Frozen Foods Handling & Storage

Revised 2008

Introduction

The successful retail marketing of frozen foods began over a half century ago, and the rapid growth of sales since that time reflects consumer satisfaction in the high quality of products, year-round availability, and general convenience in product use. Because of consumer appreciation of product values, more frozen foods are sold each year and new products are introduced to swell the total sales.

The quality of frozen foods depends fundamentally on the quality of raw materials used and product manufacture but can be jeopardized by failure to maintain product temperature at a suitable low level in any part of the cold chain, including storage, transport, distribution, and display in retail stores, or by faulty inventory control at all levels that would allow product to be retained for unduly long periods in the cold chain. Such operational failures may lead to customer dissatisfaction and harm to the entire industry, not only those who may be at fault.

General Storage Conditions

Temperature	0 °F (-18 °C) or colder for some products or if product is to be stored for 6 months or longer.
Relative Humidity	Highest possible, consistent with available equipment and good operating procedures, to prevent "freezer burn" and drying out where packaging material for the food may not be sufficiently protective.

Storage Period

Various types of frozen foods have different stabilities in frozen storage depending on how quickly they develop abnormal flavors and whether they discolor easily. Different lots of the same type of frozen food may have different stabilities, depending on many factors including but not limited to the quality of raw material and product ingredients, processing, and packaging materials. Storage life can be extended significantly as storage temperatures become colder. For most products, a temperature of 0 °F (-18 °C) or below is required if storage is expected to exceed 6 months. The following table gives the relative stability at 0 °F (-18 °C) for several types of frozen foods.

Approximate storage periods for general classes of frozen foods at 0 °F (-18 °C) without any commercially significant quality loss	
Packaged Chicken Heat Treated Citrus Concentrates Sugared Fruits Pies, including Fruit Pies	Over 12 months
Most Fruits & Vegetables Fruit Juices Bakery Products Confections Beef Veal Lamb Turkey Meat Pies	10-12 months
Lean fish Shellfish Some Fatty Fish	8-10 months
Fried foods Pork Most Dairy Products Fatty Fish	6 months or less

Storage temperatures warmer than 0 °F (-18 °C) accelerate quality losses, and research data on this acceleration vary greatly depending on the product and how it is packaged.

Time & Temperature Tolerance (TTT)

The integrated effects of time and temperature on frozen foods affect their color, flavor and texture, commonly referred to as quality. The degree to which individual products tolerate the time & temperature effects is called the **Time-Temperature Tolerance (TTT)**. Regulations or company quality-assurance standards must specify and control both the time and temperature factors to guarantee product quality.

Cost considerations will be an important factor in developing either mandatory regulations or voluntary quality assurance standards. Policing and enforcing laws appear to be unbearably costly in view of the wide distribution of products, the vast number of products to be controlled, and the considerable variation in the stability of individual products. On the other hand, the extreme importance of frozen food quality to consumers makes imperative the utmost efforts of all segments of the frozen food industry to prevent conditions that could lead to product deterioration in any part of the cold chain and would cause consumer dissatisfaction.

Practical Storage Life (PSL)

Attempts have been made to determine how long certain categories of products can be effectively stored without creating undue quality damage to the products. This storage period is commonly called the Practical Storage Life (PSL), or shelf life which is about equivalent to the duration of consumer acceptability. Examples are listed below for several categories of food products.

Storage Temp.		Practical Storage Life, in Months						
° F	° C	**Raw and pre-cooked lean meat**	**Raw and pre-cooked fat meat**	**Lean fish**	**Pre-cooked foods without gravy**	**Fat fish without any special treatment**	**Fruits and berries**	**Vegetables**
23	- 5	2-12	1 - 5	1- 3	2- 6	1- 2	1- 5*	1- 4
14	-10	5-21	6-17	2- 6	3- 9	1- 3	3- 17	3- 10
5	-15	10-37	10-27	4-12	5-15	2- 5	17-70	8-20
-4	-20	16-70	13-40	6-20	8-28	3- 8	Over 70	21-70
-13	-25	30-70 +	20-60	11-40	15-47	4-12	--	---
-22	-30	53-70 +	30-70 +	---	27-70 +	6-18	---	---

*Soft fruits packed in syrup will thaw, causing distribution of pigment and water soluble vitamins into the syrup with an equivalent loss of both from the fruit.

