Seminar on
Food Freezing Technology

Organized by the
Research Committee on Food Science of the National Science Foundation
in collaboration with the Technology Watch Centre (TWC)

Venue : NSF Auditorium *Date : 17th September 2004*

PROGRAMME

09.00 a.m.	Registration	
09.30 a.m.	**Welcome Address**	Chairperson/ Director, NSF
09.35 a.m.	**Address by Mr D.B. Sumithraarachchi**	Director ADB STPD Project
09.40 a.m.	**Introduction to the seminar**	Mr M. Watson Director - NSF
09.45 a.m.	**Basic Technology of Food Freezing**	Mr P. Arampath Dept. of Food Science & Technology University of Peradeniya
10.15 a.m.	Discussion	
10.30 a.m.	**Meat Freezing Technologies**	Prof. H.W.Cyril Dept. of Animal Science University of Peradeniya
11.00 a.m.	Discussion	
11.15 a.m.	Tea	
11.30 a.m.	**The Status of the Long line Fish Industry in Sri Lanka**	Mr Roshan Fernando Director Tropic Frozen Foods Ltd.
12.00 noon	Discussion	
12.15 p.m.	**Fish Freezing Technologies**	Dr Ranjith Edirisinghe National Aquatic Resources Research & Development Agency
12.45 p.m.	Discussion	
01.00 p.m.	Lunch	
01.45 p.m.	**Freezing Technologies on Dairy Products**	Dr J. Punjrath Managing Director Cargills (Ceylon) Ltd
02.15 p.m.	Discussion	
02.30 p.m.	**Vegetable & Fruit Freezing Technologies**	Dr D.B.T. Wijeratne Chairman – Coconut Research Institute and Director (R & D and Marketing) – Ministry of Agriculture and Livestock
03.00 p.m.	**Safety of Frozen Foods**	Ms Malini Mallawarachchi Industrial Technology Institute
03.30 p.m.	**Final Discussion & Summing up**	
03.45 p.m.	Tea & Close of seminar	

Resources

- Sri Lanka has a land area of 65,510 km2.
- The coastline is 2,825 km.
- The Area of the continental shelf is 19,247 km2.
- The claimed Exclusive Economic Zone is 500,750 km2. (approx 6 times land area)
- The production from off-shore fishery has increased from 800 MT in 1984 to 84,400 MT in 2000.

Resource Potential

- The MSY of coastal fishery is estimated at 250,000MT per annum.(170,000 MT p.a. pelagic and 80,000 MT p.a. demersal and semi-demersal).
- The coastal fishery is nearing its MSY.
- The MSY for off-shore fishery is 90,000 MT p.a.
- Only 16% of this potential exploited.

The Unutilized potential is 86%

Fishery Sectors

- **Coastal Fisheries** – any fishing done from the coast up to 250 km.
- **Off-shore Fisheries** – any fishery carried out beyond 250 km.

EEZ of Sri Lanka

LONG LINE FISHERY

Principle methods used:

- Bottom Long Lining
- Surface Long Lining

Roshan Fernando

- Long lining is one of the most common fish capture methods in the world.
- In the last few years there has been an increasing debate about responsible and sustainable fisheries, and in this regard long lining has many advantages.

Roshan Fernando

Advantages

- Environmentally Friendly Gear-Long lining is one of the most conservative methods of harvesting fish. Prior to its development, pelagic fish were caught by hand line, rod and reel, and harpoon. Long lining combines the quality afforded by "one-at-a-time-handling" fishing methods with the conservation and efficiency of the "hook-and-line" long lining method.

Roshan Fernando

Advantages

- Compared to towed fishing gear that has a serious negative impact on the seabed, like the damage to coral reef it has only a minor impact on the seabed.
- Selectivity - low discard rate of undersized fish and non- target species.
- Good quality catch - rate of damaged fish is low and this optimizes the economic value of the catch landed.

Roshan Fernando

Methods of Long Line Fishing

- Rather than a net, *long lining* uses baited hooks on offshoots (or leaders) of a single main line to catch fish at any level.
- Bottom Lining is carried out by dropping the line to the bottom of the sea by means of weights and buoys.
  - Target Species –*Demersals*
- Surface long lining is carried out by floating the line on the surface of the water by means of floats.
  - Target Species – *Pelagics*

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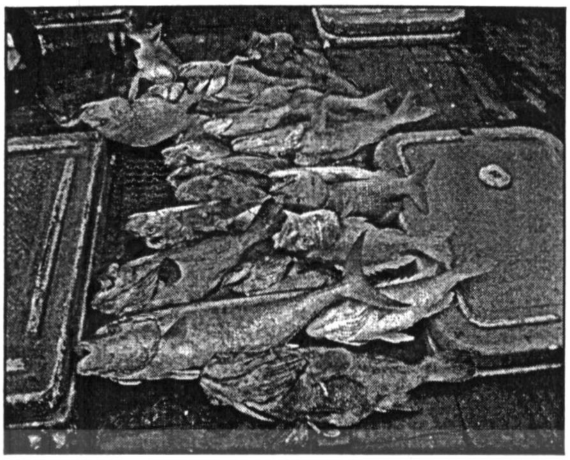
BOTTOM LONG LINE FISHERY

Target area continental shelf and tip of the continental shelf

Roshan Fernando

- Long-lining has proven extremely effective for catching a large number of commercially valuable demersal species.
- Bottom long-line systems can be deployed from any size vessel and efficiently capture fish ranging from mullets, trevally, , snapper, grouper and shark.
- The introduction of modern materials and new techniques into a basic bottom system can result in consistently larger catch, lower cost per unit effort and improved gear recovery.

Roshan Fernando

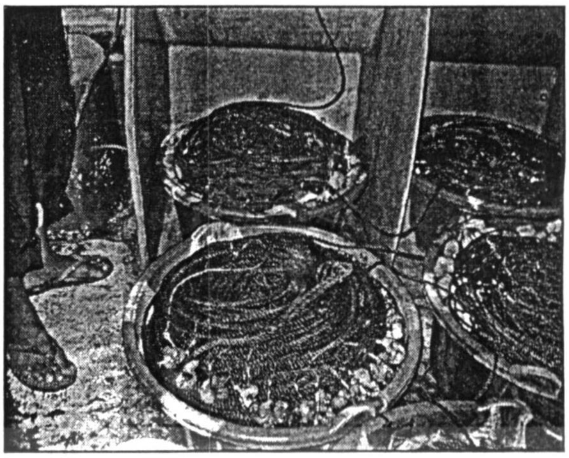


Bottom Line Method

Bottom long-lining possesses several advantages that account for its popularity

- Low cost of initial capitalization, low direct fishing related expenses, limited crew requirement, simple and efficient operation and proven catch record.
- A typical bottom long-line set includes; a main-line, buoy system and branch lines or leaders.
- Each gear element are largely a function the demands of depth, ocean conditions, vessel sophistication.

Roshan Fernando

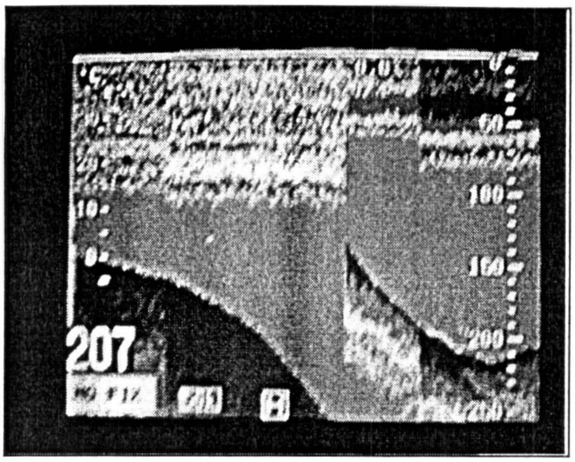


Fishing Gear

- A typical bottom fishing system can be designed to fish between 2000 - 2500 one meter (1.0 meter) leaders, spaced approximately five meters (5.0 meters) apart.
- Hook spacing is an important variable in all bottom long-line sets.
- The catch location of previous sets is often the best indication of productive grounds

Technology - Electronics

- Significant advances in electronics and computer software have allowed bottom long-line operations in developed countries, to become more technically advanced.
- The use of navigation chart plotters, differential GPS receivers, high powered color video sounders and Windows compatible three dimensional bathymetric software are now common onboard commercial, foreign bottom long-line vessels.
- Application of this equipment has allowed fishermen to be more selective in their gear location and hook spacing, Where gear is not blindly set over familiar grounds with an emphasis on hook quantity. Instead, great time and consideration is taken prior to and during each set, to review the vessel's position and bottom conditions, to best determine hook spacing and maximize catch results.



SURFACE LONG LINE FISHERY

Target area – off shore areas within and outside the EEZ of Sri Lanka

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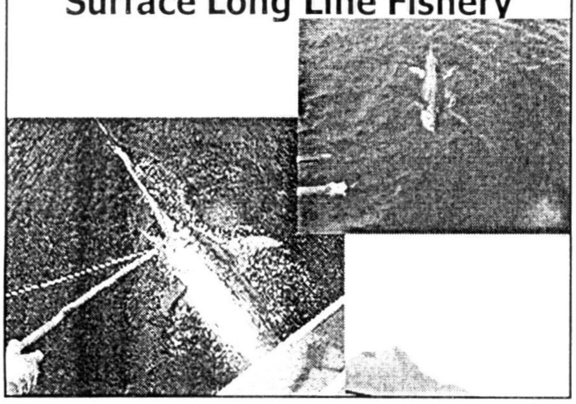
Surface Long Line Fishery

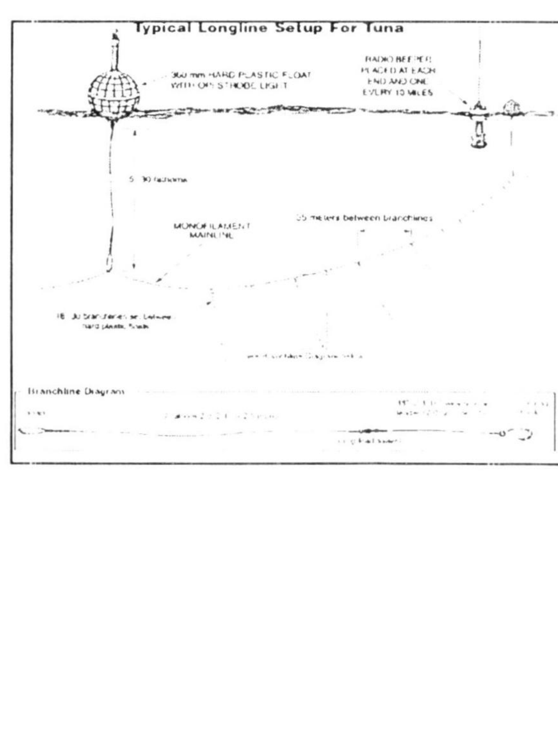


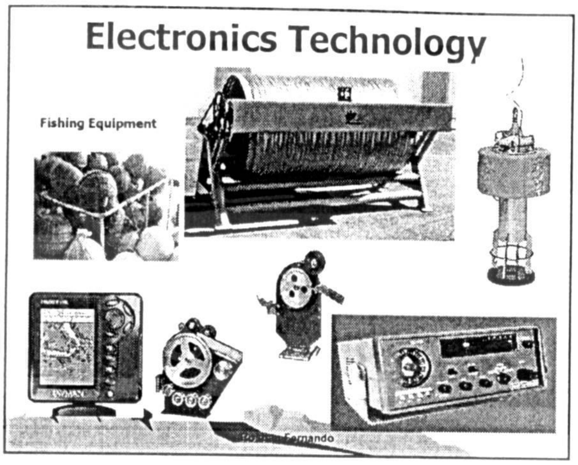
- International participation in the Surface - long-line fishery for pelagic swordfish and tunas has been increasing steadily since the late 1980's.
- Many countries have adopted monofilament long-line equipment and practiced this fishery with local modifications and influences.
- Pelagic monofilament long-line gear fishes specifically for highly migratory, actively feeding swordfish, tunas and sharks

Fishing Gear

- Longline gear consists of a continuous mainline supported by buoys and float lines, with regularly spaced branch lines that end with baited hooks.
- Typical gear consists of a monofilament 3-4 mm thick mainline with 1,200 to 3,000 hooks spaced at 50 -70 m.

Branch lines /leaders are 22 m long with approx 1.6 mm thick line.





Thank You

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Seminar on

Basic Technology of Freezing

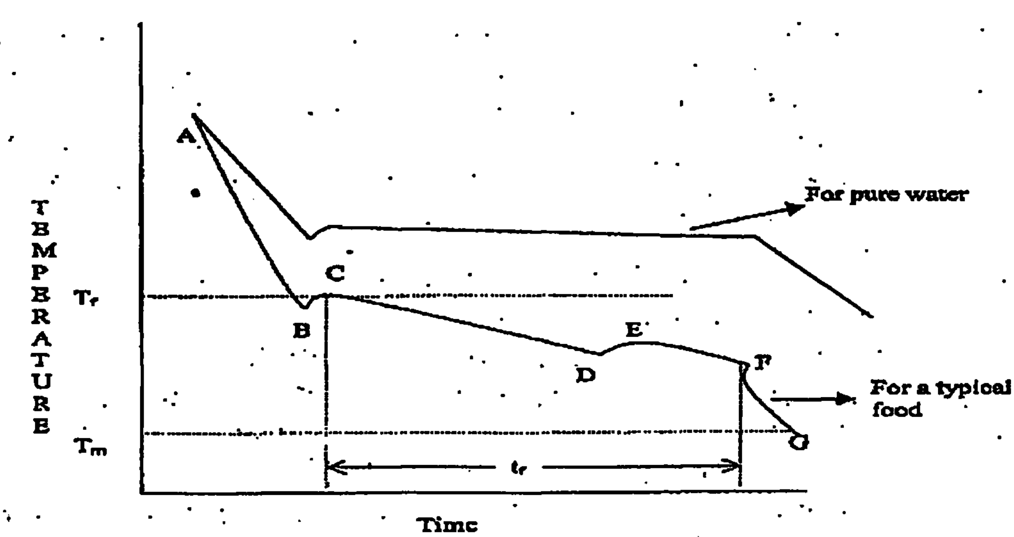
Mr. P.C. Arampath, Dept. of Food Science & Technology, Faculty of Agriculture, University of Peradeniya.

