CC ;7. Unit 2 CHILLING AND FREEZING OF FISH

The main objective of chilling is to cool the fish as quickly as possible because delayed chilling drastically reduces the quality of fish. The chilling of fish is a process by which the temperature of fish is reduced close to 0^0C but not below the freezing point of water. Chilling delays both biochemical and bacteriological spoilage in fish and prolongs the storage life of fish but the deteriorative reactions are not completely stopped. The quality of chilled fish depends on the initial quality of fish, duration of chilling and the storage temperature. Lower the temperature slower is the enzyme and bacterial activity and longer is the storage life of fish. Packaging of fish under appropriate proportions of different gases (modified atmosphere) such as CO_2, N_2 and O_2 also helps extension of shelf life of product during storage.

The following aspects will be studied in this episode:

1. Properties of ice
2. Chilling of fish
3. Freezing of fish
4. Modified atmosphere packaging of fish
5. Conclusion

1. PROPERTIES OF ICE

Refrigerants are liquids which have low boiling point and high latent heat of evaporation. Ice is a cheapest refrigerant. At normal atmospheric pressure, pure water changes from liquid to a solid at 0^oC and ice will melt at the same temperature. For water to change to ice, heat energy, that is latent heat of fusion, must be removed. The latent heat of fusion for water is 80 calories /gram and the specific heat of water is 1 calorie/g. When ice melts, it absorbs large quantities of energy. When ice comes in contact with fish, it will absorb heat from fish and the temperature of fish drops to 0^0C, which is ideal for maintaining quality fish. The advantages of ice are:

- Ice has high heat absorption capacity (80 times higher than same quantity of water).
- Melting of ice helps to wash away bacteria and contaminants.
- Ice keeps the fish wet and moist.
- The ice melt water in contact with fish is a good conductor and facilitates cooling.
- Ice made from potable water is non - toxic.
- Ice can be transported from place to place and can be considered as portable refrigeration.
- Ice is relatively cheap compared with other means of preservation.

Types and production of ice: Ice is produced as block ice and small ice. Block ice is made of different sizes from 12 to 150 kg block. Based on shape small ice are flake, tube and platen nugget ice. Each type has advantages and disadvantages. In India block ice is crushed and used widely. Ice manufacture requires suitable site, supply of water and electricity. The mechanical refrigeration system consists of an evaporator. In this system, the liquid refrigerant passes and

changes into gas, whose latent heat is drawn from evaporator. The refrigerant gas then passes to a compressor which converts it to a high pressure, high temperature gas. The hot pressurized gas is liquefied by cooling in the condenser. From the condenser the liquid passes through an expansion valve back to the evaporator.

Requirement of ice for chilling of fish: The quantity of ice required to chill a given quantity of fish can be calculated by knowing the following.

- Temperature change (Fish temperature – required temperature)
- Quantity of fish
- Specific heat of fish and
- Latent heat of fusion of water.

Theoretically 1 part of ice to 3 parts of fish is sufficient but at the end of the cooling cycle, there would be no ice left to keep the fish cool. Therefore additional quantity of ice is required. The factors to be considered are:

- Ambient temperature
- Type of container
- Contact of ice with fish
- Length of storage and
- Thickness / size of fish.

Normally 1 part of ice to 1 part of fish is used for chilling of fish.

Storage life of fish in ice: The length of time that the fish will remain edible in ice depends on many factors such as

- Species
- Size
- Method of capture
- Fat content of fish and
- Feeding and breeding cycle.

Generally, fish from warm water (tropical) keeps longer than fish from temperate water, non - fatty fish keep longer than fatty fish and fresh water fish keeps longer than marine fish. The storage life fish stored in ice is presented in **Table 1.** Results of this table reveal that temperate marine fish can be stored in ice for 10 – 15 days while tropical fish for 15 – 20 days. Similarly temperate fresh water fish can be stored in ice for 12 – 20 days while tropical fresh water fish for 15 – 20 days.