A general conclusion is that as storage temperatures become colder, shelf life increases. For example, raw and pre-cooked lean meat at 5 °F (-15 °C) may be stored between 4 and 20 months, depending on the initial quality, processing method and packaging material. However, at -4 °F (-20 °C) the range increases to between 8 and 33 months. At temperatures of -22 °F (-30 °C) the potential storage period increases to between 20-33 months.

Raw and pre-cooked fatty meat products have shorter storage ranges than lean meat, since the high fat content can result in oxidative rancidity and off flavors, thereby reducing the practical storage life by about half when compared to lean meats.

Pre-cooked foods without gravy as well as lean fish products stored at 5 °F (-15 °C), have substantially shorter shelf life than red meat. Therefore, it is more important to freeze these commodities rapidly and to hold them at colder temperatures.

Fat fish products are the most sensitive protein group to quality deterioration during frozen storage. This is due to the high level of unsaturated fatty acids, which can easily become rancid or off condition over time in storage.

Fruits and vegetables are the most sensitive products to storage deterioration, especially at relatively warm frozen storage temperatures. For example, at a storage temperature of 23 °F (-5 °C), maximum recommended storage period is between 1 and 5 months. It should be noted, however, that these products may undergo a slight thaw over time, thereby releasing fluids and losing high-quality nutrients as a result. As storage temperatures are lowered, the products are more stable and can be held for longer periods of time. It should be noted, however, that ultra-low storage temperatures of -13 °F or lower (-25 °C) are not recommended.

The following are general conclusions pertaining to Practical Storage Life:

1. There is no reason for maintaining freezer storage at -20 °F (-29 °C) for any commodities except for unpackaged fat fish and some high-fat ice cream products.
2. A temperature of -10 to -15 °F (-23 to -26 °C) may be desirable for lean fish and precooked foods without gravy if they are to be held for well over 6 months in storage.
3. All other commodities may be stored at 0 °F (-18 °C) or colder even if they are to be held for longer than 1 year.
4. Rapid pre-cooling and ultra-rapid freezing are of particular benefit to fruits, vegetables, and fat meats, and of least benefit to lean meats.
5. Regulations requiring all frozen foods to be stored colder than 0 °F (-18 °C) and for not more than 1 year may be unrealistic. Specific products may benefit from colder storage temperatures.
6. Quality of product entering storage, method of processing and handling, and method of packaging have a profound influence on storage life of the frozen product. The warehouse therefore should be aware of these pre-storage conditions when receiving products in order to protect against claims that quality has deteriorated during storage.