17/09/2004

Freezing of Foods

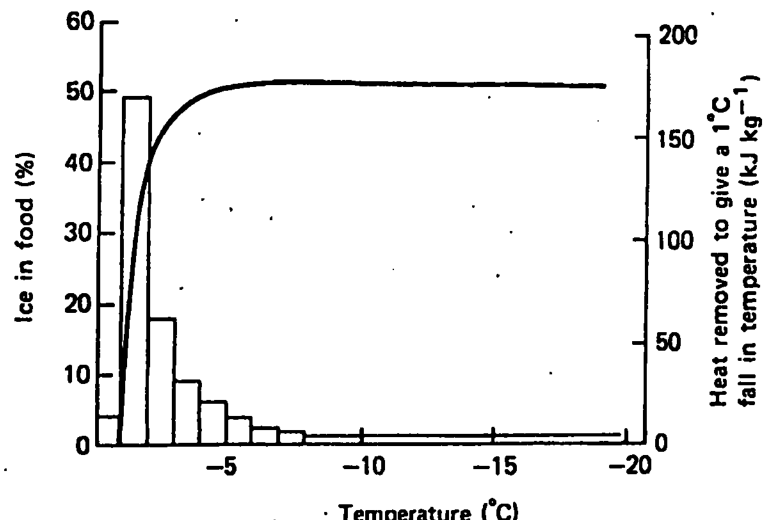
Water contents and freezing points of selected foods

Food	Water content (%)	Freezing point (C)
Vegetables	78-92	-0.8 to -2.8
Fruits	87-95	-0.9 to -2.7
Meat	55-70	-1.7 to -2.2
Fish	65-81	-0.6 to -2.0
Milk	87	-0.5
Egg	74	-0.5



t_f = freezing time; T_f = freezing temperature; T_m = temperature of freezing medium

The time taken for the temperature of a food to pass through the *critical zone* (Fig. 21.2) determines both the number and the size of ice crystals. .



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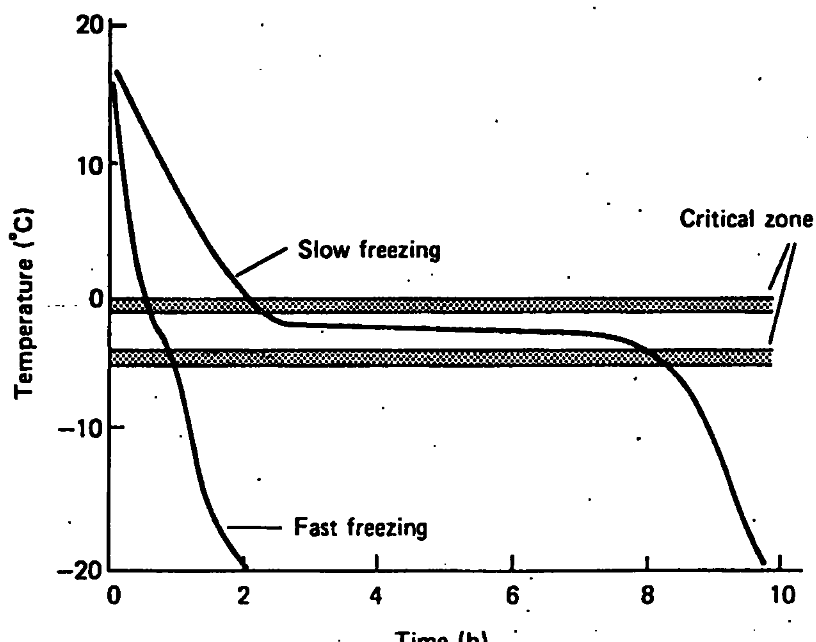


(b)

Solute concentration

Defn. of **eutectic temperature -**

(for example for glucose this is -5°C, for sucrose -14°C, for sodium chloride -21.13°C and for calcium chloride -55°C)

Final eutectic temperature -

(for example for ice-cream this is -55°C, for meat -50 to -60°C and for bread -70°C).

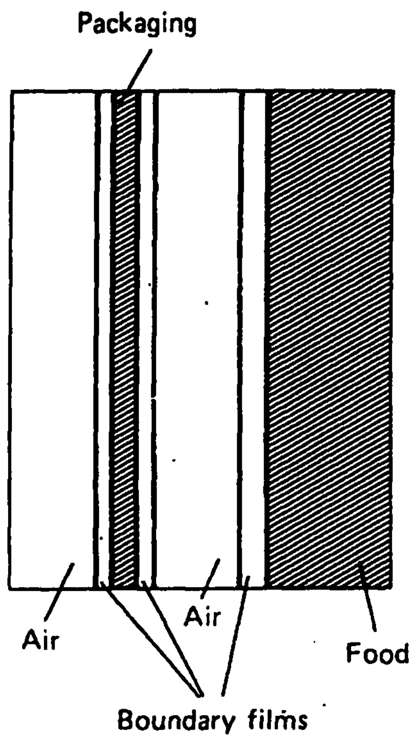
Volume changes

The volume of ice is 9% greater than that of pure water, and an expansion of foods after freezing would therefore be expected.

Calculation of freezing time

The factors which influence the rate of heat transfer are:

(1) the thermal conductivity of the food,
(2) the area of food available for heat transfer,
(3) the distance that the heat must travel through the food,
(4) the temperature difference between the food and the freezing medium,
(5) the insulating effect of the boundary film of air surrounding the food. (If packaging is present, this is an additional barrier to heat flow)



Mathematical solution of freezing rate of a food is not possible - unsteady state - approximate solution based on formulae developed by Plank.

The freezing time for cubes of food is calculated using

$$t_f = \frac{\rho\lambda}{T_f - T_a}\left[\frac{L}{6}\left(\frac{1}{h} + \frac{x}{k_1}\right) + \frac{L^2}{24k_2}\right]$$

where t_f is the freezing time, L (m) the length of cube, h(W m^{-2} K^{-1}) the surface heat transfer coefficient, T_f(°C) the freezing point of food, Ta (°C) the temperature of freezing λ

medium, (J kg^{-1}) the latent heat of crystallization, p (kg m^{-3}) the density of food, x (m) the thickness of packaging, k_1 (W m^{-1} K^{-1}) the thermal conductivity of packaging and k_2 (W m^{-1} K^{-1}) the thermal conductivity of frozen zone; 6 and 24 are factors. Other shapes require different factors (which represent the shortest distance from the centre to the surface of the food); these are 2 and 8 for a slab,4 and 16 for a cylinder, and 6 and 24 for a sphere.

Equation (19.1) may be rearranged to find the heat transfer coefficient as follows:

$$h = \frac{L}{6}\left[\frac{t_f(T_f - T_a)}{\rho\lambda} - \frac{Lx}{6k_1} - \frac{L^2}{24k_2}\right]$$

Sample problem 21.1

Five-centimeter potato cubes are individually quick frozen (IQF) in a blast freezer operating at -40C and with a surface heat transfer coefficient of 30 Wm^{-2}K^{-1} (Table 21.3). If the freezing point of the potato is measured as -1.0C and the density is 1180kg m^{-3}, calculate the expected freezing time for each cube. If the cubes are then packed into a cardboard carton measuring 20cm x 10cm x 10cm, calculate the freezing time. Also calculate the freezing time for IQF freezing of 2.5cm cubes. (Additional data: the thickness of the card is 1.5mm, the thermal conductivity of the card is 0.07 Wm^{-1}K^{-1}, the thermal conductivity of potato is 2.5 Wm^{-1}K^{-1} (Table 1.4) and the latent heat of crystallization 2.74 x 10^5 J kg^{-1}). (λ).

Freezers are broadly categorized into

(1) mechanical refrigerators

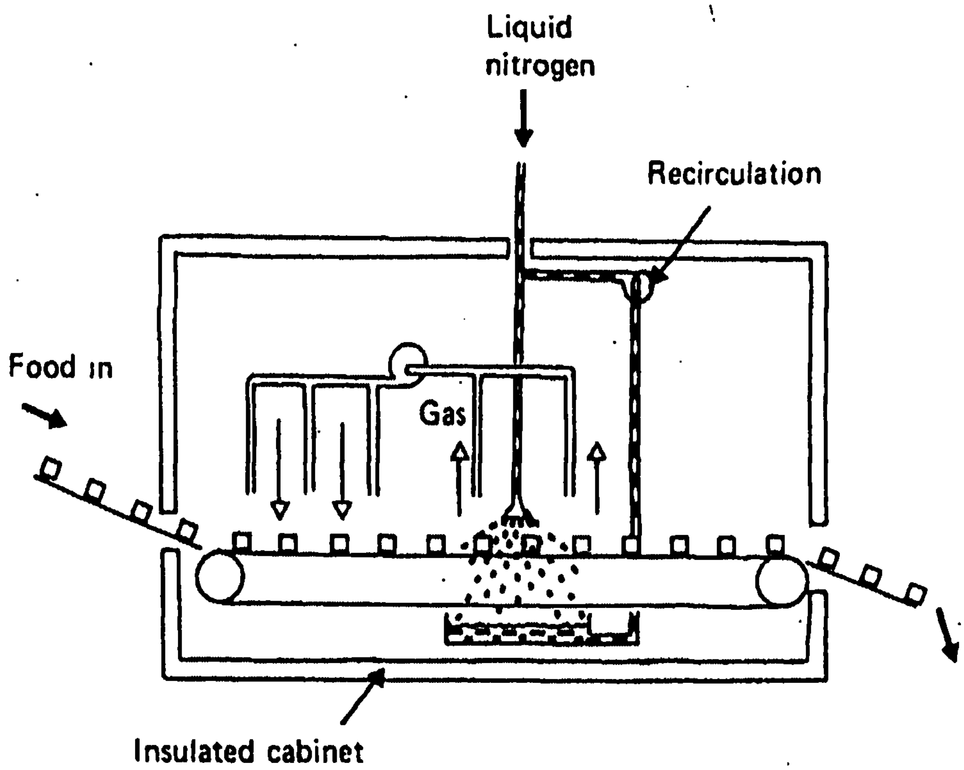
(2) cryogenic freezers:

An alternative classification, based on the rate of movement of the ice front is:

(1) *slow freezers* and *sharp freezers* (0.2 cm h^{-1}) including still-air freezers and cold stores,
(2) *quick freezers* (0.5-3 cm h^{-1}) including air-blast and plate freezers,
(3) *rapid freezers* (5-10 cm h^{-1}) including fluidized-bed freezing and
(4) *ultrarapid freezers* (10-100 cm h^{-1}), that is cryogenic freezers.

Table 19.2--Properties of food cryogens

	Liquid N_2	CO_2
Density (kg m^{-3})	784	464
Specific heat (liquid) (kJ kg^{-1}K^{-1})	1.0	2.2
Latent heat (kJ kg^{-1})	358	352
Total usable refrig. effect (kJ kg^{-1})	690	565
Boiling point (C)	-196	-78.5 (sub)
Consumption per 100 kg of product frozen (kg)	100-300	120-375



Immersion of foods in liquid nitrogen:

A comparison of freezing methods

Method of freezing	Typical film heat transfer coefficient	Typical freezing times for specified foods to -18C (min)	Food
Still air	6-9	180-4320	Meat carcass
Blast (5 ms^{-1})	25-30	15-20	Unpackaged peas
Blast (3 ms^{-1})	18		--
Spiral belt	25	12-19	Hamburgers; fish fingers
Fluidized bed	90-140	3-4	Unpacked peas
		15	Fish fingers
Plate	100	75	25 kg blocks of fish
		25	1 kg carton vegetables
Scraped surface	--	0.3-0.5	Ice cream (layer ca.1mm thick)
Cryogenic (liquid N)		1.5	454 g of bread
	1500	0.9	454 g of cake
		2-5	Hamburgers; seafood

		.5-0.6	Fruits and vegetables

	Storage	Time	(months)
Product			
Fruits	-12°C	-18°C	-24°C
Raspberries (raw)	5	24	>24
Peaches	3	18	>24
Vegetables			
Carrots	10	18	>24
Mushrooms	2	8	>24
Spinach	4	18	>24
Meats			
Lamb carcass	18	24	>24
Pork steaks	6	10	15
Liver	4	12	18
Seafood			
Fatty fish	3	5	>9
Shrimp (cooked)	2	5	>9
Dairy Products			
Butter	20	>24	>24
Ice cream	1	6	24
Bakery goods			
Breads	-	3	-
Raw dough	-	12	18

The loss in quality of strawberries during a typical manufacturing through distribution chain. (Source: Singh and Heldman, 1993. Introduction to Food Engineering, Academic Press. From: Jul, 1984, The Quality of Frozen Foods, Academic Press)

Stage	Time (Days)	Temperature (C)	Acceptability (Days)	Loss per day (%)	Loss (%)
Producer	250	-22	660	0.15152	37.88
Transport	2	-14	220	0.45455	0.91
Wholesale	50	-23	710	0.14085	7.04
Transport	1	-12	140	0.71429	0.71
Retail	21	-11	110	0.90909	19.09
Transport	0.1	-3	18	5.55556	0.56
Home freezer	20	-13	180	0.55556	11.11
Total storage (days)	= 344.1			Total quality loss	(percent) = 77.30