2. CHILLING OF FISH

Chilling is an effective way to reducing spoilage of fish, if it is done quickly. Fish should be chilled and handled hygienically throughout the distribution chain. Ice is an ideal cooling

medium and widely used at the point of harvest to control the loss of freshness. Now a days, the use of ice on board the fishing vessel is a common practice in many commercial fisheries where voyages are of several days duration.

The boxing method of icing of fish is the best as the handling of fish is minimal and fish can be packed according to size species. Plastic boxes are commonly used. They are strong and robust, easy to clean and filled boxes can be stacked one above the other, so that the weight of the top box is taken by the box below without pressing the fish. When empty, the boxes can be nested to save the storage space. The correct and incorrect way of packing fish with ice in boxes is presented **in Fig. 1.**

The delay in icing has profound effect on storage life of fish. The rate of spoilage of fish is temperature dependent. For every 5 ^{0}C increase in temperature, the storage life in ice is reduced by half. Effect of storage temperature on shelf life of fish is presented in **Table 2**. Relative rate of spoilage of fish stored at 0 ^{0}C increases from 1 to 16 when stored at 30 ^{0}C with the concomitant decrease in shelf life of fish from 14 days to only 4 h.

Super chilling of fish: Reducing the temperature of fish slightly below 0^{0}C (0 ^{0}C to -3 ^{0}C) is referred to as super chilling or partial freezing of fish. Super chilling is obtained by using refrigerated sea water and chilled sea water. Chilled sea water is more cost effective than refrigerated sea water. It is an excellent method for preservation of small pelagic fish species such as sandiness and mackerels. Shelf life of fish under super chilling conditions is presented in **Table 3.** Under super chilling conditions, as the water temperature decreases the amount of frozen water increases with an increase in shelf life of fish. Under super chilling conditions, the amount of frozen water varies from 15% at -1 ^{0}C, 55% at -2 ^{0}C and 70% at - 3 ^{0}C with similar increase in shelf life of fish from 17 days, 22 days and 29 days, respectively.

The advantages of super chilling are:

- Rapid cooling
- Less damage
- Less labor and
- Less ice

The disadvantages of super chilling are:

- Salt up take by fish
- Growth of anaerobes

3. FREEZING OF FISH

Freezing is an excellent method of preservation for sea foods. Freezing is a process of removing heat so that the water in fish is converted in to ice. Freezing is superior to other methods of preservation due to: (i) Lowering of temperature retards or stops most reactions including

bacterial activity, (ii) Water in ice form is not available for bacteria for their biological functions, and hence their growth is prevented and (iii) There is complete immobilization of the system, thereby reducing spread of organisms by convection. Fish preserved by freezing retains its original quality attributes without significant modification.

Proper method of freezing and storage at right temperature gives a product resemblance to fresh fish so that the consumer will be unable to distinguish between a frozen and a fresh fish. If freezing is not proper and the product is stored for a long time, the product exhibits number of defects such as

- Changes in texture (changes in proteins – tough / coarse / rubbery / spongy)
- Changes in odor and flavor (changes in lipids –oxidation / rancidity)
- Losses in weight (15 - 20% drip loss / fluid loss / loss of WHC)
- Changes in color (fading of pigments) and
- Dehydration / freezer burn.

These changes result in to reduction of fish quality. Therefore it is important to minimize these changes which are avoidable. There are certain normal changes during freezing of fish which are unavoidable. They are mentioned below.