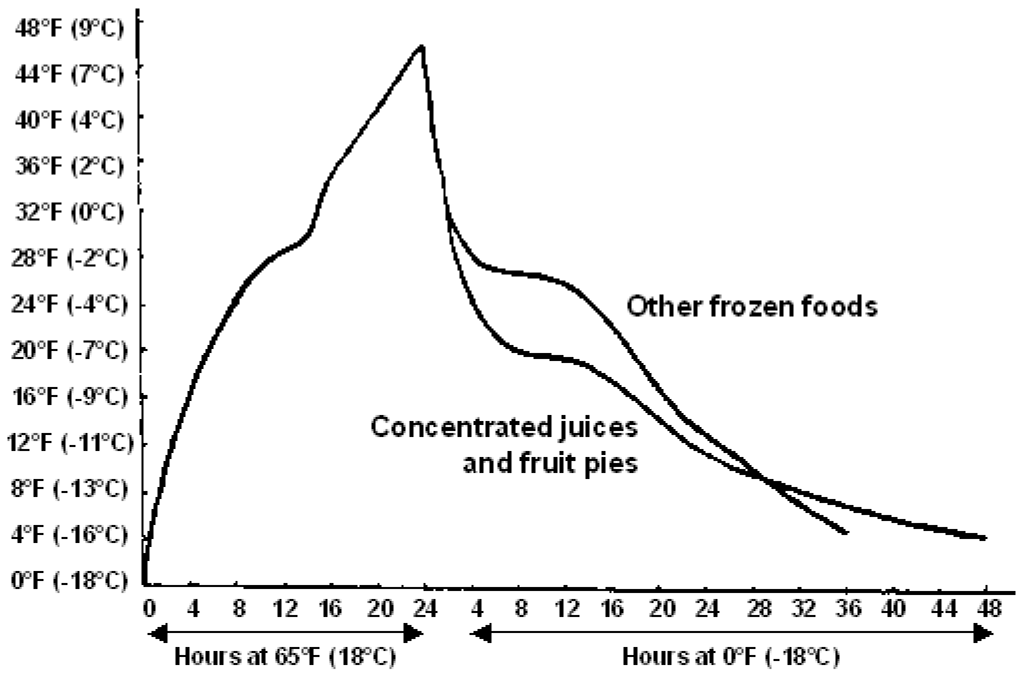
Handling

Exposure to elevated temperatures can be a serious contributing factor to quality loss in frozen foods. Generally, short periods of exposure are not serious, unless often repeated, but prolonged exposure can cause damage. However, for some particularly sensitive products, even a short exposure to temperatures warmer than 10-15 °F will result in marked loss in quality which will only become apparent after further storage. Temperature fluctuations should be avoided because they will cause migration of moisture from the product or within the package causing formation of ice crystals and partial dehydration of the product. In general, the product temperature is more important than the air temperature. A change in air temperature for a short period may not affect the product temperature significantly.

Refrigeration equipment used to transport frozen foods is designed to remove heat that may leak into the load compartment of the railcar, truck, or container. It should be noted that the refrigeration capacity does not provide for removal of much heat from the load. Therefore, if products are loaded with the temperature warmer than 0 °F (-18 °C), there is little or no opportunity for the product temperature to be reduced to the desired level during transit. Similarly, retail display equipment cannot be expected to remove significant heat from frozen foods. Therefore, it is imperative that frozen foods be at 0 °F (-18 °C), or colder, when they are loaded for transport or placed in retail cabinets.

Retail and institutional sized packages in standard shipping containers warm up rather rapidly when exposed to elevated temperatures and cool down slowly when placed in the ordinary still air of a storage room. For the duration of the warming up and the cooling down, quality losses are occurring even though the air temperature of the storage room is 0 °F (-18 °C). Large sized products, such as whole turkeys and bulk frozen food containers of 30 lbs. (13.6 kg) and over, warm up much more slowly.

Average temperature curve of corner package of single case of frozen food standing in air at 65°F (18°C) and then returned to still air freezer room at 0°F (-18°C)



Details of this temperature curve are as follows:

Average temperature of corner package of single case standing in air at 65°F (18°C)

Initial Temp.		Temperature after			
°F	°C	½ hour	1 hour	2 hours	4 hours
0	-18	4°F (-15°C)	6°F (-14°C)	10°F (-12°C)	16°F (-9°C)
10	-12	12°F (-11°C)	14°F (-10°C)	16°F (- 9°C)	19°F (-7°C)
15	- 9	16°F (- 9°C)	18°F (- 7°C)	20°F (- 6°C)	23°F (-5°C)

Figures represent average for a large variety of frozen foods packed in a variety of case sizes and shapes. The temperature of items packed in small thin cases will rise somewhat faster, and temperatures in large thick cases will rise somewhat slower than indicated in the table. It is important to note how rapidly the temperature rises to 5°F (-15°C), which can be detrimental for sensitive products. Also, note how slowly the temperature recovers.

Average time to reduce temperature in corner package of single cases in still air at 0°F (-18°C)

Temperature Change		Time in hours	
°F	°C	Concentrated juices and fruit pies	Other frozen foods
30 to 5	-1 to -15	45	33
25 to 5	-3 to -15	43	23
20 to 5	-6 to -15	39	18
15 to 5	-9 to -15	30	13
10 to 5	-12 to -15	19	7
30 to 10	-1 to -12	26	26
25 to 10	-3 to -12	24	16
20 to 10	-6 to -12	20	11
15 to 10	-9 to -12	11	6
30 to 15	-1 to - 9	15	20
25 to 15	-3 to - 9	13	10
20 to 15	-6 to - 9	9	5
30 to 20	-1 to - 6	6	15
25 to 20	-3 to - 6	4	5
30 to 25	-1 to - 3	2	10

Figures represent averages for a variety of case sizes and shapes. Items packed in small thin cases will cool somewhat faster and those in large thick cases will cool somewhat slower than indicated in the table.

The temperature of frozen foods or food to be frozen should be determined and recorded as they are received at the warehouse because 1) high temperature frozen foods should be moved into storage rapidly, while low temperature foods can be handled normally and 2) these records are evidence if a damage claim should be made at a later date.