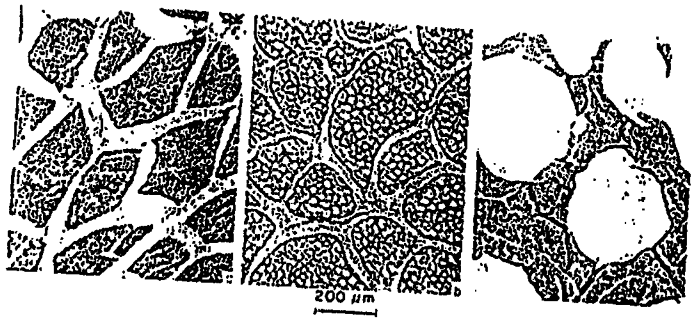
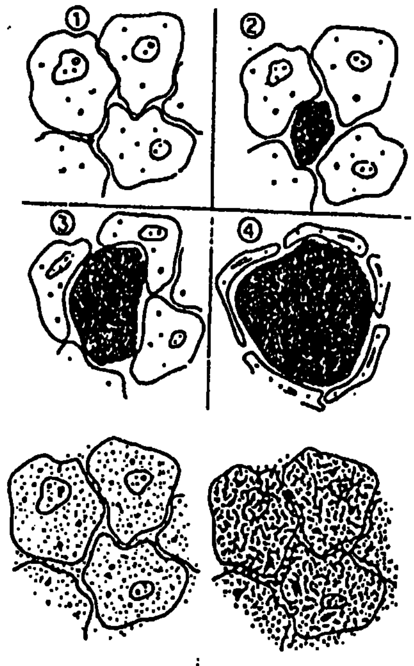
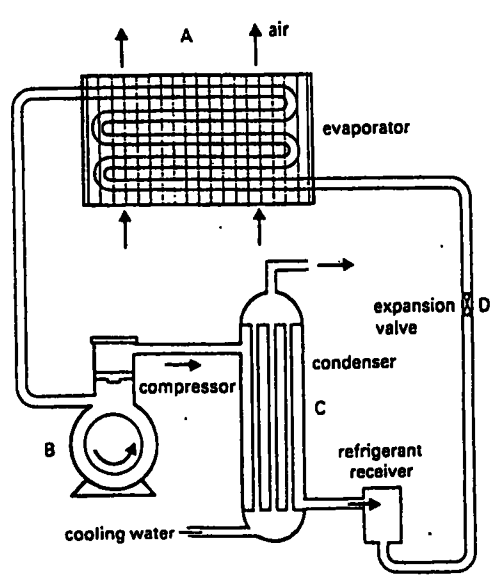
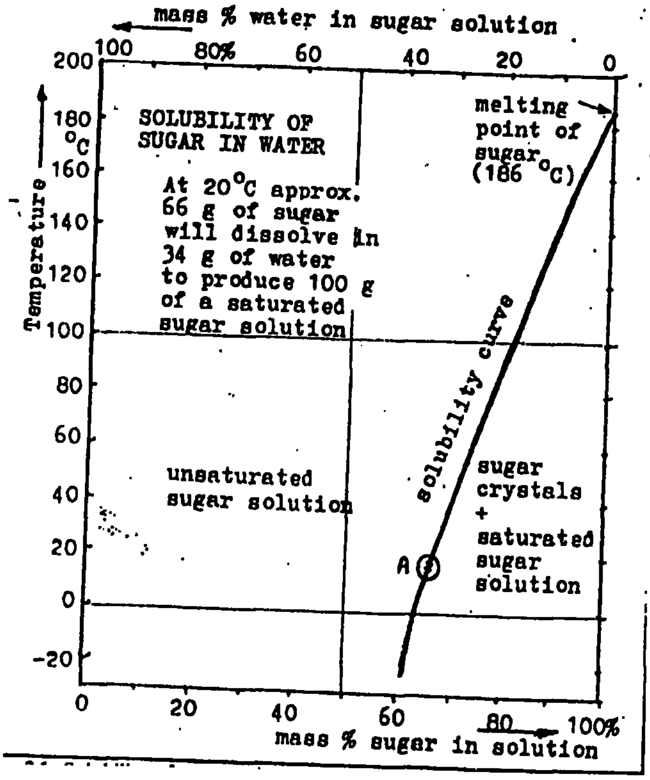
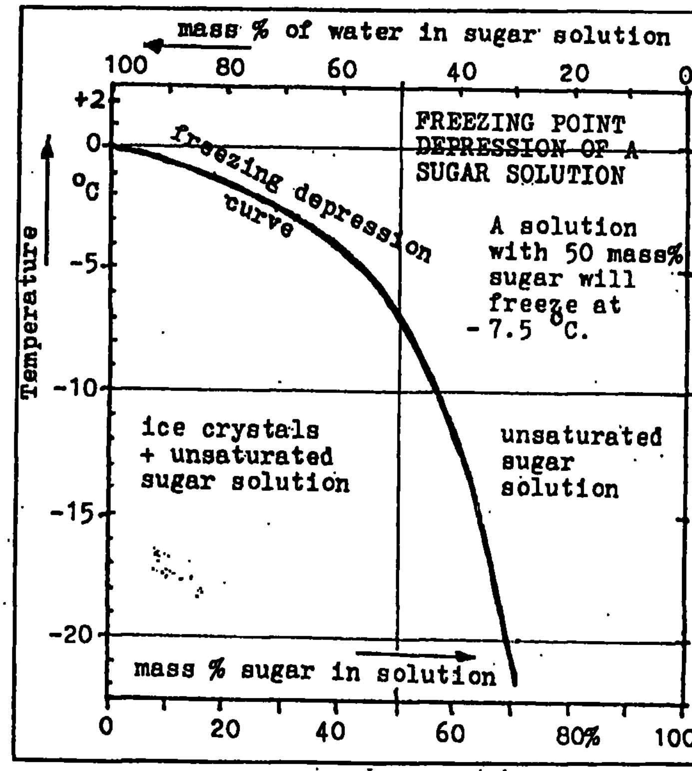


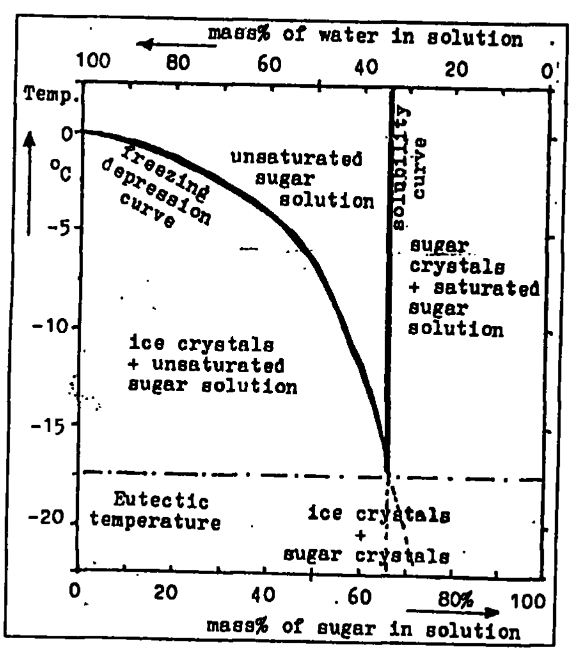
FIG. 6-4. Effect of freezing rate on the location of ice crystals in postrigor cod muscle. (a) Unfrozen, (b) rapidly frozen, (c) Slowly frozen. From Love [47], courtesy of Academic Press.











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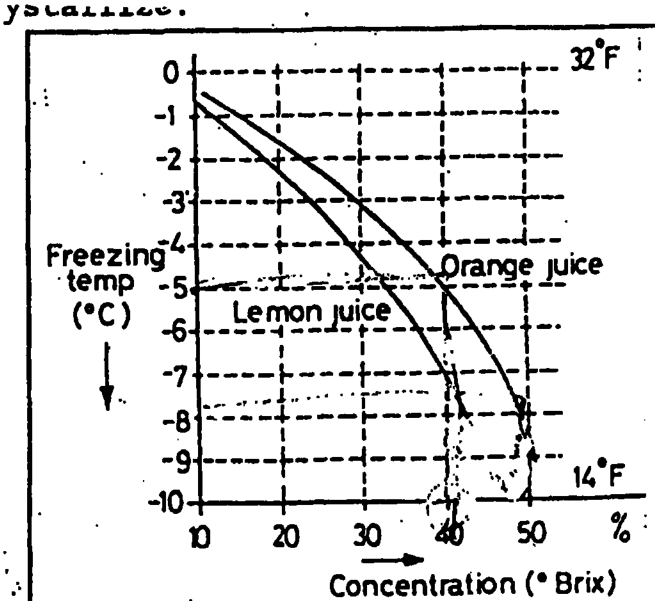

Fig. 3.4: Freezing point depression of orange juice and

3.2 FREEZING EQUIPMENT

Freezers are broadly categorised into

(1) mechanical refrigerators, which evaporate and compress a refrigerant in a continuous cycle
(2) cryogenic freezers.

Mechanical freezers use cooled air, cooled liquid or cooled surfaces to remove heat from foods. Cryogenic freezers use carbon dioxide, liquid nitrogen or liquid Freon directly in contact with the food.

The selection of freezing equipment should take the following factors into consideration:

(1) rate of freezing required;
(2) size, shape and packaging requirements of the food;
(3) batch or continuous operation, depending on the scale of production and the number of product types.

An alternative classification, based on the rate of movement of the ice front is

(1) *slow freezers* and *sharp freezers* (0.2 cm h^{-1}) including still-air freezers and cold stores,
(2) *quick freezers* (0.5–3 cm h^{-1}) including air-blast and plate freezers,
(3) *rapid freezers* (5–10 cm h^{-1}) including fluidised-bed freezing and

(4) *ultrarapid freezers* (10–100 cm h^{-1}), that is cryogenic freezers.

All freezers are insulated with expanded polystyrene, polyurethane or other materials which have low thermal conductivity

3.2.1 Cooled air freezers

3.2.1.1 *Chest freezers*

Food is frozen in stationary (natural-circulation) air at between −20°C and −30°C. Chest freezers are not used for commercial freezing owing to low freezing rates (3–72 h), which result in poor process economics and loss of product quality (section 19.3). Cold stores can be regarded as large chest freezers. They are used to freeze carcass meat, for frozen storage of foods frozen by other methods, and as hardening rooms for ice cream. Air is usually circulated by fans to improve the uniformity of temperature distribution, but heat transfer coefficients are low (Table 19.3).

3.2.1.2 *Blast freezers*

Air is recirculated over food at between −30°C and −40°C at a velocity of 1.5–6.0 m s^{-1}. The high air velocity reduces the thickness of boundary films surrounding the food (Chapter 1) and thus increases the surface heat transfer coefficient (Table 19.3). In batch equipment, food is stacked on trays in rooms or cabinets. The trolleys should be fully loaded to prevent air from bypassing the food through spaces between the trays. Continuous equipment consists of trolleys stacked with trays of food or of conveyor belts which carry the food through an insulated tunnel. Multipass tunnels have a number of belts, and products fall from one to another. This breaks up any clumps of food and allows control over the product depth (for example a 25–50 mm bed is initially frozen for 5–10 min and then repiled to 100–125 mm on a second belt). The smaller surface-area-to-volume ratio of these freezers permits a 30% saving in energy from reduced heat penetration and 20% less floor space.

Air flow is either parallel or perpendicular to the food and is ducted to pass evenly over all food pieces. Blast freezing is relatively economical and highly flexible in that foods of different shapes and sizes can be frozen. The equipment is compact and has a relatively low capital cost and a high throughput (200–1500 kg h^{-1}). However, the large volumes of recycled air can cause freezer burn and oxidative changes to unpackaged or IQF foods. Moisture from the food is transferred to the air and builds up as ice on the refrigeration coils, and this necessitates frequent defrosting.

3.2.1.3 *Belt freezers (spiral freezers)*

There are modified air-blast freezers in which a continuous flexible mesh belt is formed into spiral tiers. Food is carried up through a refrigerated chamber on the belt. In some designs each tier rests on the vertical sides of the tier beneath (Fig. 19.4) and the belt is therefore 'self-stacking'. This eliminates the need for support rails and improves the capacity by up to 50% for a given stack height. Cold air or sprays of liquid nitrogen (section 19.2.4) are directed down through the belt stack (counter-current flow) to reduce weight losses due to evaporation of moisture. Spiral freezers require relatively small floor-space and have high capacity (for example a 50–75 cm belt in a 32-tier spiral processes up to 3000 kg h^{-1}). Other advantages include

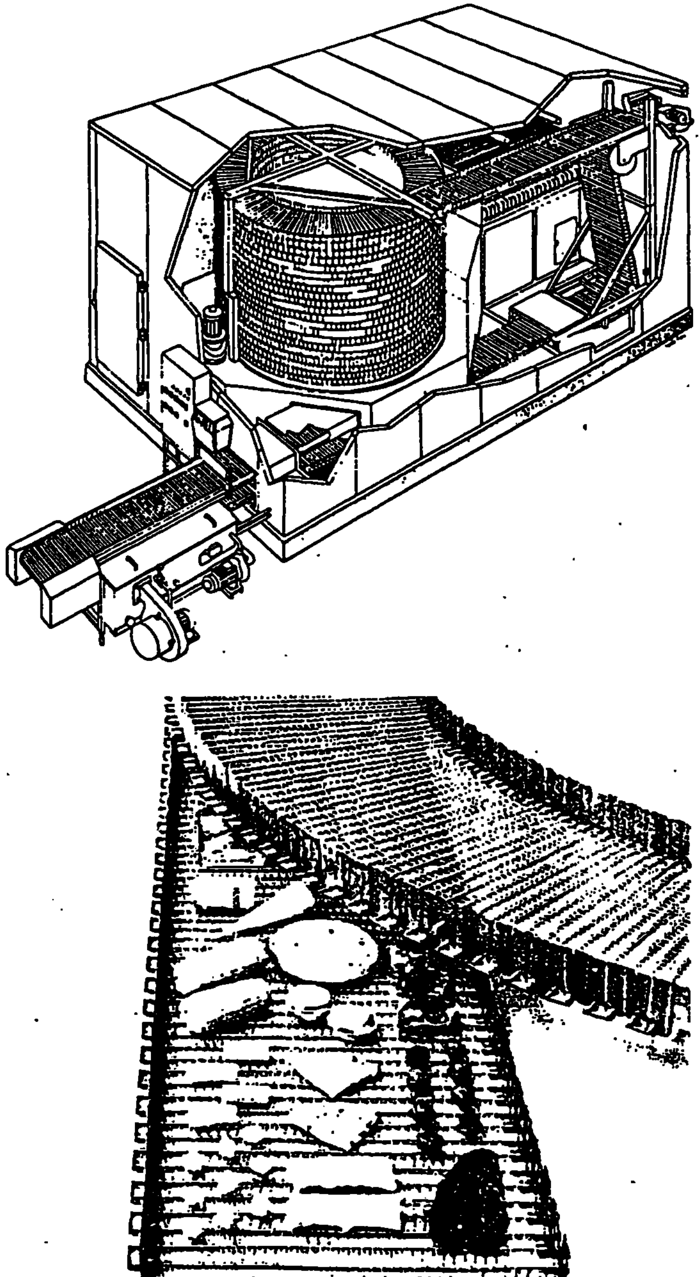

Fig. 19.4 — Spiral freezer, self-stacking belt. (Courtesy of Frigusca[illegible] Ltd.)

automatic loading and unloading, low maintenance costs and flexibility for different products. They are used for a wide range of foods including pizzas, cakes, pies, ice cream, whole fish and chicken portions.

