

Chilling of fish – methods and equipment for chilling; icing – quality of ice, ice making; refrigerated or chilled sea water, chilling rate; spoilage of fish during chilled storage; use of antibiotics and chemicals

Chapter 1: Fresh fish handling

2.1.1. Introduction to Icing

Icing is the most prevalent method of preserving fish. Ideal icing involves packing crushed ice and fish alternatively in insulated boxes, in the fish to ice ratio of 1:1 (w/w). By this, the temperature of the fish is lowered to near 1 to 2 °C in about 2-3 hrs (the melting of the ice needs 80 calories of heat/g and this heat is removed from the fish in contact with ice and hence, the fish get cooled). **This lowering of temperature brings about**

1. **arrest of almost all enzymatic changes,**
2. **killing of about 50-60% of the mesophilic bacteria and**
3. **slowing down of the activities and growth of all other bacteria,** which are cold-loving (psychrophilic) and cold-tolerant (psychrotrophic).

As a combined effect of all these three factors, the spoilage of fish is delayed to a considerable length of time in ice. During iced storage of fish, there is an initial drop of bacterial count due to the death of the cold sensitive mesophiles. The surviving cold tolerant bacteria, however, get adapted to growth in low temperature. Consequently, there is a gradual increase in population, which takes about 6 to 8 days to reach a count of one million per gram or above. By that time, the fish has reached the stage of incipient spoilage.

Qualitatively, **there is a selection of bacterial flora during iced storage of fish.** Irrespective of the composition of the initial flora, the *Pseudomonas/ Alteromonas* group emerges as the predominant group of bacteria at the time of spoilage. **This is because most of the psychrotrophic bacteria capable of spoilage belong to these genera.**

In the case of **tropical fishes,** it is not the psychrophiles, **but the psychrotrophs, which are the actual spoilers during iced storage.** These psychrotrophs, whose population is very low in the fresh tropical fish, easily adopt to grow at low temperature during iced storage and grow very rapidly and spoil the fish. Further, psychrotrophs have a shorter generation time compared with psychrophiles.

2.1.2. Advantages of chilling of fish with ice

- i) **Temperature reduction.** It reduces the temperature to about 0°C. The growth of spoilage and pathogenic micro-organisms is reduced, thus reducing the spoilage rate.
- ii) **Melting ice keeps fish moist.** This action mainly prevents surface dehydration and reduces weight losses. Melting water also increases the heat transport between fish and ice surfaces (water conducts heat better than air); the quickest practical chilling rate is obtained in a slurry of water and ice (e.g., the CSW system).
- iii) **Advantageous physical properties.** Ice has some advantages when compared with other cooling methods, including refrigeration by air. The properties can be listed as follows:
 - a) **Ice has a large cooling capacity.** The latent heat of fusion of ice is about 80 Kcal/kg. This means that a comparatively small amount of ice will be needed to cool 1 kg of fish.
 - b) **Ice melting is a self-contained temperature control system.** Ice melting is a change in the physical state of ice (from solid to liquid), and it occurs at a constant temperature (0°C).
- iv) **Convenience.** Ice has a number of practical properties that makes its use advantageous. They are:
 - a) **It is a potable cooling method.** It can be easily stored, transported and used. Depending on the type of ice, it can be distributed uniformly around fish.
 - b) Raw material to produce ice is widely available. Although clean, pure water is becoming increasingly difficult to find, it is still possible to consider it a widely available raw material and it should be properly treated, e.g., chlorination.
 - c) Ice can be a **relatively cheap** method of preserving fish. This is particularly true if ice is properly produced (avoiding wastage of energy at ice plant level), stored (to avoid losses) and utilized properly (not wasted).
 - d) Ice is a safe food grade substance. If produced properly utilizing drinking water, ice is a safe food substance and does not cause any harm either to consumers or those handling it. Ice should be handled as food.
- v) **Extended shelf life.**

The overall reason for icing fish is to extend shelf life fresh fish of in a relatively simple way as compared to storage of un-iced fish at ambient temperatures above 0°C. Extension of shelf life means producing safe fresh fish of acceptable quality.

2.1.3. Chilled storage

In general, two types of plastic fish boxes are used: stack-only and nest/stack boxes.