Steps in taking temperatures

A method is described below involving either a dial thermometer with stem or a thermocouple (electrical devices for measuring temperature).

1. Open top of case and remove top corner package.
2. Make hole through the case from inside in line with the second layer of product. Use an ice pick or similar tool. Do not use the stem of the thermometer.

3. Place the thermometer or thermocouple in the hole from the outside, so that the end of the stem, the sensing element, is about 3 inches (8 cm) in from the case wall. Make sure the sensing element is held firmly between packages.
4. Place package back in its normal place and close top of case. Do steps 1 to 4 as quickly as possible.
5. Place two or more cases on top to assure contact of stem with packages of product.
6. Read temperature after 5 minutes.
7. Check the accuracy of the thermometer or thermocouple regularly and keep a record of the checks and any recalibrations.

This method supplies approximate measurements of product temperature rather than temperatures of air around the packages. It is simple, fast, and does not require puncturing of individual packages.

After the temperatures are taken

The following advice is offered as a guide. Practice will vary somewhat with commodities and with other factors. It is important, however, that refrigerated warehouses and other handlers of frozen foods have well defined policies in the matter of action following the taking of temperatures.

If the highest reading is 25°F (-3.9°C) or higher	Damage to quality is occurring rapidly and immediate steps should be taken to prevent further damage. Product should be placed in a blast freezer or equally rapid freezer with spacers between cases to permit air circulation and rapid temperature drop. Cases should not be removed to storage room or restacked until product is at 0°F (-18°C) or lower. Product which has been above 25°F (-3.9°C) should be evaluated after it has been returned to 0°F (-18°C) or below. It may no longer have acceptable quality. Even if quality is still acceptable, the remaining shelf life has been shortened.
If the highest reading is 10°F (-12°C) or higher, but below 25°F (-3.9°C)	Damage to quality is occurring slowly but at an unacceptable rate. To prevent further damage, it is necessary to place the product in 0°F (-18°C) or lower temperature within an hour. If this is not done, damage to quality can be expected. If the product has risen above 10°F (-12°C), air circulation should be provided between cases. Even if the quality is still acceptable, the life of product with readings above 10°F (-12°C) is significantly reduced. Steps should be taken to rotate this inventory quickly.
If the highest reading is 0°F (-18°C)	This temperature is satisfactory for most, but not all, products. Thus, for most products it can be assumed that the quality achieved after the initial freezing has been retained. Every effort possible should be made to protect that quality.
General Rule	If frozen foods are at a desired low temperature, they may be stacked tightly to prevent air movement between cases to reduce the effects of a possible undesired increase in air temperature. If frozen foods are at an undesired high temperature that needs to be lowered without delay to preserve quality, cases should be stacked to allow circulation of colder air between cases to hasten the lowering of product temperature. Other products should be protected during this procedure to avoid inadvertent warming by the product under treatment.

Freezing

Clarence Birdseye of Gloucester, Massachusetts (deceased 1956), is credited with being the "Father of Frozen Foods." As a missionary, trapper, and U.S. Wildlife Service employee in Labrador, he recognized that fish caught and thrown onto the ice in extremely cold weather had markedly better eating quality than those frozen at higher temperatures. Using his natural inventiveness, in 1920 he developed the first machine that quickly froze foods either as bulk pieces or in retail size packages. This invention made possible better quality frozen foods than those produced by the slower, older methods. This process was called "Quick Freezing," and the products from it were called "Frosted Foods."

Frozen foods in retail packages for home consumption were first introduced to the buying public on March 6, 1930, by General Foods Corporation in 10 test food stores in Springfield, Massachusetts. Retail marketing of ice cream was well established and ice cream cabinets were commonly used to hold frozen foods in retail markets. As early as 1905, fruits and berries had been frozen in 50- and 100-lb (22- and 45-kg) barrels for use by the bakery, preserve, and ice cream industries. The earliest history of commercial freezing of foods coincides approximately with the advent of mechanical refrigeration in 1880. Meat, poultry, and fish began to be frozen by this method for transportation over long distances.