1. **Phase change:** Fresh fish contains about 80% water. Pure water freezes at 0 ^{0}C. Since the fish flesh contain dissolved salts, the freezing temperature varies usually between -1 to -2^{0}C. At -5^{0}C, it would appear that all the water in fish is frozen, but nearly 20% of water is unfrozen. At -20 to -30% , nearly 85 - 90% of water in fish is frozen and 10 - 15% is still unfrozen.
2. **Expansion in volume:** Pure water expands by 9%. This results in possible damage in texture.
3. **Concentration of solutes:** As the temperature is lowered and cellular water is frozen. The mineral salts and soluble organic substances become concentrated in the remaining unfrozen state. This increase in cellular condition causes protein denaturation.
4. **Rate of freezing:** The speed of freezing has a major influence on ice crystal formation. Slow freezing produces large ice crystal outside the cell walls and damages the cell wall (extracellular). Quick freezing produces small ice crystals inside the cell walls (intra cellular), which causes minimum damage to cell walls.
5. Slow bacterial growth and enzyme activity.
6. Mechanical stress causes freeze damage

Freezing **curve (Fig. 2)** is a temperature plotted against time defining different stages of fish freezing. The different stages of freezing are:

Stage 1: Temperature of fish falls rapidly to 0 ^{0}C.

Stage 2: Temperature of fish remain fairly constant -1 ^{0}C and slowly moves to -5 ^{0}C when about 80% of water is frozen due to removal of latent heat.

Stage 3: Temperature drops rapidly due to removal of sensible heat as the water remains frozen.

The amount of heat removed from 1 kg fish at 25 ^{0}C is:

From 25 ^{0}C to 0 ^{0}C (Stage 1): 1 x 26 x 4.2 K Joules (KJ) = 109.2 KJ
From 0 ^{0}C to -1 ^{0}C (Stage 2): 1 x 334.7 KJ = 334.7 KJ
From -1 ^{0}C to -30 ^{0}C (Stage 3): 1 x 29 x 2.1 (Specific heat) = 60.9 kJ
Total: 109.2 + 334.7 + 60.9 = 504.8 KJ.

During freezing 65 % of heat extracted in stage 2. Thermal Arrest Time (TAT) or Critical Temperature Zone refers to the time required for stage 2. For the production of good quality frozen fish the TAT should be as short as possible.

Quick freezing: If the time required to lower fish temperature from 0 ^{0}C to -5 ^{0}C is 2 hours or less, it is referred to as quick freezing. In quick freezing, the fish is frozen at -20 ^{0}C and stored at -30^{0}C. If the temperature is not brought down to -20 ^{0}C, the salt concentration increases autolytic spoilage. After freezing, the fish should be unloaded and stored immediately. If it is left in freezer for too long, it causes freezer burn. Freezing is faster near the surface and slower in the centre of fish. **Table 4** lists the rate of freezing in terms of thickness of fish frozen per hour in different methods of freezing. Based on thickness of fish the rate of freezing is 2 mm / hour under slow freezing condition, 5 – 30 mm / hour under quick freezing, 50 – 100 mm / hour under rapid freezing and 100 – 1000 mm / hour under ultra rapid freezing condition.

Types of freezers: Three types freezers commonly used are:

1. *Air blast freezers:* They are of Batch or Continuous type. Features of this type of freezers are:

- The point of entry and exit should be protected with plastic air curtains.
- The speed of belt can be adjusted according to desired freezing time.
- Useful for coated products and value added products.
- Fluidized bed freezer (Cold air produces a fluidized bed) is suitable for small and uniform sized products.

Eg: Cooked shrimp, green peas, Individually Quick Frozen products

2. *Contact plate freezer:* Plate should be free of ice, good contact with fish.
   They can be horizontal type (Shore based generations) and vertical (Sea based generations). The plate freezers are useful for freezing in block of 2 kg / 5kg.
3. *Immersion freezers:* They operate at very low temperature and give rapid freezing rates. There is no dehydration, no drip loss and provide good quality fish.

Cryogenic freezing: Freezing is caused by direct contact with the refrigerant. Refrigeration by using salt solution below freezing point can be used for on – board freezing especially for tuna. Use of liquid nitrogen is most common. Liquid nitrogen boils at – 196 ^{0}C. This method is most useful for individual freezing of fillets and high priced shrimp.

In this method, the fish are sprayed first with liquid nitrogen at about -50 ^{0}C and then the temperature is reduced gradually. Cryogenic freezing requires regular supply of liquid nitrogen and its operation cost is high.