3.2.1.4 *Fluidised-bed freezers*

These are a modified blast freezers in which air at between −25°C and −35°C is passed at a high velocity (2–5 m s^{-1}) through a 2–13 cm bed of food, contained on a perforated tray or conveyor belt. In some designs there are two stages; after initial rapid freezing to produce an ice glaze on the surface of the food, freezing is completed on a second belt in beds 10–15 cm deep. The formation of a glaze is useful for fruit pieces and other products that have a tendency to clump together. The shape and size of the pieces of food determine the thickness of the fluidised bed and the air velocity needed for fluidisation. A sample calculation of air velocity is shown in Chapter 1. Food comes into greater contact with the air than in blast freezers, and all surfaces are frozen simultaneously and uniformly. This produces higher heat transfer coefficients, shorter freezing times (Table 19.3), higher production rates (10 000 kg h^{-1}) and less dehydration of unpackaged food than blast freezing. The equipment therefore needs less frequent defrosting. However, the method is restricted to particulate foods (for example peas, sweetcorn kernels, shrimps, strawberries or French fried potatoes). Similar equipment, named *through-flow freezers*, in which air passes through a bed of food but fluidisation is not achieved, is suitable for larger pieces of food (for example fish fillets). Both types of equipment are compact, have a high capacity and are highly suited to the production of IQF foods.

3.2.2 Cooled liquid freezers

3.2.2.1 *Immersion freezers*

Packaged food is passed through a bath of refrigerated propylene glycol, brine, glycerol or calcium chloride solution on a submerged mesh conveyor. In contrast with cryogenic freezing (section 19.2.3), the liquid remains fluid throughout the freezing operation and a change of state does not occur. The method has high rates of heat transfer (Table 19.3) and capital costs are relatively low. It is used commercially for concentrated orange juice in laminated card–polyethylene cans, and to pre-freeze film-wrapped poultry before blast freezing.

3.2.3 Cooled-surface freezers

3.2.3.1 *Plate freezers*

Plate freezers consist of a vertical or horizontal series of hollow plates, through which refrigerant is pumped at −40°C (Fig. 19.5). They may be batch, semi-continuous or continuous in operation. Flat, relatively thin foods (for example filleted fish, fish fingers or beefburgers) are placed in single layers between the plates and a slight pressure is applied by moving the plates together. This improves the contact between surfaces of the food and the plates and thereby increases the rate of heat transfer. If packaged food is frozen in this way, the pressure prevents the larger surfaces of the packs from bulging. Production rates range from 90–2700 kg h^{-1} in batch equipment. Advantages of this type of equipment include good economy and space utilisation, relatively low operating costs compared with other methods, little

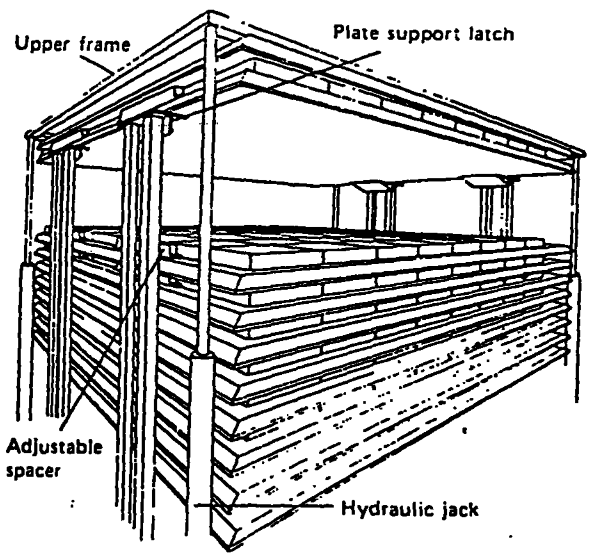

Fig. 19.5 — Plate freezer. (Courtesy of Frigoscandia Ltd.)

dehydration of the product and therefore minimum defrosting and high rates of heat transfer (Table 19.3). The main disadvantages are the relatively high capital costs, and restrictions on the shape of foods to those that are flat and relatively thin.

3.2.3.2 *Scraped-surface freezers*

Scraped-surface freezers are used for liquid or semi-solid foods (for example ice cream). They are similar in design to equipment used for evaporation (Fig. 12.8) and heat sterilisation (Chapter 11) but are refrigerated with ammonia, brine or a fluorocarbon refrigerant (Table 18.3). In ice cream manufacture, the rotor scrapes frozen food from the wall of the freezer and incorporates air (Chapter 3). The temperature is reduced to between −4°C and −7°C when the forzen aerated mixture is pumped into containers and freezing is completed in a hardening room (section 19.2.1.1).

3.2.4 Cryogenic freezers

Freezers of this type are characterised by a change of state in the refrigerant (or cryogen) as heat is absorbed from the freezing food. The cryogen is in intimate contact with the food and rapidly removes energy from the food to provide its latent heat of vaporisation or sublimation, to produce high heat transfer coefficients and rapid freezing. The two most common refrigerants are liquid nitrogen and solid or liquid carbon dioxide.

Dichlorodifluoromethane (refrigerant 12 or Freon 12) is also used to a lesser extent and is claimed to be the only refrigerant that is almost fully recoverable (Table 19.2) and is thus more economical (Astrom and Lascelles, 1976). It produces less

Table 19.2 — Properties of food cryogens

	Liquid nitrogen	Carbon dioxide	Freon 12
Density (kg m^{-3})	784	464	1485
Specific heat (liquid) (kJ kg^{-1} K^{-1})	1.04	2.26	0.984
Latent heat (kJ kg^{-1})	358	352	297
Total usable refrigeration effect (kJ kg^{-1})	690	565	297
Boiling point (°C)	−196	−78.5 (sublimation)	−29.8
Thermal conductivity (W m^{-1} K^{-1})	0.29	0.19	0.095
Consumption per 100 kg of product frozen (kg)	100–300	120–375	1–3

From: Graham (1984).
*Low consumption of Freon because it is recovered and re-used.

heat shock than other cryogens and is particularly useful for sticky heat-sensitive foods (for example tomato slices and meat paste). Production rates are 500–9000 kg h^{-1}. The main limitation is the risk of excessive cryogen residues in foods and a limit of 300 mg kg^{-1} is a legislative requirement in many countries.

Both liquid-nitrogen and carbon dioxide refrigerants are colourless, odourless and inert. When liquid nitrogen is sprayed onto food, 48% of the total freezing capacity (enthalpy) is taken up by the latent heat of vaporisation needed to form the gas (Table 19.2). The remaining 52% of the enthalpy is available in the cold gas, and gas is therefore recirculated to achieve optimum use of the freezing capacity. Carbon dioxide has a lower enthalpy than liquid nitrogen (Table 19.2) but the lower boiling point produces a less severe thermal shock. Most of the freezing capacity (85%) is available from the subliming solid. Liquid carbon dioxide is therefore sprayed onto food to form a fine snow which sublimes on contact, and gas is not recirculated. Carbon dioxide is a bacteriostat but is also toxic, and gas should be vented from the factory to avoid injury to operators (also Chapter 18). Carbon dioxide consumption is higher than liquid-nitrogen consumption, but storage losses are lower and gas recovery systems are sometimes used to improve the economics. The choice of refrigerant is largely determined by its cost and the nature of the product. Liquid nitrogen is widely used in the UK, whereas carbon dioxide is more popular in the USA and Europe where production costs are lower.

In liquid-nitrogen freezers, packaged or unpackaged food travels on a perforated belt through a tunnel (Fig. 19.6), where it is cooled by gaseous nitrogen and then frozen by liquid-nitrogen sprays. The temperature is allowed to equilibrate at the

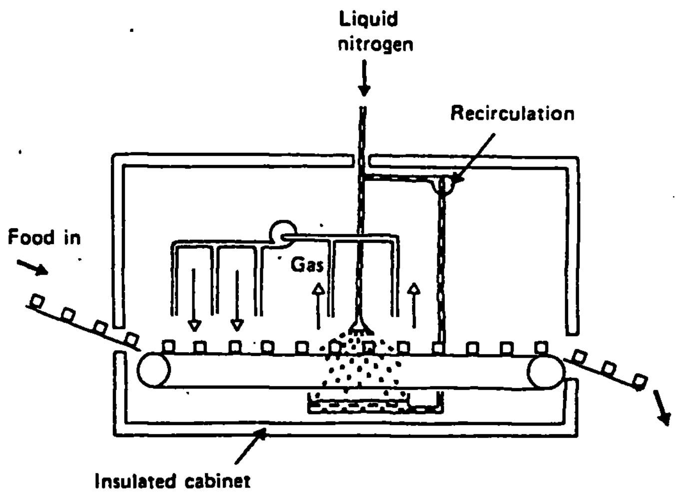

Fig. 19.6 — Liquid-nitrogen freezer.

required storage temperature (between −18°C and −20°C) before the food is removed from the freezer. Production rates are 45–1350 kg h^{-1}. Gaseous nitrogen reduces the thermal shock to the food, and the recirculation fans produce higher rates of heat transfer than would be achieved by stationary gas. The temperature and belt speed are controlled by microprocessors to maintain the product at a pre-set exit temperature, regardless of the heat load of incoming food. The equipment therefore has the same efficiency at or below its rated capacity. This results in greater flexibility and economy than mechanical systems, which have a fixed rate of heat extraction. Other advantages include

(1) simple continuous equipment with relatively low capital costs (approximately 30% of the capital cost of mechanical systems),
(2) smaller weight losses from dehydration of the product (0.5% compared with 1.0–8.0% in mechanical air-blast systems),
(3) rapid freezing (Table 19.3) which results in smaller changes to the sensory and nutritional characteristics of the product,
(4) the exclusion of oxygen during freezing,
(5) rapid startup and no defrost time and
(6) low power consumption (Leeson, 1987).

The main disadvantage is the relatively high cost of refrigerant (nitrogen consumption is shown in Table 19.2).

Liquid nitrogen is also used in spiral freezers (section 19.2.1.3) instead of vapour recompression refrigerators. The advantages include higher rates of freezing, and smaller units for the same production rates because heat exchanger coils are not used. Other applications include rigidification of meat for high-speed slicing, and surface hardening of ice cream prior to chocolate coating.

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Table 19.3 — A comparison of freezing methods

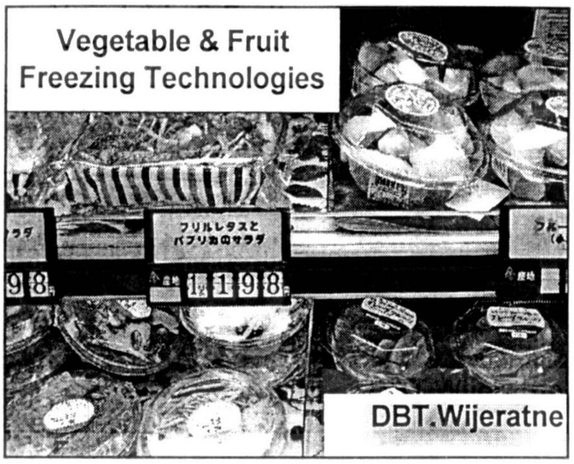
Method of freezing	Typical film heat transfer coefficients (W m^{-2} K^{-1})	Typical freezing times for specified foods to −18°C (min)	Food
Still air	6–9	180–4320	Meat carcass
Blast (5 m s^{-1})	25–30	15–20	Unpackaged peas
Blast (3 m s^{-1})	18	—	
Spiral belt	25	12–19	Hamburgers, fish fingers
Fluidised bed	90–140	3–4	Unpacked peas
		15	Fish fingers
Plate	100	75	25 kg blocks of fish
		25	1 kg carton vegetables
Scraped surface	—	0.3–0.5	Ice cream (layer approximately 1 mm thick)
Immersion (Freon)	500	10–15	170 g card cans of orange juice
		—	
		0.5	Peas
		4–5	Beefburgers, fish fingers
Cryogenic (liquid nitrogen)		1.5	454 g of bread
	1500	0.9	454 g of cake
		2–5	Hamburgers, seafood
		0.5–6	Fruits and vegetables

Adapted from Earle (1983), Olsson and Bengtsson (1972), Desrosier and Desrosier (1978), Leeson (1987) and Holdsworth (1987).

Immersion of foods in liquid nitrogen produces no loss in product weight but causes a high thermal shock. This is acceptable in some products (for example raspberries, shrimps and diced meat), but in many foods the internal stresses created by the extremely high rate of freezing cause the food to crack or split. The rapid freezing permits high production rates of IQF foods using small equipment (for example a 1.5 m long bath of liquid nitrogen freezes 1 t of small-particulate food per hour).

3-12 Freezing equipment

Vegetable & Fruit Freezing Technologies



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Freezing Vs Other Preservation methods in F & V

Freezing
- The most elegant method of preservation

Other
- Irreversible changes

Meat Vs Fruits & Veg.