The freezing process consists of pre-freezing operations, freezing, and frozen storage. Depending on the food being frozen, some pre-freezing steps are: washing, husking, shelling, cutting, boning, trimming, pitting, and slicing. Inspection and grading on long moving belts, formerly a visual operation, is now being increasingly mechanized. Fruits may have sugar or syrup added, and vegetables may be subjected to steam or hot water blanching to retard enzymatic or chemical changes such as browning and off-flavor development that can occur during subsequent storage. Filling and sealing of packages are usually done by complicated machines designed for the purpose. New equipment, especially with labor saving principles, is constantly being introduced to improve product quality and reduce processing costs.

The freezing step can be accomplished in several ways. A common method is simply a variation of the basic Birdseye process: indirect contact with a refrigerant that flows through shelves or belts that may touch the bottom or both top and bottom of the packages, commonly called convection freezing.

An increasing quantity of foods is being frozen by a free flow freezing process to achieve individually quick frozen (IQF) product pieces. The unpackaged food is frozen either on belt freezers where air at -30°F (-34°C) blows up through a mesh belt and through a thin layer of small food product pieces or in fluidized-bed freezers where the blast of upcoming air is of sufficient velocity to partially suspend the food.

Freezing by these techniques takes only a few minutes. The free-flowing frozen foods are quickly conveyed to large storage bins and thence to the cold store. Since the frozen product is bulk-stored in bins holding over 15,000 lbs (6,800 kg) with minimum moisture barrier, special precautions must be taken to avoid dehydration or transfer of moisture from the frozen food to cold walls or coils. This is accomplished by eliminating circulation of air and keeping the walls at the same temperature as the food itself, or at most only a few degrees lower. The walls are surrounded with ducts through which the cold air blows.

This method of storage has proved most successful, especially for those processing plants that repack during the off season. (In the UK, the bins are known as palletainers [now being replaced by octobins]. They hold approximately 2,000 lbs. [907 kg] and are lined with black polythene as a moisture barrier with the polythene folded over the top of the product for protection.)

Rapid freezing methods, such as liquid nitrogen, for commercial freezing have increased. In one commercial line, shrimp are frozen by passing them under a liquid-nitrogen spray for less than 2 minutes. The shrimp are conveyed first through a cooling area where nitrogen gas from the freezing part of the process is used to cool the product. The shrimp then come into direct contact with liquid nitrogen sprays at -320°F (-195°C), and the major part of the freezing process takes place in this phase. The product then equilibrates to -20°F (-29°C) and is finally ready for the cold store. This technique, commonly called conduction freezing, can be used for vegetables, fruits, and other products. Turkeys, wrapped in Cryovac™, are "Crust Frozen" by immersion in propylene glycol at about 0°F (-18°C) to produce a chalky white surface color. Freezing is then completed by placing them in cold storage rooms at about the same temperature. Rapid freezing technique, sometimes called cryogenic freezing, has reduced freezing times for some items to a matter of seconds; for larger products, a few minutes. Such rapid freezing rates result in better texture retention after thawing for many products. Because of the higher cost of cryogenic freezing, this method is usually limited to high-cost items where improved quality or yield more than pays for increased cost.

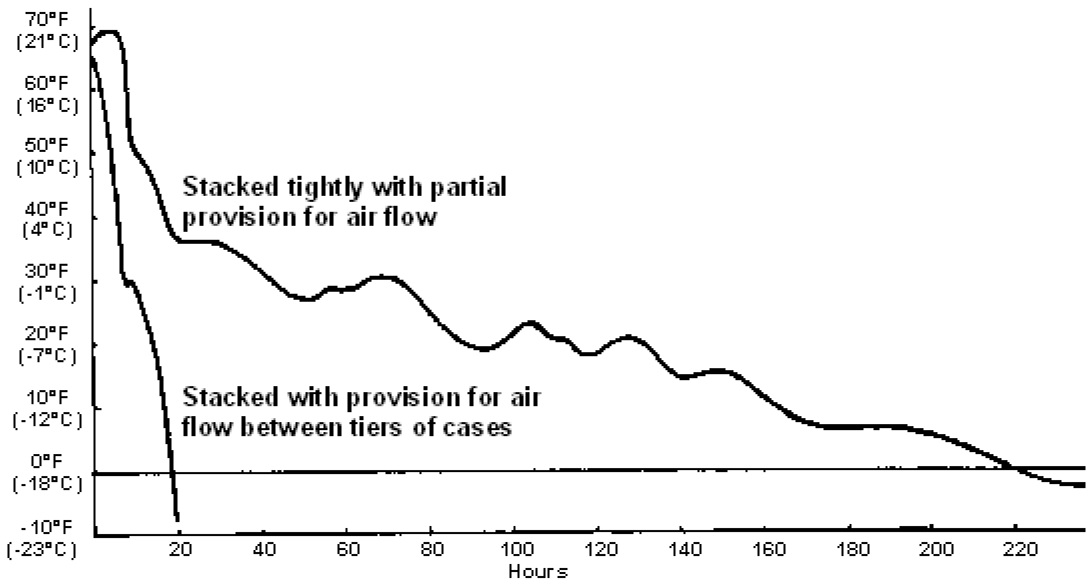
Another common method, referred to as blast freezing, is to rapidly pass cold air over packages as they move through a tunnel or when they are stacked in rooms. This method is in most common use by refrigerated warehouses for freezing foods—either from the unfrozen state for a processor with limited freezer capacity or for bringing the temperature of still-frozen foods back to 0°F (-18°C) after they have been exposed to elevated temperatures. The freezing of retail size packages in cases is not recommended because freezing cannot be accomplished at an acceptable rate.