1. The handling rate is necessary to prevent quality loss because of delayed icing. Pre-chilling can be of advantage to compensate lack in handling rate.
2. Handling methods, which make it possible to guarantee that the icing procedure is sufficient to chill the fish to 0°C and maintain this temperature until landing.
3. The hold must be constructed in such a way, that safe and easy stacking of the boxes can take place.
4. Hold insulation of a relatively high quality should be considered. A small mechanical refrigeration plant can be of advantage. Air temperature in the hold should be +1° or -3°C.

Use of antimicrobial agents in ice and cold liquids

By ordinary method of icing, fish can be preserved for 10-12 days. However, studies have shown that use of antimicrobial agents in ice or cold liquids, enhance the shelf life of fish by 60 to 100%. The following antimicrobial agents were used.

a) Chlorine compounds

If liquid chlorine or bleaching powder is mixed with ice or cold liquids, shelf life of fish can be enhanced. If the cooling media (ice or chilled liquid) contains less than 30 ppm of chlorine, no damage is done to fish. However if the proportion is more than this, the fish gets acrid smell. Also due to oxidation, the colour of fish may change. By this method fish can be preserved for 18-20 days.

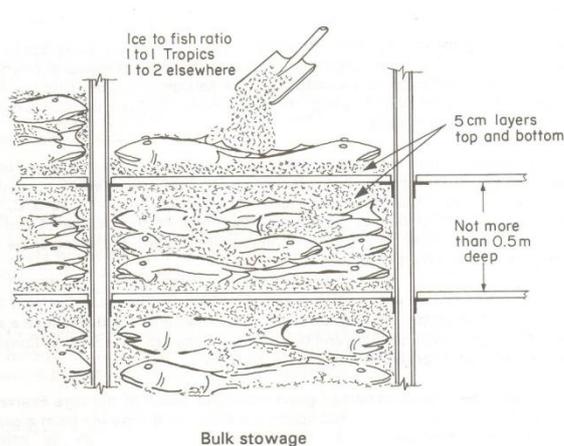
b)Antibiotics

By the **use of antibiotics in ice or cold liquids, shelf life of chilled fish can be increased.** Among the antibiotics, chlorotetracycline and oxytetracycline are important. These are powerful broad spectrum antibiotics and are very effective even at low concentrations. Antibiotics were used for chilling fish as follows.

1. By dip treatment in antibiotic solution and then chilling.
2. Incorporating antibiotic in water and then ice is prepared and used for chilling.
3. Incorporating in chilling liquids (CSW or RSW)
4. It has been found that dip treatment of fish in water containing 30 to 100 mg of CTC for 1-5 min and then icing increases the shelf life by 5-10 days. Ice containing 5 mg/kg of CTC, when used, increase the shelf life of fish from 10 days to 20-22 days. However at present use of antibiotics is banned as per Codex Alimentarius standards.

2.1.4 Storage method

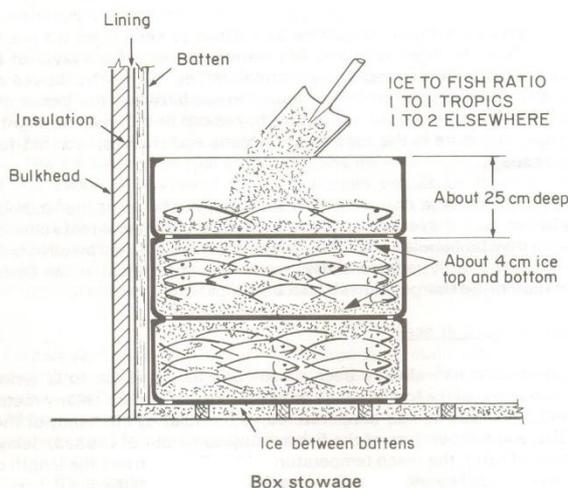
5. *There are three methods of storing fish in ice on fishing vessels*
6. **Bulking:**
7. The fish hold is a insulated chamber located at the near side of the Boat. It is divided into different compartments using wooden boards supported by an upright beam. A layer of ice at least 5 cm thick is spread over the bottom of a compartment followed by a layer of fish. Ice is then spread over the fish and around the edges so that the fish are not in direct contact with the sides of the board.
8. Further layers of fish and ice are added until a depth of about 45cm ice and fish is achieved, with a layer of 5 cm of ice at the top. A horizontal wooden board is now placed over the section. The wooden board must be supported by the stanchion structures, not by the fish and ice in the lower compartment. More fish and ice are added in the same way, again to a depth of 45cm. The operation is repeated until the compartment is full. Wooden boards and stanchions must be kept clean and out of direct contact with the fish.
9. **Shelving:** The fish hold is divided into sections as it is for bulking but this time removable shelves spaced at about 23 cm are used for holding the fish. The lowest shelf is covered with a layer of at least 5 cm of ice. Fish are placed in rows on the ice and more ice is used to cover the fish to about 5 cm. Only one layer of fish is to be put on to each shelf. Shelves must be supported by stanchions, not by the fish and ice below.