- Protein systems
  - Conventional freezing

- Carbohydrate systems
  - Blast freezing

Process Flow-Chart

Preparation ← (treatment)

↓

Enzyme inactivation ← Steam blanching / Hot water Blanching / Chemical treatments

↓

Freezing

Vegetables

- Inactivation of enzymes
  - heat treatment — Off flavour, colour & vitamins
  - pH manipulation — Colour
  - sulphitation — Browning
- Quick freezing
  - Blast / rapid
  - IQF

Fruits

Process

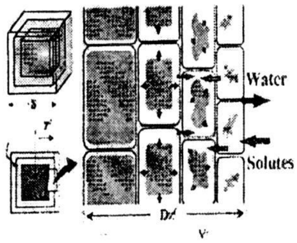
- Preparation
- Peeling, slicing,
  - Squeezing
- Quick freezing
  - IQF
  - Frozen juice / pulp

Problems

- Dripping
- Textural Changes
- Flavour changes/ cooked taste if blanched

Special Techniques

- Dehydro-freezing
  Osmotic- freezing
- Freeze concentration



Quick freezing

- Turbulence of air
- Temperature of Air
- Characters of the commodity

Air Direction

1 AIR DIRECTION AND ITS RELATIONSHIP TO TURBULENCE

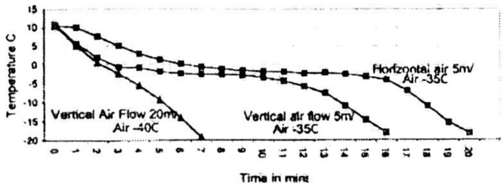


Figure 1. Freezing 80 mm long, shell on Tiger prawns

Air Velocity

4 REDUCTION IN FREEZING TIMES BY THE USE OF HIGH AIR VELOCITIES

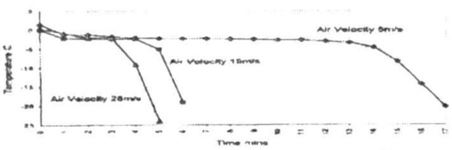


Figure 6. Freezing 16 mm thick fish fillets in air at -39°C

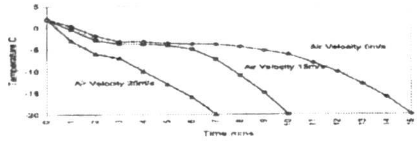


Figure 7. Freezing 11 mm thick, 80 mm diameter beef burgers in air at -39°C

Commercial Freezing Equipment

Figure 2 Down blast tunnel

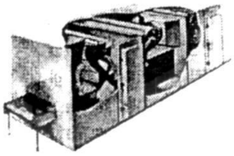
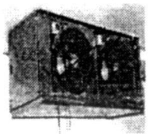


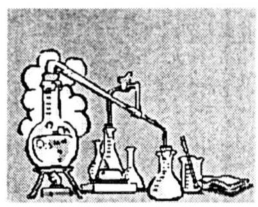
Figure 3 Horizontal air-flow tunnel

Storage



Potential Products

- Frozen vegetables
- Frozen curries
- Frozen meals



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Freezing of Meat

Objective of freezing is to slow down or arrest the microbiological, biochemical and other effect that resulted in spoilage of meat. Frozen meat can be kept wholesome up to 12 to 18 months in storage defending on storage temperature. Quality of frozen meat is determined by the initial quality of meat, the standards of hygiene and sanitation during the processing, temperature throughout the holding operation, final storage temperature and duration of storage. Air blast freezing, (mainly for carcasses) and plate freezing techniques (generally for deboned meat and meat products) are used more commonly. Freezing efficiency of meat mainly depend on the air temperature, Air velocity and thickness of meat.

Meat contains approximately 75% water but not all of it is capable of being frozen . The remainder of the water is in the form of highly concentrated solution which freezes only at lower temperatures.

Physical and chemical changers take place in meat during freezing and frozen storage

1. Thaw rigor

The most important aspect of freezing red meat is the time of freezing in relation to onset of rigor mortis. If meat is frozen before ATP and glycogen levels are depleted, post mortem glycolysis is suspended. On thawing, however, the meat undergoes severe contraction with associated toughening and loss of large quantities of drip (Thaw rigor). For this reason meat has normally been frozen post rigor. It has been found that the electrical stimulation of carcasses immediately after slaughter can be avoided thaw rigor development. Thawing of pre rigor frozen meat at –3c for 5 days will also help to prevent thaw rigor. Thaw rigor is not a problem with poultry where post-mortem glycolysis is rapid. Freezing of meat requires relatively large amount of energy and hot deboning is common practice to avoid the cost of freezing bones. But electrical stimulation of carcass is necessary avoid toughening of meat during thawing.

2. Flavour changers

It is necessary to minimize the flvour changers in meat during frozen storage by

i). Incorporation of herbs and other flavourings to compensate for the loss during storage and to mask incipient rancidity

ii). Inclusion of MSG as flavour enhancer to increase overall flavour strength

iii). Addition of anti oxidant (natural or artificial) mainly to meat products

iv). Feeding of vit. E to animals

iv). Packaging of meat by using packaging material having ultraviolet impermeable layer which help to reduce photo oxidation specially in cured meat

v). Vacuum packaging/ Shrink wrapping/ Modified atmosphere packaging can be employed with primal cuts/joints and meat products to minimize oxidation deterioration.

3. Colour changes

Colour changes of meat can take place due to light, freezer burn, and excessive drying out of the surface of the meat. During frozen storage muscle surfaces continue to lose water at a fairly fast rate and this desiccation leads to an increased concentration of salt at surface which cause oxidation of the muscle pigment. The formation of brown metmyoglobin tend to develop in the lean in parallel with fat oxidation and rancidity. Freezer burn is the name given to the whitish or amber colour patches seen on the surface of frozen meat. On the other hand freezer burn do not occur when properly packed the meat.

4. Microbial growth

Micro-organisms do not grow below -10c and consideration of spoilage are normally relevant only to handling before freezing or during thawing. At the storage temperatures of –5 to –10c, psychrotropic mould grow slowly and during prolong storage cause spoilage. Very little meat is stored at these temperatures in present day. Some death of micro-organisms may be expected during freezing and subsequent frozen storage.

5. Weight loss

It is usual to use plastic film wrap to prevent dehydration and protect from contamination during subsequent handling of carcass.

6. Drip formation

Drip is undesirable for aesthetic and economical reasons and it minimized by freezing the meat as rapidly as possible. The numerous small ice crystals resulting from rapid freezing do less damage to cell wall and hence cause less fluid leakage than the slow freezing. The drip yield is determined by the size and shape of the pieces of meat and orientation of cut surface with respect to muscle fibre axis. The fluctuation of frozen storage temperature may increase the drip yield during the thawing. Thaw rigor may produce excessive quantities of drip which may amount to 30-40% of the muscle weight. There are other ways in which drip can be minimized by conditioning of meat before freezing

7. Formation of frost

Because of the extra space between meat/ carcass , sublimation of ice can occur which cause accumulation of frost which affect the appearance of the product.

8. Denaturation of proteins

Freezing of meat tend to denature the muscle proteins which leads to lower the water holding capacity and to reduce functional properties of the myofibrillar proteins.

Freezing Technology in the Dairy Industry

Freezing Technology is frequently utilized for increasing the shelf life of the dairy products. Freezing Technology is also used to manufacture some frozen products, which are enjoyed by the consumers.

Freezing helps to decrease the rate of physical changes (colour changes, flavour changes, texture changes) and chemical & microbial activity. Reducing temperature slows molecular and microbial activity – thus extend the useful storage life. (See annexure 1 for storage life of dairy products at different temperature)

Some Basic Concepts

Before I proceed further I would like to review some basic scientific concept involved in the freezing technology.

Relation between vapour pressure and temperature and concentration

The diagram 1.1 shows the relationship between partial vapour pressure and temperature for pure water and solutions at a constant pressure. The diagram 1.2 and 1.3 show the temperature-concentration phase relationship for (a) a binary system forming a eutectic mixture and (b) for a system in which solute crystallization is kinetically constrained respectively.

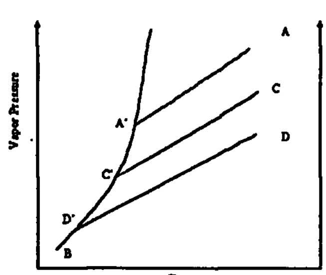


Figure 1.1

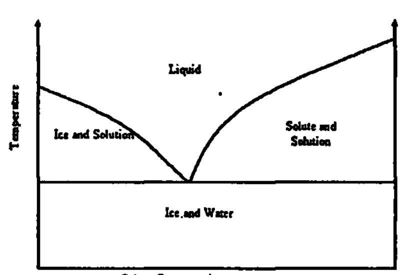


Figure 1.2

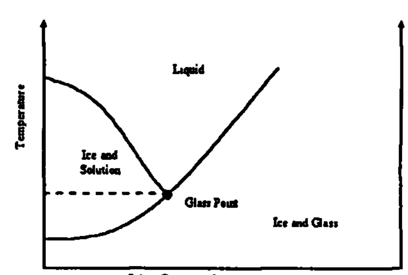


Figure 1.3

The curve AA' show the vapour pressure of pure water, curve BD'C'A' is for ice and curves CC' and DD' are for solutions of increasing concentrations. Points A', C' and D' are the freezing points of pure water, solution C and solution D. The increase in concentration of solute lowers the equilibrium partial vapour pressure of water in the solution and also the freezing point i.e. the point where the partial pressure of water vapour in the solution is the same as the vapour pressure exerted by water as ice.

Initial Freezing Point

The temperature at which the mix starts to freeze varies with percentage of soluble solids .You will note that as ice separates out from a solution, the concentration of the solute in the remaining liquid phase will tend to increase thus lowering the partial vapour pressure and also the freezing point. Unlike water, the freezing point of a solution, therefore, is not constant and freezing point process continues even to much lower temperatures. In fact, foods high in soluble solids (sugar, salt etc) may never be completely frozen. There is therefore no distinct freezing point but an initial freezing point at which the crystallization process begins. ***The highest***

temperature at which ice crystals have a stable existence in a food material is conventionally known as the initial freezing point. (See annexure 2 for the freezing point of dairy products.)

The mathematical expression for an ideal solution is given by the ***Lewis and Randell fugacity rule*** i.e. $\bar{f}_i = x_i \times f_i$ where f_i is the fugacity of pure component i at a temperature and pressure of the solution, $\bar{f}_i$ is the fugacity of component i in solution and x_i is the mole fraction of the component i. For a dilute solution, this reduces to ***Raoult's law*** which is $\bar{P}_i = x_i \times P_i$. P_i is the partial vapour pressure of the pure component i at the temperature, $\bar{P}_i$ the partial vapour pressure of component i in the solution, and x_i the mole fraction of component i in the solution.

This equation can be used to predict the initial freezing point of products with high water content. However for concentrated solutions which are encountered after freezing out of some of the water, freezing point curve is generated using different formulae by calculating the depression in freezing point because of each solute based on its concentration in the unfrozen portion of water. The total freezing point depression is then obtained by adding the depressions caused by individual solute and freezing point is calculated by subtracting the cumulative depressing from 0°C. (32° F) One such formula is given below. It is based on the **assumption that solutes do not dissociate, do not hydrate or combine with water or do not ionize in the water.**

Freezing point depression $\Delta t_f = K \times G/M$,
Where, K is a constant, for water it equals 18.6
G is grams of solute in 100 gms of solution
M is molecular weight of solute.

Thermo Physical Properties of Frozen Products

To predict the thermo physical properties of frozen products, which depend strongly on the fraction of ice within the food (product) mass fraction of water that has crystallized, must be determined. Below the freezing point, the mass fraction of water that has frozen (crystallized) is a function of temperature and type and contribution of dissolved solids. For rough work the Latent heat and Specific heat capacity of fusion of a food are calculated by the following equations;

$L = 3.3 \times M \times kJ/kg$
Specific heat capacity $(c_p) = (M/80 + 0.84)\ kJ/kg$
Where, M is the percentage by weight of water in the food stuff (wet basis)

Freezing time

The prediction and control of freezing time are matters of importance, not only because of quality considerations (high rate of freezing improves the quality) but also because the freezing time controls the through put possible with a given freezing plant and therefore the economics of the freezing process.

The definition of term "freezing time" presents some difficulty. Two instances need to be defined, the instant that the freezing time starts and the instant that it stops. Because of presence of water-soluble constituents (lactose, salts), all of the water present does not solidify at the initial freezing temperature. Under equilibrium conditions and at a temperature just below the freezing point, a certain fraction of the water present remains in a fluid phase. This fraction falls when the temperature is lowered and **eutectic mixture** may separate from the unfrozen fluid, but unfrozen water is still present even at comparatively lower temperature. Thus it is not possible to define a clear end point to the freezing process. A number of practical alternatives are used.

The International Institute of Refrigeration defines the "nominal freezing time" to be the time elapsing from the instant the surfaces of a body (package) reach 0 ^{0} C to the instant that the "thermal center" reaches a temperature 10 ^{0} C colder than the temperature of initial ice formation at that point.

It should be noted that for a typical package virtually the whole of the ice formation would have occurred by that time. This definition is therefore useful where influence of freezing time on quality is under consideration.

The Estimation of Freezing Times

Calculations involving unsteady state conduction heat transfer with change of phase are not easy. However if it is desired to estimate a freezing time from physical properties, rather than determine it experimentally, two approaches are possible;

1. A crude and simple mathematical model is assumed and an equation derived which highly approximate, can be used to estimate freezing time in a wide variety situation.

2. Using modern computer technology – differential equations for heat flow are solved by numerical rather than analytical methods.

Formulae for estimating freezing times are usually based on the following assumptions

- Uniform initial temperature of the package / product to be frozen
- Constant temperature of cooling media.
- Uniform and constant heat transfer co efficient between surfaces of the package / product and the cooling media.
- Constant thermal conductivity and specific heat of the product. (Different for the frozen and unfrozen status)
- A density which does not change with temperature
- A definite freezing point at which all the latent heat of fusion is liberated

Further simplification occurs if the material at the thermal center at the end of the freezing process is assumed to be frozen, but still at its freezing point.