There are four important points to consider in efficient operation of air blast freezing:

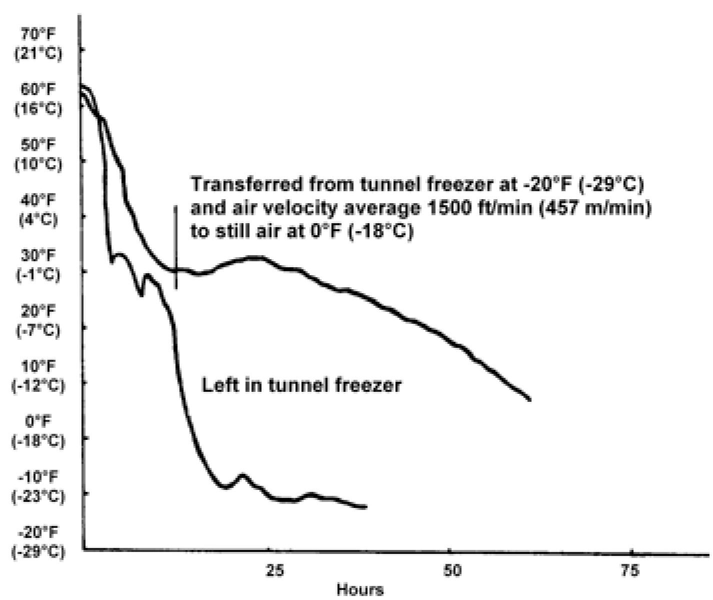
1. Air temperature of the freezer should be -10°F (-23°C) or preferably lower. Typically, the temperature is -30 to -40°F (-34 to -40°C).
2. Air velocity should be 1,000-2,000 ft/min (305-610 m/min) or higher.
3. Product should not be transferred to the still-air storage room until the product has attained 0°F (-18°C).
4. A stacking arrangement on pallets should be used that enables cold air to contact all cases.

For freezing on pallets, stacking to provide air flow between tiers and layers of cases is very important. Pallet loads providing only partial air flow through the stack may be satisfactory for refreezing when the temperature has only risen slightly, but are not satisfactory when large reductions in temperature are desired. Tightly stacked pallets are efficient for storage, but are completely unsatisfactory for freezing purposes.

A comparison of freezing rates as influenced by two different stacking methods is shown below.