Bulk stowage

Boxing: Fish boxes come in a variety of sizes and materials. Ideally, a box should:

- i. Be strong and robust.
- ii. Be able to be stacked so that the weight of the top boxes are taken by the boxes below, not by the fish in the box below.
- iii. Be able to nest to save on stowage space when empty.
- iv. Be easily cleaned and, if necessary, sterilized.
- v. Allow ice melt-water to flow away outside the box below and not through it on to the fish in the lower box.
- vi. Have good thermal insulation.



Box stowage

Fish boxes should be used as follows

A layer of ice 5 cm thick should be placed in the bottom of the box, followed by a layer of fish. A thin layer of ice follows, interlacing fish and ice, until the box is almost full. The ice should be placed around the sides of the box as well as amongst the fish and the top layer of fish should be covered with at least 5 cm of ice. The box must not be over filled. This prevents crushing the fish when the boxes are stacked into the fish hold. **When boxing fish, the fish hold does not require any compartments or Stanchions.**

Refrigerated fish rooms

Some fish rooms not only have insulation but also have refrigeration facilities. Earlier this refrigeration is usually in the form of cooled grids and pipes on the roof of the fish room. **Now-a-days a unit cooler with fan is placed in the chill room.** It is important to get the maximum cooling effect from the ice that is allowed to melt. For this reason the temperature in the fish room should not fall below 0°C. In order to prevent melting of ice, it is common practice for refrigeration to be used only before fishing starts when the vessel is carrying ice alone. Under these circumstances, the temperature can be below 0°C.

Insulated boxes

In small boat fisheries, insulated boxes are used to carry ice to sea, and for storing ice and fish, when

fishing occupies only a short period. The size of the boxes depends on the size of the boat and the amount of fish normally caught in a day's fishing. The ambient temperature will govern the amount of insulation required in the box, though about 10-15cm of expanded polystyrene is common. Insulated boxes for small fishing boats can often be made locally at low cost.

Chapter 2: Calculation of the ice requirement for cooling fish

2.2.1. Calculation of the ice requirement of cooling fish

The mass of ice needed to cool fish from the initial temperature to the final holding temperature can be calculated from an expression, which equates the heat taken up by the ice with the heat lost by the fish.

$$\text{Heat taken up by Ice} = \text{Heat lost by fish}$$

$$(M_i) (L_i) = (M_f) (C_{pf}) (t_i - t_f) \quad (1)$$

Where

- M_i = mass of ice which melts (kg)
- L_i = latent heat of fusion of ice (80 kcal/kg)
- M_f = mass of fish (kg)
- C_{pf} = specific heat of fish (kcal/kg^oC)
- t_i = initial temperature of fish (°C)
- t_f = final temperature of fish (0°C)

From equation (1) the ice requirement will therefore be:

$$M_i = \frac{(M_f) (C_{pf}) (t_i - t_f)}{(L_i)} \quad (2)$$

The specific heat of lean fish is 0.8 kcal/kg °C and this value should be used if there is a species mix or if there is a possibility that all the fish are of a lean species.

The specific heat value, however, may be refined to take account of variations in the oil content of the fish and this refined value may be used if the fish composition is reasonably consistent.

$$C_{pf} = 0.5 X_l + 0.3 X_s + 1.0 X_w \quad (3)$$

- Where C_{pf} = specific heat of fish (kcal/kg)
- X_l = mass fraction of lipids (oil)
- X_s = mass fraction of solids
- X_w = mass fraction of water

To illustrate the effect of oil content on the quantity of ice required for chilling the following comparison is made between lean and fatty fish.