Freezing time t_f = $f(N_{fo}, N_{Bi}, N_{Ko})$

where t_f is the calculated freezing time
N_{fo} = **Fourier number,** $K \times t/l^2$
N_{Bi} = **Biot number,** $h \times l/k$
N_{Ko} =**Kossovitch number,** $L/(c_p \times \Delta\theta)$

Plank's formula has also proved valuable in extending the results of experimental studies and is given below;

$$t_f = \rho \times L/(T_f - T_o)\ \{A \times l/h + B \times l^2/k\}$$

where t_f **is freezing time,** ρ is the **density,** T_f is the **initial freezing point,** T_o **is the final temperature,** L **is the latent heat of fusion** of the material, c_p is its **specific heat in frozen state,** Δθ the **difference** between the **freezing point of material and the temperature of the cooling medium,** h is the **heat transfer coefficient** at the surface of the body, A & B are **constants,** k is the **conductivity of the material,** l is the **characteristic dimension** of the body- this is taken to be the shortest distance between the surface of the body and the **thermal centre** (i.e. the location that heats or cools slowest). For a sphere or infinite cylinder, this distance is the radius and for an infinite slab it is half the thickness, and K is **thermal diffusivity** of the body.

A number of Nomographs are available in literature for evaluation of temperature distribution in bodies of arbitrary shapes using Geometrical Index. A number of other equations are also available in the literature to estimate freezing time.

However, in dairy industry, the freezing time used is mostly based on experience; e.g. varying the speed of the conveyor controls the residence time in the tunnel. The freezing is also adjusted by varying the speed of cooled air depending upon the type and size of product and packaging.

Nucleation

The molecules in the liquid phase do not align into a configuration required for a solid. For a liquid –solid transformation to happen, it is necessary to have a seed (nucleus- a cluster of molecules of size sufficient to sustain growth) on which the solid can grow. At any temperature below the melting point a given number of molecules in any volume of solid phase will have less **volume free energy** than the same number of molecules in the liquid phase. However a cluster of molecules will have an interface with the remaining liquid, which is thermodynamically unstable.

The sum of the bulk energy and the surface energy together make up the total free energy of formation of the seed. At a small cluster size, the surface term is larger. At some critical size, the addition of one molecule to the cluster will gain more in bulk energy than it costs in the surface energy, and the process of nucleation becomes spontaneous.

Since the bulk term per molecule, increases as the temperature is lowered, whilst the surface term is relatively temperature insensitive, the size of critical nucleus reduces with lowering temperature. For water, the critical nucleus size can be reached by spontaneous fluctuation at around -40° C. This is the temperature of **homogeneous nucleation.**

However if there is catalytic template, the probability of formation of critical nucleus at higher temperature increases and **heterogeneous nucleation can take place at even higher temperature. Heterogeneous nucleation is therefore very important in real freezing processes.**

It is to be noted that once nucleation starts, **control of growth is possible through control of thermodynamic equilibrium, controlling heat and mass transfer processes, controlling mobility of molecules through agitation, control of viscosity etc.**

Glasses

A reference to figure 1.3 will indicate that the concentration in the liquid phase increases as the ice is formed from the liquid phase. There is therefore increase in viscosity of the liquid phase and if the solute does not crystallize, continued separation of ice can lead to a state, where the liquid phase has very restricted mobility and it is no longer possible for ice to crystallize. **This state at which no more ice can crystallize due to increased viscosity because of increased concentration and decreased temperature have the typical characteristics of a glass.**

The temperature Tg at which "Glass State" is reached has great significance for stability of frozen foods. The diffusion rates will be very slow and those reactions that are dependent on molecular diffusion to bring reactants into contact will therefore slow down.

Application of Freezing Technologies to Dairy Products

The applications of freezing technology to dairy sector can be divided into following categories according to the objectives that are to be achieved.

1. Preserve the milk or milk products for future use- the frozen product is thawed before consumption.
2. Manufacture products, which are to be consumed as frozen products.
3. Freeze concentration- to concentrate dilute solutions.

Cream, plastic cream, and butter are frozen on commercial scales to prolong the shelf lives of these products. Since the milk production varies with the season and period of lactation, cream, plastic cream and butter are prepared and frozen during peak production periods when the prices are low and availability high-to be converted into products during lean season. Good quality pasteurized cream (50%), plastic cream (80%) or butter is frozen to – 23 °C (-1° F) and remains acceptable for 1 to 2 years.

Freezing of Cream or Plastic Cream.

When cream is frozen, there is a tendency to disrupt the fat emulsion and to destabilize the milk protein. The physical equilibria of both components are changed, depending upon the severity of freezing conditions. Half or more of fat in 50% cream can be destabilized and "oil off" on thawing to temperature above melting point of fat. **Rapid freezing tends to lessen the destabilization and 'oiling off'**. If the cream is to be used for ice cream manufacture, addition of sugar to cream before freezing also helps in protecting the fat emulsion because of lowering of freezing point and hence ice formation.

The problem of "oiling off" particularly for cream to be used in manufacture of ice cream is not a serious handicap as the homogenization process during manufacture of ice creams completely re-emulsify the oiled off portion. Decrease in protein percentage help in protein destabilization problem. Therefore cream with higher fat will show more protein stability. The freezing is normally achieved by filling 30-50 lb. metal cans or 2 ½ or 5 gallon, single service polythene lined containers and by stacking them in a freezing room. **Scraped surface heat exchanger** can also be used and the frozen cream is filled in plastic bags for further freezing by storage in freezing room.

Freezing of Butter

Unsalted butter freezes at 0°C (32°F). If it contains 2% salt, the water freezes at-9°C (15.8° F); at 3.5% salt, its water is frozen at –19.8°C (-3.6° F). The cryohydric point of sodium chloride is – 21.2°C (-4.2° F). Below this temperature some salt crystallizes during frozen storage, but readily dissolves when the butter is warmed. Water expands on freezing while butter fat shrinks, but these changes in volume apparently do not affect the properties noticeably.

For long-term storage a temperature below –20°C (-4°F), preferably –29° C (-20°F) is used. Butter under normal storage conditions, is a poor substrate for bacterial growth. In general, the numbers of bacteria decrease during storage until there may be only 10% of the original population viable after 8 to 12 month's storage at –18°C.

Butter to be used for manufacturing other products is usually frozen after filling in polyethylene lined card boxes or tins in 20 kgs lots, which are transferred to a deep freeze for freezing and long term storage. Butter to be sold as table butter (50 gms, 100gms, 200gms etc) is packaged in gas-tight foil, aluminum foil or film impervious to light, placed in cartons and transported immediately to cold storage for freezing.

Contact freezing of butter by passing through a multiple plate freezer produces excellent results. The second best method is the passage through tunnel freezers; however deep freezers are the most practiced system because of cost consideration.

Freeze Preservation of fluid milk.

Homogenized fluid milk is sometimes frozen to preserve it for short periods. During long storage there is deterioration in flavour. To minimize the deterioration in flavour heating above pasteurization temperature and homogenization is preferred to addition of anti oxidants such as ascorbic acid, sodium gentistat (0.01%). The sulpha hydryl compounds developed during heating are dissipated in frozen storage after 1 to 2 weeks. Feeding of cow adequate quantities of alpha-tocopherol (1 gm) is said to help.

Separation of milk solids during thawing can be delayed by addition of a small quantity of citric acid after pasteurization. The sodium poly phosphates prevent casein insolubility by their peptizing action but are not normally used. The high water content of milk (87%) makes freezing an expensive method of storage. Nevertheless some milk is frozen in cartons for use by armed forces, on ships and where supplies of fresh milk are difficult to obtain.

The common polyethylene lined paper containers provide excellent packages for frozen milk. The milk, homogenized at about 57°C (135°F) and at least 1500 *psi* is pasteurized and then packaged in the paper carton using conventional equipment. Use of additives such as 2 gms of sodium citrate and 0.1 gm of ascorbic acid per litre of milk is normally done after pasteurization. The packages are then transferred to deep freezer and stored at –18°C (0°F). Attempts to freeze milk rapidly by spraying it into a cold air stream at about –29°C have proved un-economical.

Freezing of Concentrated Milks

The freezing of 2:1, 3:1 or 4:1 milk concentrates has been practiced commercially for some special markets but is still not a regular commercial practice. Milk can be concentrated under vacuum in multi effect evaporators without impairing its flavour. The concentrated products are sealed in cans after cooling and frozen by placing the retail containers in a cold storage room at about –29°C. Same defects are experienced in frozen concentrated milk as are experienced in frozen pasteurized milk. Higher milk solids however protect the fat emulsion. The thickening however increases in magnitude with the increase in concentration.

Freezing Starter Cultures

Freezing of starter cultures is now being done on regular basis for quite some time. The objective here is to ensure purity of cultures, remove uncertainty in the manufacturing process because of phase attack and control expense involved in daily transfers. Survival is excellent when cultures are frozen and held in deep frozen state until thawed for use in the manufacture of cheeses or other fermented milk products.

The suspension of selected culture in growth media (10 % solids reconstituted skim milk or other suitable substrate supplemented with pancreas extract) at the late logarithmic growth phase in sterile polyethylene bags are frozen at –32.6°C (-29°F). Commercial liquid nitrogen–frozen cultures are available for cheese making to provide optimum activity. The suspension of the culture is packaged in vials and frozen and stored in liquid nitrogen at –196°C. The organisms retain high activity for upto three years.

Freezing of Cheeses and Other Milk Products

Freezing is not an entirely satisfactory way to preserve cheese, but cold storage is desirable. Freezing of canned evaporated milk may cause rupturing of the can and subsequent spoilage. Sweetened condensed milk is preserved by sugar, which also lowers its freezing point to about -15°C (5°F). There is no advantage in holding it below this temperature.

Freeze Concentration of Milk, Whey and Other Liquids.

Processes are being developed whereby milk, whey, and other liquids can be concentrated by freezing part of their water content and removing the ice crystals. Concentration by freezing should be an energy efficient operation because the latent heat of fusion of water is 80 kcal/kg (144 BTU per lb), whereas its latent heat of evaporation is 540 kcal/kg (972 BTU per lb). Cost of refrigeration and the mechanical difficulties experienced while removing ice crystal continue to be however challenging and processes are still confined to research laboratories.

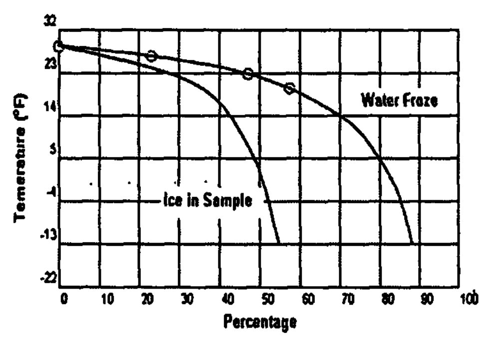
Freezing Technology in Manufacture of Ice creams, Sherbets, Ice Milk, Water Ices etc.

The basic steps in manufacture of ice cream and related products are composing, blending and heating of mix, homogenization, pasteurization, cooking, aging, flavoring, freezing, packaging, hardening, and storage. There are four phases of the freezing process; (1) lowering of temperature from aging temperature (usually about 4°C, 40° F) of the homogenized and pasteurized mix to the freezing point of the mix; (2) freezing of a portion of water in the mix to a large number of small ice crystals; (3) incorporating air into the mix; (4) hardening the ice cream after it is drawn from the freezer.

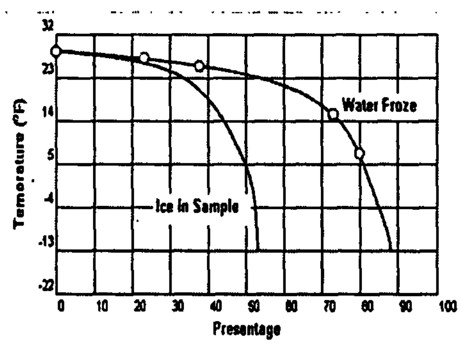
The mix is pumped into a cylinder, refrigerated by a sub zero liquid refrigerant (ammonia, Freon etc.) or brine. The freezing process is very rapid; this is very important for formation of small ice crystals to ensure smooth and high quality ice cream. A "rotating knife-equipped mutator" inside the cylinder, continuously scrapes off the layer of frozen mix from the cylinder wall and helps in whipping of air into the ice cream mix while it is frozen to between - 3° C and –6° C and in some cases as low as -11° C depending on the ice cream product.

The increase in the volume by incorporation of air in ice cream mix is called "overrun" and is normally 80-100 %, i.e. 0.8 to 1.0 litre of air per litre of mix. Without this overrun, ice cream would be an almost inedible hard frozen mass.

The modern ice cream freezer is a very sophisticated and expensive piece of equipment, totally PLC controlled. The overrun, mix flow, cylinder pressure, viscosity of mix, temperature etc. are all controlled automatically. The equipment is energy efficient and easy to clean in place. The ice cream leaving the freezer has a texture similar to soft ice cream, and some 40-45 % of water content is frozen. It can therefore be pumped to the next stage in the process, which is packing, extrusion or moulding. The amount of frozen water varies the composition of mix and the freezing temperature as shown in the figure below:



Ice cream : 12.15 % fat;
38.14% Total solids



Ice cream : 18.68 % fat;
39.68% Total solids

The product then goes to a hardening tunnel where the product is rapidly frozen by exposure to a blast of air at a temperature of -45°C to ensure that most of remaining water also gets frozen and ice crystal size remain small. The ice cream then goes to a deep freeze room for long term storage at below – 30°C. **Fluctuation in temperature is not acceptable as it results in melting of existing ice crystals and re-crystallization of water on already existing nucleus giving bigger ice crystals and coarse texture.** The ice creams are therefore transported under low temperatures (below -25° C) to retail points.

The truck chambers are either provided with continuous refrigeration during transport or cooled to -30° C and provided with stored refrigeration in the form of eutectic plates at – 30°C or dry ice or liquid nitrogen, which is continuously released in the chamber to maintain temperature thought out the journey.

Freezing Systems

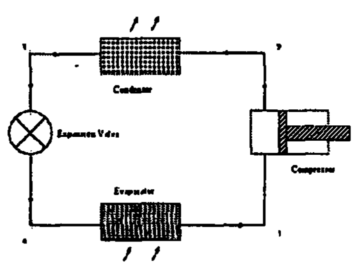
Single Stage Vapour Compression Systems

The main elements of a refrigeration system are shown below. The closed system is charged with a refrigerant such as ammonia or a hydrofluorocabon. The refrigerant as a gas is pulled from the evaporator (1) by the compressor (2), which is driven by an electric motor (M). The Compressed gas at high pressure and temperature goes to the condenser where gas condenses to liquid form because of cooling by circulating water or surrounding air. The liquid refrigerant then goes to expansion valve (4), which regulates the flow of the refrigerant being evaporated in the evaporator. And also maintain the pressure difference between high and low pressure sides. The energy gained in the evaporator (Q2), energy rejected in the condenser(Q1) and energy introduced by compressor(E) shaft are governed by the first and second laws of thermodynamics and given by the following equation;

$$Q_2 + E = Q_1$$

The single stage systems are generally used for all installation where the purpose is to achieve a temperature around freezing point of water. For temperature which is around –30° C, or lower multi stage mostly two stage systems are used being more economical.