Other types of low boiling point liquid freezers are:

a. *R12 dicholordifluromethane:* It is environmentally not friendly and leads to ozone depletion in the atmosphere.
b. *Liquefied CO_2:* Liquefied CO_2 is refrigerated before spraying. Its sublimation point is – 79 ^{0}C. Management of CO_2 freezing is more difficult than liquid nitrogen freezing.

Factors affecting freezing rate: The rate of freezing fish is influenced by several factors as mentioned below.

- *Air speed:* Faster the air speed, higher the freezing rate but high energy cost. The air speed in blast freezers may vary from 5 – 15 meters / second.
- *Temperature:* Higher the temperature slower is the freezing rate. Normal air temperature lies between -30^{0}C and -40^{0}C.
- *Uniform air flow:* It depends on position of fan, design of fan, stacking of the product and periodical defrosting of evaporator.
- *Other factors:* Product temperature, thickness, area, size, shape, thermal conductivity, density, latent heat of fusion of food and surface heat transfer coefficient also influence the rate of freezing fish.

Cold storage: After freezing the fish is kept at -30 ^{0}C temperature. Uniform and steady temperature without fluctuation throughout the storage period and proper air circulation are necessary for good keeping quality of fish.

Glazing: Serious problems in storage of frozen fish are dehydration, oxidation of fats, color changes, protein denaturation. To maintain quality the product must be glazed by dipping / spraying chilled water. This gives protection to the product by controlling water loss and 0_2 uptake. A thin protective layer may increase the gross weight of fish by 2%,followed by suitable packaging. Shelf life of different kinds of fish under frozen conditions is presented in **Table 5.** At the storage temperatures of - 18^{0}C, - 25^{0}C and - 30^{0}C, fatty fish can be stored for 4, 8 and 12, lean fish for 8, 18 24 months, lobster / crab for 6, 12 and 15 months and shrimp for 6, 12 and 12 months, respectively.
General guidelines for good storage practice are:

- All products should be labeled clearly (product, type, date of production, code and traceability).
- Storage plan and temperature records should be maintained.
- Storage period should be as minimal as possible.
- Proper glazing and packing improves keeping quality of fish.
- The product should be kept away from floor, wall and ceiling.
- Regular defrosting is essential for proper maintenance of storage temperature.

4. MODIFIED ATMOSPHERE PACKAGING (MAP) OF FISH

Modified atmosphere packaging (MAP) is an expensive method of fish preservation, in combination with chilling. It involves replacement of air in the package with a gas mixture consisting of CO_2, N_2 and O_2. The storage life of fish is marginally increased based on proportions of CO_2, N_2 and O_2. Normally the composition of CO_2, N_2 and O_2 for lean fish is 40%, 30 % and 30 % and 60%, 40% and 0%, respectively for fatty fish.

Higher levels of CO_2 leads to discoloration and a cellulose pad is provided to absorb the drip, if any. Anaerobic condition leads to risk of *clostridium botulinum* and hence strict temperature control in the range of 0^0C - 5^0C during storage is important. Laminates consisting of 12 µ polyester, 3 µ PVDC and 60 µ polythene is most appropriate for packaging of fish for MAP. The MAP improves presentation of the product for marketing.

Conclusion: Chilling and freezing of fish are the most widely used processing methods for preservation of fish. The quality of chilled and frozen fish resembles closely to that of fresh fish, if they are properly chilled or frozen. In many cases, the consumer will be unable to distinguish between fresh fish and chilled / frozen fish. The initial quality of fish, hygiene and sanitation, freezing and storage conditions are critical for maintenance of fish quality. Modified atmosphere packaging of fish with appropriate laminate and composition of CO_2, N_2 and O_2 helps extend keeping quality and marketing of fish and fish products.