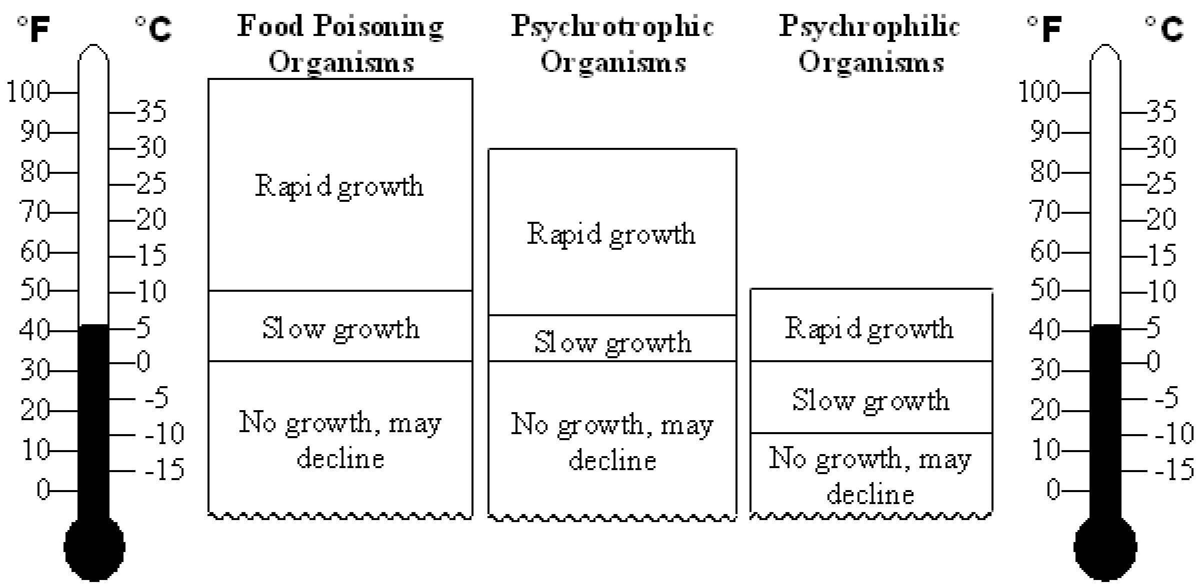


An indication of the increase in length of freezing time if the product is removed from the cold air blast to still air before freezing is complete is indicated below.



For efficient use of freezing equipment and space and to minimize any color or flavor changes, retail and institutional size packages are usually frozen to below the zone of maximum crystal formation (about -14°F or -10°C) in approximately 24 hours and then transferred to the storage room for reduction to 0°F (-18°C). Bulk packs of fruit with sugar, in 30-, 50-, and 100-lb (14-, 22-, and 45-kg) containers for the ice cream, bakery, and preserve industry, are usually frozen more slowly, or the containers are rotated during the freezing process to permit the sugar to penetrate the fruit. In all instances air movement should be rapid.

Freezing prevents food from spoiling because spoilage agents, including bacteria, yeasts, and molds, cease functioning at temperatures below approximately 14°F (-10°C). Vegetative organisms gradually die during frozen storage, but may not be complete eradicated, and spores are unaffected. Thus, growth activity may resume when returned to a more suitable temperature. Hence, there is a need to ensure that raw materials are of good microbiological quality to reduce survivors after thawing. Food poisoning organisms and psychrotrophic (spoilage) organisms cease functioning at just below 32°F (0°C), and psychrophilic (spoilage) organisms, which are less common in foods, cease functioning at approximately 14°F (-10°C), as shown in the following illustration**.***



*Note: *Listeria monocytogenes* has the characteristics of a psychrophilic organism, but is a food poisoning organism.

Frozen foods cannot become a hazard to public health during frozen storage. A hazard can, however, develop if they are exposed to temperatures well above 32°F (0°C) for extended periods before freezing or after thawing.

Packages for food in all instances should be sealable, and the packaging material should be a moisture-vapor proof barrier to prevent the food from drying out. "Freezer burn" is a term used to describe the surface of frozen poultry, meat, and other products that have dried out because of poor packaging. The surface has a whitish, mottled appearance. Foods whose color or flavor may be changed due to the presence of air in the headspace of the container are sometimes packaged in rigid containers and the air in the headspace replaced with an inert gas such as nitrogen.

Frozen foods, in general, maintain their color and flavor better than foods preserved by other conventional methods, but they are still preserved foods and differ from the fresh product in these characteristics, as well as in texture. Nutritionally, freezing retains vitamin values better than other conventional preservation procedures because high temperatures, damaging especially to Vitamins C and B_1, are not present. Studies sponsored by WFLO have demonstrated that while losses of Vitamins C and B_1 and protein bioavailability are not totally arrested during frozen storage, the losses at 0°F (-18°C) storage for 1 year are equivalent to losses that occur in the raw unfrozen product in days or weeks. The nutritive value of minerals, fats, proteins, and carbohydrates are not impaired by the freezing process. Any increase in these components can usually be ascribed to loss of moisture due to inadequate packaging.

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