A Single Stage Vapour Compression System



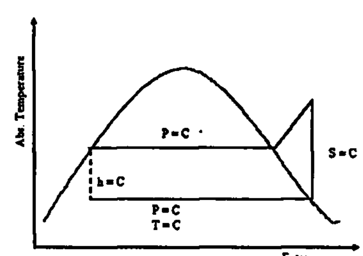
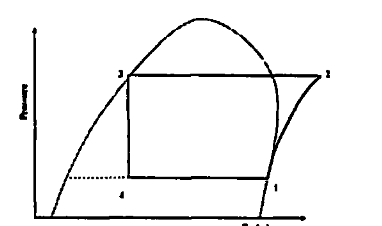
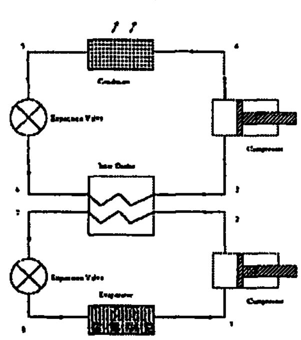


Figure 2.2



The two-stage systems contain in principles two systems, a **low-stage (Also called booster)** and a **high stage** system, working together. The condensing pressure for the low-stage compressor is about the same as the evaporation pressure for the high-stage compressor. (See the figure). The intermediate pressure is selected so that the two compressors will work with the same compression ratio. For economic operation the compression ratio should not be more than 7-10.

A Two Stage Vapour Compression System



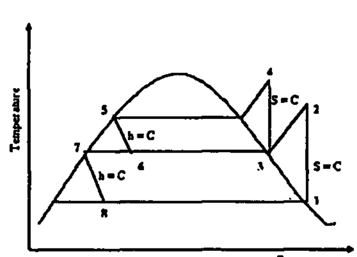


Figure 3.2

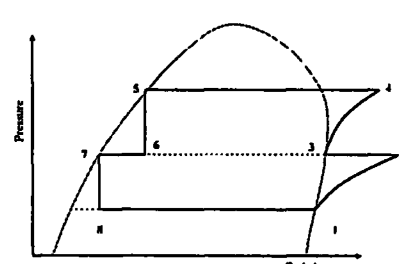


Figure 3.3

Compressors

Until about 25-30 years ago, piston compressors of various sizes dominated the industry. Today, screw compressors are more and more commonly used for industrial applications, whilst for small systems like small stand alone ice cream freezers, freezer cabinets, cold chain vehicles, hermetic piston compressors are still the standard. Large compressors are often equipped with soft starters, are often PLC controlled, to monitor and control the capacity, control evaporation temperatures even when the demand varies, monitor and control the condenser pumps, condenser temperature, oil temperature and flow, viscosity of oil, record all the operating parameters and help identify the reasons for any trouble. It should however be noted that the efficiency normally goes down when the compressor works with reduced capacity.

The refrigeration systems in a modern ice cream plant use lot of power and hence every attempt is made to use energy efficient systems. The integrated systems, which involve centralized refrigeration plant meeting need at different temperatures, are complex and require careful and expert planning. All such plants are highly automated and have sophisticated computerized controls to save energy and ensure safety. An example of such system used in ice cream plant at Banduragoda is shown in annexure 3.

Two Phase Freezing System

Two-phase freezing systems are also known as cryogenic freezers. The refrigeration effect is provided by the heat transfer agent (cryogen) itself as a consequence of its phase change. These systems are common in the industry because of convenience and in cases where rapid freezing is imperative to good quality. These systems are some times economical also.

Carbon dioxide systems

Carbon dioxide is most conveniently handled as a liquid under pressure. Sprayed through nozzles to atmospheric pressure, it gives a mixture of cold gaseous carbon dioxide and carbon dioxide snow (a subliming solid), which can be contacted with ice cream in packages to prevent increase in temperature.

The system used is either to boost the capacity of conventional blast freezing line at the peak processing period or to provide the sole cooling as in ice cream vending cabinets.

Liquid Nitrogen based Systems

The boiling point of liquid Nitrogen (- 196° C at atmospheric pressure) is such that it can freeze the ice cream very rapidly and thus can improve the quality. (Smooth, creamy, no ice crystals). Because of the low water holding capacity of very cold gaseous nitrogen, there is negligible transfer of water from ice cream to the gas during freezing by immersion.

This system is particularly useful for manufacture of very high quality expensive products like "Magnum" or where fruit juices are applied as an outer coating (Salora). The rapid cooling prevents formation of big crystal and result in products, which have exceptionally smooth texture.

The cost of liquid nitrogen freezing is very dependent on the cost of the gas itself. The capital cost of equipment used is comparatively low. The price is very dependant on the quantity used and expense on transport and storage. At present the process is more expensive than conventional freezing and hence such systems are used for very expensive and premium quality products only. These systems are also now regularly used for freezing starter cultures and semen used in artificial insemination.

The latent heat of evaporation of liquid nitrogen at – 196°C is 200 kJ / kg (50 kcal./kg)
Gaseous Nitrogen warming at constant pressure from this temperature to -18° C absorbs another 209 kJ / kg.(52.25 kcal./kg)
Following 3 methods are used commercially.

1. Liquid nitrogen is sprayed directly onto food and evaporates completely, the resultant cold gas moving to left and right to effect further cooling.
2. Similar to method 1, but and excess of liquid nitrogen is sprayed over the food and re circulated
3. Liquid nitrogen is used to cool down one or more chambers in which the temperature is thermostatically controlled, but does not contact the food.

Freon 12 Freezant (Di chloro Di fluro methane)

The Du Pont company has developed a freezing technique based on Freon '12' Freezant. This material boils at – 30°C (-22° F) at atmospheric pressure and is an excellent heat transfer medium.

Ice cream packages can be frozen by immersion in the liquid or by having the liquid sprayed onto its surface. Since the gas is expensive, it must be recovered. It is therefore re condensed on a refrigerated surface below its boiling point and re cycled. Because the gas has a high density, the input conveyor that has closed sides, is angled steeply down onto the enclosed freezing zone and output conveyor, are similarly mounts upwards.
The heavy Freon vapors are thus retained in the unit and Freon losses are reduces to a few percent of the product weight. Because of consumer safety and environmental considerations the system is not however universally approved. The method has two unique advantages (1) Positive separation of individual product particles (good for IQF) (2) Very low weight loss. Some refrigerant is however left on the surface of the product and is cause of concern even though the company claims it to be safe.

Annexure 1

Approximate Storage Life at Specific Temperatures

Product (Commercial Pack)	Months	Temperature °F	°C	Critical or Dangerous Storage Conditions
Butter (in bulk)	1 12	40 -10	4 -23	Above 50°F. (10°C.) or damp wet storage
Butteroil (sealed,full tins; maximum moisture 0.3%	3 6 9	70 50 32	21 10 0	Above 75°F. (24°C.)
Ghee (sealed,full tins)	6 9 18	90 70 40	32 21 4	Above 90°F. (32°C.)
Cream (50% fat)	12	- 10	- 23	Above 20°F. (-7°C.)
Plastic Cream (80% fat)	12	- 10	- 23	Above 20°F. (-7°C.)
Frozen Milk	3	- 10	- 23	Above 10°F. (-12°C.)
Frozen conc. milk	6	- 10	- 23	Above 10°F. (-12°C.)
Frozen cultures	6	- 10	- 23	Above 10°F. (-12°C.)
Nonfat dry milk, Extra Grade (moisture-proof pack)	6 16 24	90 70 40	32 21 4	Above 110°F. (43°C.)
Dry whole milk,Extra Grade (gas pack; maximum oxygen 2%)	3 9 18	90 70 40	32 21 4	Above 100°F. (38°C.)
Sweetened condensed milk	3 9 15	90 70 40	32 21 4	Above 100°F. (38°C.) or below 20°F.(-7°C.) or dampness sufficient to cause can rusting
Grated cheese (in moisture-proof pack)	3 12	70 40	21 4	Above 70°F. (21°C.) or above 17% moisture in the product
Cheddar cheese	6 18	40 34	4 1	Above 60°F. (16°C.) or below 30°F. (-1°C.)
Processed cheese	3 12	70 40	21 4	Above 90°F. (32°C.) or below 30°F. (-1°C.)
Sterilized whole milk	4 12	70 40	21 4	Above 90°F. (32°C.) or below 30°F. (-1°C.)
Evaporated milk	1 12 24	90 70 40	32 21 4	Above 90°F. (32°C.) or below 30°F.(-1°C.) or dampness sufficient to cause can rusting

Annexure 2

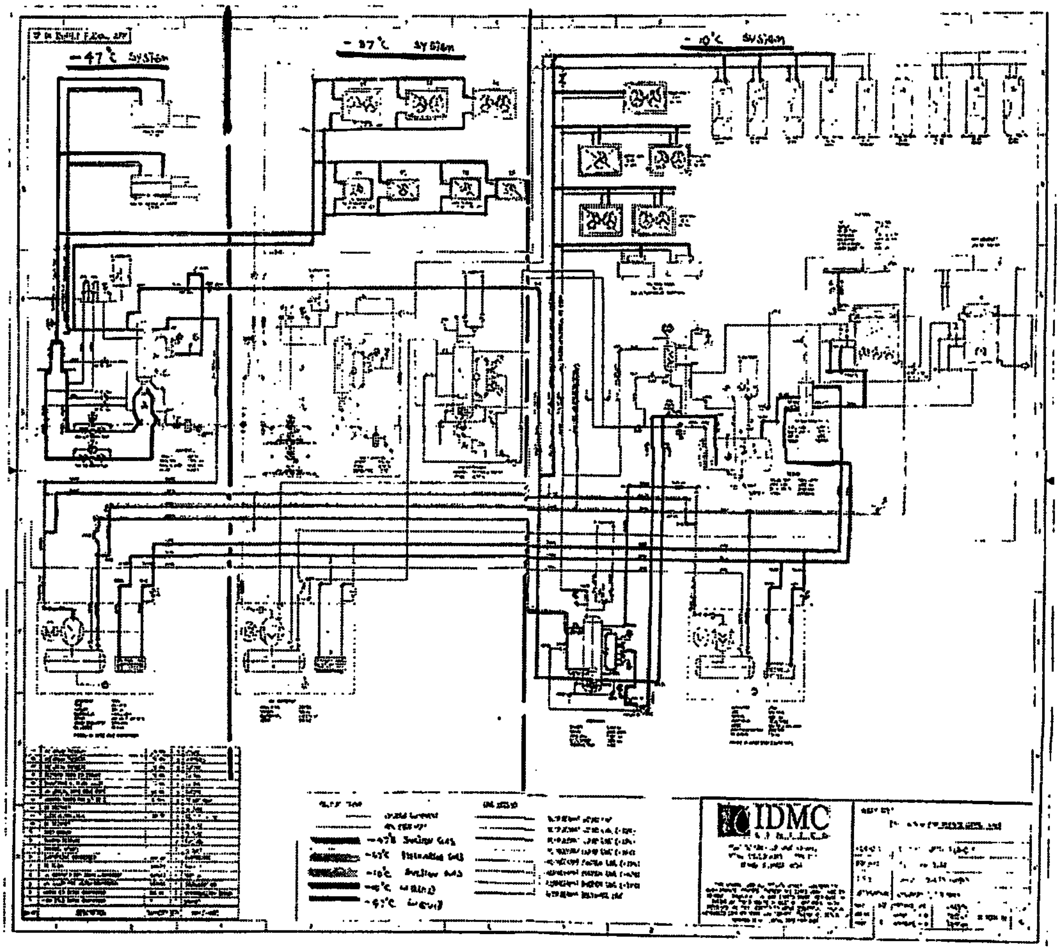
Initial Freezing Points and Moisture Contents of Some Dairy Products

Product	Freezing Point °F.	Freezing Point °C	Moisture Content %
Milk	31.30	-0.54	87.5
Evaporated Milk	29.50	-1.38	74.0
Concentrated Milk			
Whole (10% fat, 23% SNF)	28.40	-2.00	67.0
Skim (36% TS)	26.40	-3.13	64.0
Cheese			
Cottage	29.80	-1.20	78.7
Cheddar (processed)	19.60	-6.90	38.8
Swiss	14.00	-10.00	34.4
Cheddar	8.80	-12.90	33.8
Roquefort	2.70	-16.30	39.2
Sweetened condensed milk	5.00	-15.00	27.0
Butter (water phase)			
Unsalted	32.00	0.00	15.8
Salted (2.0%)	15.80	-9.00	15.8
(3.5%)	- 3.60	-19.80	15.8

(Cream, Skim milk, whey, and starter cultures have approximately the same freezing point as milk unless products are chemically altered in processing.)