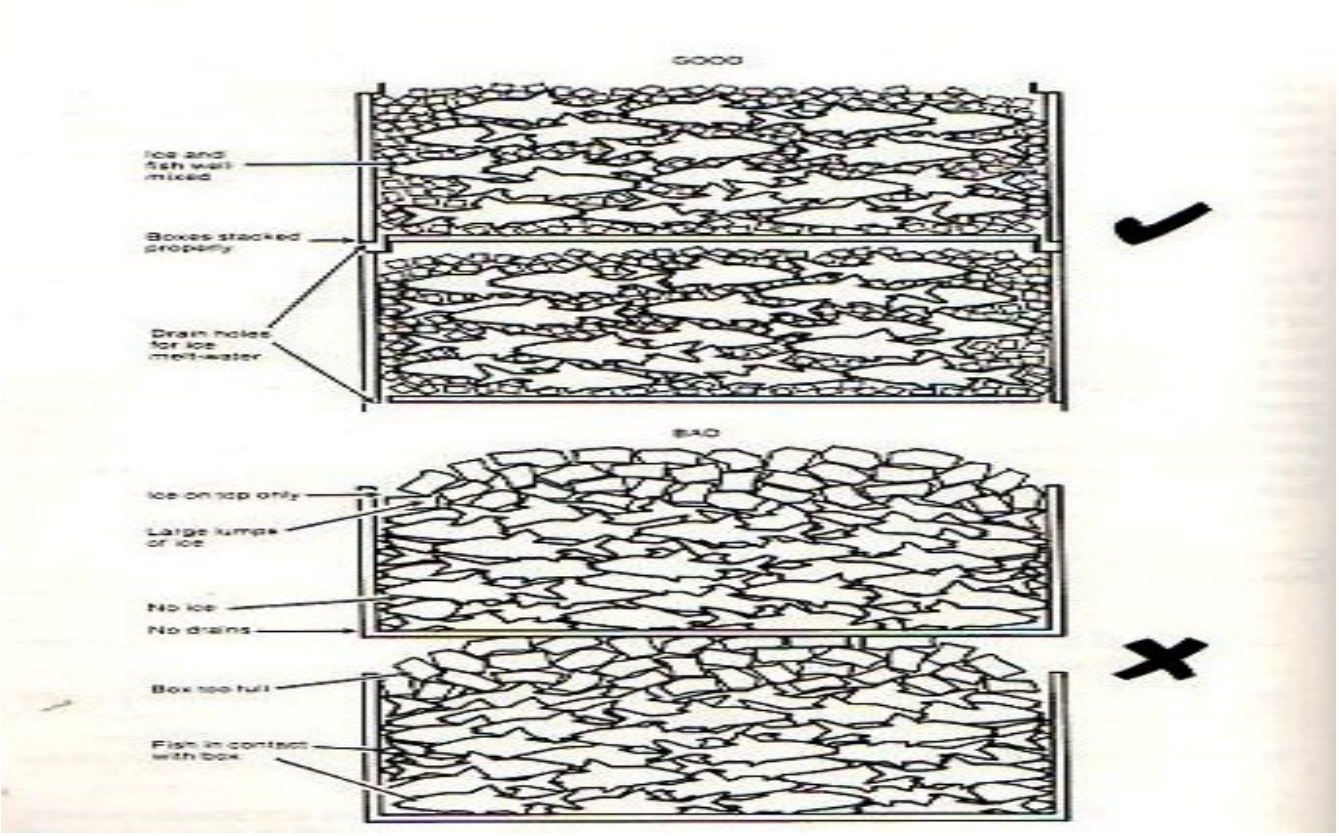

Fig. 1. Correct and incorrect method of icing fish in boxes

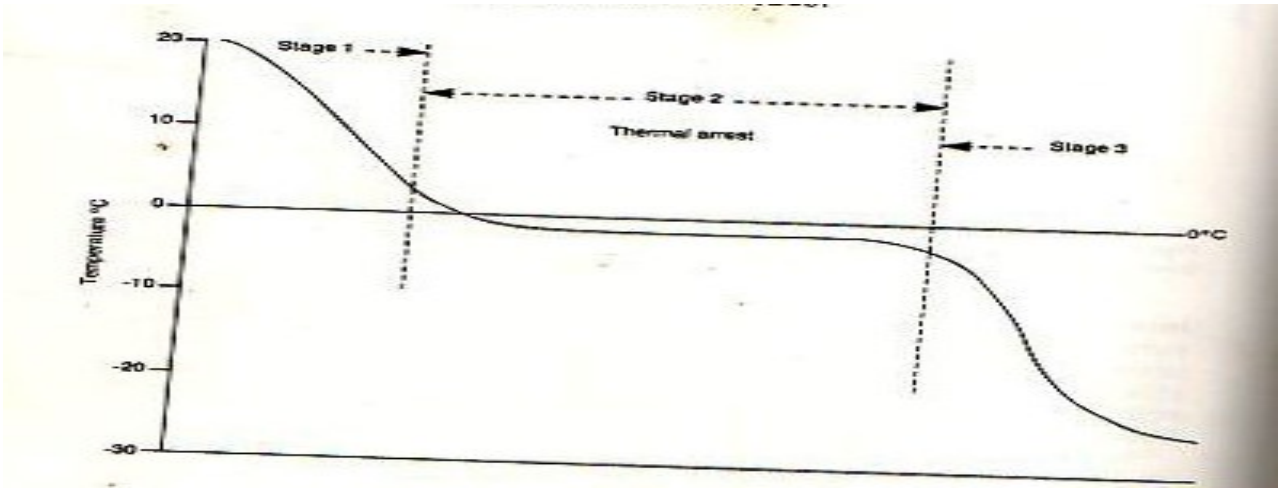

Fig. 2. Fish freezing curve.

Table 1. Storage life of fish stored in ice

Species	**Types**	**Length of storage, days**
Marine	Temperate	10 – 15
Marine	Tropical	15 - 20
Fresh water	Temperate	12 - 20
Fresh water	Tropical	15 - 20

Note: Tropical fish can be stored in ice for longer fish than temperate fish. Similarly fresh water fish has longer storage life than marine fish.

Table 2. Effect of storage temperature on shelf life of fish

Storage temperature	**Relative rate of spoilage**	**Storage life**
0 ^{0}C	1	14 days
5 ^{0}C	2	7 days
10 ^{0}C	4	3.5 days
20 ^{0}C	8	18 hours
25 ^{0}C	12	9 hours
30 ^{0}C	16	4 hours

Note: Relative rate of spoilage of fish stored at 0 ^{0}C increases from 1 to 16 when stored at 30 ^{0}C with the concomitant decrease in shelf life of fish from 14 days to only 4 hours.

Table 3. Shelf life of fish under super chilling conditions

Water temperature	**Amount of water frozen**	**Shelf life fish under super chilling**
-1 ^{0}C	15%	17 days
-2 ^{0}C	55%	22 days
-3 ^{0}C	70%	29 days

Note: Under super chilling conditions, as the water temperature decreases the amount of frozen water increases with an increase in shelf life of fish.

Table 4. Rate freezing in terms of thickness of fish frozen per hour in different methods of freezing

Freezing method	**Rate of freezing (mm/h)**
Slow freezing	2
Quick freezing	5 - 30
Rapid freezing	50 - 100
Ultra rapid freezing	100 - 1000

Note: In terms of thickness of fish the rate of freezing increases with rate of freezing, i.e., from slow freezing to ultra rapid freezing.

Table 5. Shelf life of different kinds of fish under frozen conditions
(Storage period in months)

	-18^0C	-25^0C	-30^0C
Fatty fish	4	8	12
Lean fish	8	18	24
Lobster / crab	6	12	15
Shrimp	6	12	12

Note: Fish keeps longer freshness at lower frozen temperatures ranging from 4 months at $-18\ ^0$C to 24 months at $-30\ ^0$C.