Example (1) – 100 kg lean fish with 1% lipids, 19% solids and 80% water at an initial temperature of 20°C:

$$C_{pf} = \frac{(0.5 \times 0.01) + (0.3 \times 0.19) + (1.0 \times 0.8)}{100 \times 0.862 \times (20-0)} = 0.862 \text{ kcal/kg } ^\circ\text{C}$$

$$M_i = \frac{\dots}{80} = 21.55 \text{ kg of ice}$$

Example (2) – 100 kg of fatty fish with 21% lipids, 19% solids and 60% water at an initial temperature of 20°C.

$$C_{pf} = \frac{(0.5 \times 0.21) + (0.3 \times 0.19) + (1.0 \times 0.6)}{100 \times 0.762 \times (20-0)} = 0.762 \text{ kcal/kg } ^\circ\text{C}$$

$$M_i = \frac{\dots}{80} = 19.05 \text{ kg of ice}$$

Since the calculation for fatty fish shows only a small reduction in ice requirement and, with most species the oil content is variable, it is advisable to treat all fish as lean fish.

2.2.1.1. Heat Requirements

The heat required to change from a solid to a liquid is known as the latent heat; **1 kg of ice requires 80 kilocalories (kcal) of heat to melt it. This figure of 80 kcal/kg is known as the latent heat of fusion.** It is this property of requiring a large amount of heat to melt ice that makes it such a good cooling agent. **One kilocalory is the amount of heat required to raise the temperature of 1kg water by 1°C.**

More heat is required to warm water than almost any other substance. **This capacity of substances to hold heat, when compared to water, is known as the specific heat.** Specific heat of water is 1, for other substances it is less than 1.

Ice	About 0.5
Wet fish	About 0.96 (usually taken as 1)

Frozen fish	About 0.4
Air	About 0.25
Most metals	About 0.1

Specific heat can be used to discover how much heat has to be removed to cool a substance, i.e.

Heat to be removed = weight of substance x temperature change x the specific heat,

To cool 60 kg ice from -5 to 10°C requires the removal of:

$$60 \times [-5 - (-10)]^{\circ}\text{C} \times 0.5 \text{ (sp. Heat of ice)} = 150 \text{ kcal}$$

We can now calculate how much ice is needed theoretically to cool a given weight of fish:

If we want to cool 10 kg fish from 25 to 0°C, we would need to remove

$$10 \times 25 \times 1 = 250 \text{ kcal}$$

But when ice melts it adsorbs 80kcal/kg.

$$250$$

$$\text{Thus the weight of ice required} = \frac{250}{80} = 3.12 \text{ kg.}$$

This is strictly a theoretical calculation and does not take the following factors consideration

1. Ice is also melted by the surrounding air; thus a lot of ice is lost, particularly at high ambient temperatures, unless the fish and ice are protected from the ambient heat, preferably with insulating materials.
2. How the fish are packed in ice.
3. The length of time that the fish needs to be kept chilled once cooled.
4. How quickly the fish are chilled.

2.2.1.2. Calculation of the ice requirement for the storage of fish

Even if you are concerned with only one batch of fish held in identical containers, there are likely to be variations in ice melting rates, which make it difficult to calculate the ice requirement accurately. For instance, the containers are stacked, and then ice melting may be different in containers located at the top, bottom, sides and within the stack.

All containers should be treated equally and the assumption made that each container is fully exposed to the surrounding air.

As a first step, heat transfer may be calculated using the following simple expression:

$$q = A.U. (t_o - t_c) \text{ kcal/day} \quad (4)$$

Where q = heat entering the container (kcal/day)

A = surface area of the container (m^2)

U = overall heat transfer coefficient (kcal/day m^2 °C)

t_o = temperature outside the container (°C)

t_c = temperature inside the container (°C)

This overall calculation of heat transfer may require to be done in parts, for instance, the lid or base of the container is made of a different material or has a different thickness. The heat transfer through the various areas are then added together to give the total heat transfer.

The heat entering melts the ice, therefore it follows that:

$$q = Li \cdot mi \text{ (kcal/day)} \quad (5)$$

Where q = heat required to melt ice (kcal/day)

Li = latent heat of fusion of ice (usually taken as 80 kcal/kg)

mi = mass of ice melted (kg/day)

In order to develop a mathematical expression for ice melting rate during the storage period it is assumed that ice melting inside the containers is only due to heat transferred from the surrounding air. In this steady state approach, quantities (4) and melting (5) should be equal, therefore it follows that:

$$Li \cdot mi = A.U. (t_o - t_c) \quad (6)$$

Thus, the ice requirement will be:

$$\frac{A.U. (t_o - t_c)}{Li} = \text{kg/day} \quad (7)$$

To include the element of ice melting due to radiated heat will make the calculation extremely difficult. Therefore, if the containers cannot be protected from direct sunlight or any other radiated heat source during the storage period, the calculated values for the ice requirement should be

upgraded.