Annexure 3

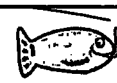
Refrigeration system used in Ice cream plant at Banduragoda



NA-293-6

FISH FREEZING TECHNOLOGIES

Dr. Ranjith Edirisinghe
Head / Post Harvest Technology Division
NARA



Composition

- Water : 60 - 80 %
- Protein : 12 - 24 %
- Lipids : 0.1- 15 %
- Vitamins A,D, E
- Minerals
- Carbohydrates

How fish go bad

- Self digestion by enzymes
- Bacteria
- Oxidation

Temperature ⇓ Rate of activity ⇓

Freezing

! Lower the Temperature
⇒ Slow down spoilage
⇒ Keep the quality

! Freezing (and cold storage) cannot improve the quality of fish

The Process

! Requires the removal of heat

! Converts most of the water into ice

Frozen Fish Products

- **Product for direct consumption**

  Individually quick frozen (IQF) products (single units) : IQF single fillets, shrimp packages, blocks of fish, fish portions

  Consumer buy this products from retailers in frozen state, and either cook it in the frozen state or thaw it for immediate consumption

  Need refrigerated storage and transportation

- **Product for further processing**

  a). The product is frozen in bilk and when thawed after storing, can be used in many ways

  b). The product is frozen in bulk and after storage it may be further processed without thawing so that it may be presented as a retail pack

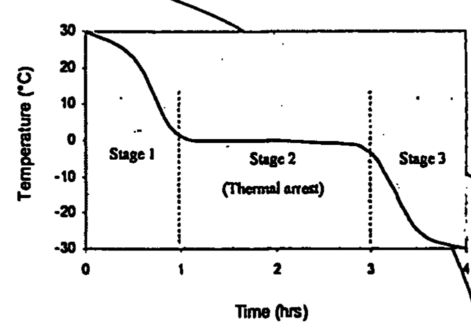


Figure –1. Temperature-Time graph for fish during freezing

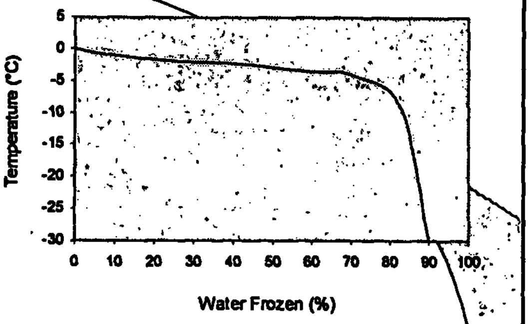


Figure -2., Freezing of fish muscle. The percentage of water frozen at different temperatures

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Rate of Freezing

** The ice in a frozen fish is in the form of myriads of tiny needles or chips, the size and number of which depend on the speed of freezing.

Slow Freezing ⇒ Particles comparatively large and few in number

Appearance of the flesh (muscle structure) affected by the size of the ice particles

Colour similar to that of unfrozen fish

Dark glassy look (very slow)

Quick freezing ⇒ Smaller particles

Less damage

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Factors affecting rate of freezing

- Freezer type
- Freezer operating temperature & conditions
- Air speed in an air blast freezer
- Product temperature
- Product thickness
- Product shape
- Product contact area and density
- Product packaging
- Species of fish

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Types of Freezers

(depending on the method of heat transfer used)

1) Blowing a continues stream of cold air over the fish –
Air blast freezers
versatility to freeze products of all shapes and sizes, suitable for batch, continuous, batch/continuous, small & large-scale production lines, operating temperature : - 35°C to - 40°C

2) Direct contact between the fish and a refrigerant surface -
Contact or plate freezers

VPF, HPF : regular-shaped fish products such as blocks, packages and cartons, common in batch freezing.
operating temperature : - 40°C

Rotating drum : limited use for freezing, IQF products (fish fillets)
operating temperature : - 45°C

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3) Immersion in or spraying with a refrigerated liquid -
Immersion or spray freezers -
limited use

operating temperatures

Sodium chloride brine	:	-21°C
Liquid nitrogen	:	-196°C
Nitrogen gas	:	-50° to -196°C
carbon dioxide	:	-50° to -70°C
Liquid Freon Freezant (Dichlorodifluoromethane R12)	:	-30° to -40°C

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How to make a good product

* Raw material should be fresh (maintain the initial quality)
* Size grading
* Quality grading
* Avoid delay before freezing particularly if freezing fillets
* Keep fish well iced, before freezing
* Follow hygiene practices
* Fatty (small) fish must be iced immediately and be frozen within 24 hours of capture

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* Addition of water to encase the fish in ice protect against rancidity and to prevent physical damage to the outside fish / Shrimp
* Do not overload or underload (use dummies if insufficient material)
* Trays must be cleaned, be robust and easily emptied
* Wrapping materials coated with wax might increase the freezing time. Polyethylene/ paper is recommended
* Freeze for the correct length of time

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Table -1. Practical storage lives of fish products

Product	Storage life in months		
	- 18°C	- 24°C	- 30°C
Fatty fish (glazed)	5	9	> 12
Lean fish (fillet)	9	12	24
Flatfish	10	18	> 24
Shrimp (cooked/peeled)	5	9	12

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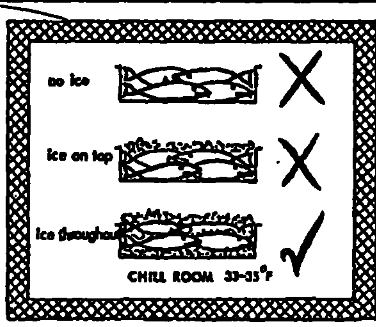

Figure -3. Icing fish awaiting freezing.

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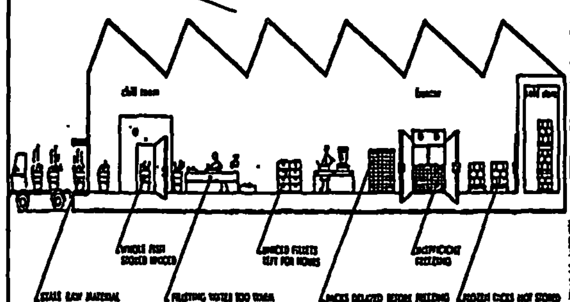

Figure -4. Some of the causes of poor quality frozen fish.

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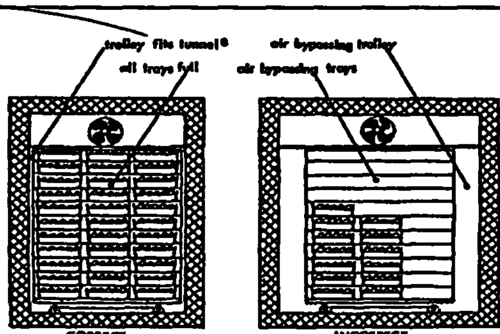

Figure -5. Loading an air blast freezer

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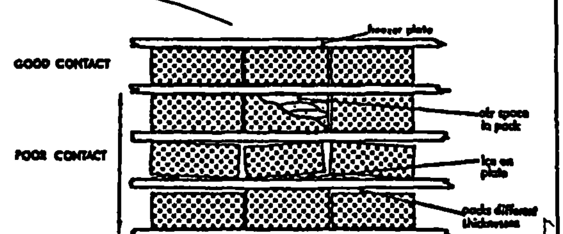

Figure -6. Causes of poor performance in horizontal plate freezers

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Calculation of freezing times

Plank's equation

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

Where

L = Heat to be extracted between the initial freezing point and final temperature (kcal/kg)

V = Specific volume of fish (m3/kg)

Δ = 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

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Table –2 Freezing times for fish products

Product	Freezing method	Product initial temperature (°C)	Operating temperature (°C)	Freezing time (h)	(min)
Whole cod block 100 mm thick	Vertical plate	5	-40	3	20
Whole round fish 125 mm, e.g. cod, salmon, frozen singly	Air blast 5 m/s	5	-35	5	00
Cod fillets laminated block 57 mm thick in waxed carton	Horizontal plate	8	-40	1	20
Haddock fillets 50 mm thick on metal tray	Air blast 4 m/s	5	-35	2	55
Whole lobster 500 g	Liquid nitrogen spray	4	[illegible]	0	12
Surimi meal 16 mm thick	Air blast 3 m/s	5	[illegible]	0	20
Shrimp meat	Liquid nitrogen spray	6	[illegible]	[illegible]	5
Single haddock fillets	Air blast	5	-35	0	12
Packaged fillets 50 mm thick	Sharp freezer	5	-12 to -30	13	00
Packaged fillets 50 mm thick	Air blast 2.5 to 5 m/s	5	-35	5	10
Single tuna, 50 kg	Sodium chloride immersion	20 to -15°C at centre	-12 to -15	72	00
Single tuna, 50 kg	Air blast	20 to -40°C at centre	-50 to -60	[illegible]	00

Notes:

1.All freezing times are to -20°C at the fish centre unless otherwise stated. Other temperatures are given within the brackets after the freezing time.

2.The times given are measured freezing times. In commercial practice, these times should be increased by a factor to allow for operating discrepancies.

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References :

1. Freezing in fisheries, FAO Fisheries Technical Paper No. 167, FAO, ROME
2. Recommended International Codes of Practice for Frozen Fish.(CAC/RCP 16-1978), FAO, ROME
3. Food Standards Programme, Codex Alimentarius Commission, Recommended international code of practice for fresh fish (CAC/RCP 9-1976), FAO, ROME
4. Freezing and refrigerated storage in fisheries, Fisheries Technical Paper No. 340 (1994), FAO, ROME
5. Aitken,A *et al.* (eds) (1982), Fish Handling and Processing. Second Edition, Edinburgh
6. Planning and engineering data, 3. Fish freezing (1984), FAO Fisheries Circular No. 771, FAO, ROME

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NA-293-7

SAFETY OF FROZEN FOOD

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Presentation at Seminar on Food Freezing Technology held on 17th September 2004 organized by National Science Foundation.

GROWTH OF MICROORGANISMS AT AND BELOW FREEZING TEMPERATURES.

Affected by :
- factors inherent within organisms
- nutrient content of food
- pH of food
- availability of liquid water in food

Temperature	a_w of water
0°C	1.00
-5°C	0.953
-10°C	0.907
-15°C	0.864
-20°C	0.823
-25°C	0.784

EFFECTS OF FREEZING ON MICROORGANISMS

Killing of certain microorganisms important to food.

- Sudden mortality immediately on freezing, varies with species.
- Proportion of cells surviving immediately after freezing die gradually when stored in frozen state.
- Decline in numbers is relatively rapid at temperatures just below freezing point (~ -2°C), less at lower temperatures and slow below -20°C.

FROZEN FOOD " FREEZER LIFE" (ie MAX. HOLDING TIME)

- not based on microbiology

Based on texture
flavour
tenderness
colour
overall nutritional quality

On thawing and subsequent cooking

Freezer burn

- browning of light coloured food (skin of chicken meat)

Due to irreversible loss of moisture at surface leaving the product more porous than original at affected site.
{Certain fruits, poultry, meats, fish (raw & cooked)}

THAWING

Thawing – v. important in the freezing survival of microorganisms.

Repeated freezing & thawing destroys bacteria by disrupting cell membranes.

Faster thaw – greater number of bacterial survivors
Thawing is slower than freezing and follows a pattern potentially more detrimental.

PROBLEMS OF THAWING OF PRODUCTS
(heat energy transmitted by conduction)

1. Under comparable temperature differential - thawing slower than freezing.
2. Maximum temperature differential permissible during thawing much less than that feasible during freezing.
3. Thawing time – temperature pattern potentially more detrimental than for freezing.
   During thawing, the temperature rises rapidly to near the melting point and remains there throughout the long course of thawing, thus affording considerable opportunity for chemical reactions, recrystallization and even microbial growth if thawing is extremely slow.

REFREEZING OF THAWED FOOD

Causes:

* Texture changes
* Flavour changes
* Nutritional quality changes

Also microbiology of thawed frozen food relevant

FOODS FROM FROZEN STATE SPOIL FASTER THAN SIMILAR FRESH PRODUCTS

- Textural changes associated with freezing aid invasion of surface organisms into deeper parts of produce and facilitate spoiling process.
- Surface condensation of water occurs on thawing.
- Concentration of water soluble substances (amino acids, minerals, B. vitamins, other nutrients)
- Freezing destroys many thermophilic and some mesophilic organisms leading to less competition among survivors upon thawing. Greater relative number of psychrotrophics on thawed foods might increase spoilage rate.

Also affected by :
* type of freezing
* relative number and types of organisms on products prior to freezing
* temperature at which produce is held to thaw

No known toxic effects of refreezing of frozen and thawed food but minimize for overall nutritional quality.

Freezing & thawing animal tissues releases lysosomal enzymes (cathepsins, nucleases, phosphotases, glycosidases etc.)

These degrade macromolecules and make available simpler compounds that are more readily utilized by spoilage flora.

SOURCES OF CONTAMINATION SPECIFIC TO FROZEN FOOD INDUSTRY

1. Cross-contamination – Contamination of cooked ingredients and final products with m.o. derived from the pre-cooking or blanching parts of the process.
2. Manual handling of product – minimize
3. Non reduction of temperature of filled packs of pre-cooked products to 10°C before freezing.
4. Long time lapse between filling & freezing
5. Entrance feeds (conveyors) not clean and free from debris .

Sources of Contamination - contd.

6. Interiors of the freezers not clean
7. Exit belts or conveyors not clean or free from debris
8. Non maintenance of good hygiene during packaging eg. Clean conveyors, minimum handling.
9. Good hygiene not maintained throughout operation.
10. Contamination by foreign bodies.

CONDITIONS TO MAINTIAN QUALITY OF PRODUCTS IN FACTORY COLD STORES

1. Minimize amplitude & duration of temperature fluctuations during storage & transfer of products - prevent weight loss by dehydration and in package desiccation.
2. Maintain high R. H. in store
3. Prevent physical damage to product or packaging during storage & handling.
4. Do not retain products beyond expected storage life.

SPECIFIC DESIGN CRITERIA FOR FACTORY COLD STORES TO MAINTAIN QUALITY

Factory cold stores as primary cold store for long term storage :

- air temperature $\leq$ -26°C.
- temperature fluctuations – minimize frequency > $\pm$2°C.
- transfer of products with <u>minimum</u> exposure to outside temperature and <u>no</u> exposure to direct sunlight, wind or rain.
- temperature of incoming product $\ngtr$ - 15°C.
- products should remain in cold stores until temperature reaches - 23°C.
- Maintain continuous record of air temperature by recording temperature.
- Cold store entrances fitted with plastic curtains or cold air curtains.
- Stack packages to allow air circulation.

WAYS TO MINIMIZE TEMPERATURE RISES DURING OUT LOADING

1. Fit loading ports to store exits to form tunnel between vehicle & store
   <u>or</u> construct covered bays & screen vehicle entrance from direct sunlight, wind or rain.
2. Pre-cool vehicles (vehicle should maintain product temperature at -23°C.
3. Minimize loading time by using pallets & mechanical handling equipment.
4. Sorting & assembly of load should be performed in cold store.

Thank you!