frozen food packaging must maintain its integrity throughout filling, sealing, freezing, storage, transportation, thawing, and often cooking.

As many frozen foods are cooked in a microwave oven, manufacturers have developed packaging that can go directly from freezer to the microwave. Today there are multiple options for packaging frozen foods. Boxes, cartons, bags, pouches, lidded trays and pansand composite and plastic cans. Scientists continue to research new aspects of frozen food packaging. Active packaging offers many new technologies that can actively sense and then neutralize the presence of bacteria or other harmful species.

Active packaging can extend shelf-life, maintain product safety, and help preserve the food over a longer period of time. Several functions of active packaging are being researched:

Oxygen scavengers

Time Temperature Indicators and digital temperature data loggers

Antimicrobials

Carbon Dioxide controllers

Microwave susceptors

Moisture control: Water activity, Moisture vapor transmission rate, etc.

Flavor enhancers

Odor generators

Oxygen-permeable films

Oxygen generators

Nutrients

The process of flash freezing itself generally effectively retain the nutrient content of foodstuff with minor losses of vitamin, making them a cost-effective and nutritious substitute for fresh equivalents. However, pre-seasoned frozen food, such as packaged meals, may have a significant amount of salt and fats added.

Effectiveness

Freezing is an effective form of food preservation because the pathogens that cause food spoilage are killed or do not grow very rapidly at reduced temperatures. The process is less effective in food preservation than are thermal techniques, such as boiling, because pathogens are more likely to be able to survive cold temperatures rather than hot temperatures. One of the problems surrounding the use of freezing as a method of food preservation is the danger that pathogens deactivated (but not killed) by the process will once again become active when the frozen food thaws. Foods may be preserved for several months by freezing. Long-term frozen storage requires a constant temperature of −18 °C or less

Quality

The speed of freezing has a direct impact on the size and the number of ice crystals formed within a food product's cells and extracellular space. Slow freezing leads to fewer but larger ice crystals while fast freezing leads to smaller but more numerous ice crystals.

This difference in ice crystal size can affect the degree of residual enzymatic activity during frozen storage via the process of freeze concentration, which occurs when enzymes and solutes present in a fluid medium are concentrated between ice crystal formations. Increased levels of freeze concentration, mediated by the formation of large ice crystals, can promote enzymatic browning. Large ice crystals can also puncture the walls of the cells of the food product which will cause a degradation of the texture of the product as well as the loss of its natural juices during thawing.

That is why there will be a qualitative difference observed between food products frozen by ventilated mechanical freezing, non-ventilated mechanical freezing or cryogenic freezing with liquid nitrogen.

Table.1 Recommended storage condition of Meat products.

S. No	Food products	Short term storage	Long term storage	Air circulation	Forced air circulation	Freezing point in °C Celsius	Composition in % water	Maximum storage period
1.	Poultry (fresh)	-2.2 to -1.1	-2.2 to -1.1	84	87	-2.8	74	10 days
2.	Poultry (Frozen)	-9.4 to -6.7	-17.8 to -15	85	85	-2.8	74	10 months
3.	Pork (fresh)	1.1 to 3.3	-1.1 to 0	80	85	-	57	15 days
4.	Pork (smoked)	4.4 to 7.2	-2.2 to -1.1	80	85	-	57	15 days
5.	Beef (fresh)	1.7 to 4.4	-1.1 to 0	84	87	-2.8	68	3 weeks
6.	Fish (fresh)	1.1 to 3.3	-1.1 to 0	85	85	-2.2	70	15 days
7.	Fish (frozen)	-9.4to -6.7	-15 to -12.2	80	80	-	70	6months
8.	Sausage (fresh)	1.7 to 4.4	-6.1 to -2.8	80	85	-3.3	65	15 days
9.	Eggs (crated)	4.4 to 7.2	-1.1 to -0.6	85	85	-2.8	73	12months
10.	Eggs (frozen)	-9.4 to -6.7	-17.8 to -15	60	60	-2.8	-	18 months

Freezing as a preservation process to obtain a high-quality product for consumption, the quality is partial by the freezing process and frozen-storage conditions. The freezing rate or time allowed for the product temperature to be decrease from above to below the initial freezing temperature will impact product quality. For some products, rapid freezing is required to ensure formation of small ice crystals within the product structure and without damage to the product. Some food products have geometric shapes and sizes that do not allow rapid freezing. The storage temperature conditions influence frozen food quality in a significant manner.

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