

## Chapter 9

### Hygienic handling, chilling and freezing of fish and shell fish

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Food hygiene relates to "all the conditions and measures necessary to ensure the safety and suitability of food at all stages of the food chain". The production of safe and quality fish and its products requires effective hygienic practices throughout the food chain from fish harvest to consumption. These hygienic measures aim at preventing or reducing fish contamination and microbial growth.

Fish is a food commodity loaded with important components such as proteins, omega-3 fatty acids, vitamins and minerals which are incredibly vital for the functions of body. However, seafood is simultaneously highly perishable and hence requires effective preservation protocols to maintain its quality and safety. Ensuring the quality of fish begins with harvest and extends throughout the post-harvest chain. Fish being highly delicate, critically requires efficient cold chain management throughout the supply chain to guarantee quality of the fresh, chilled, frozen or processed fishery products. Along the cold chain, right from the harvesting routed through onboard storage, landing centre, transportation, till domestic/export/retail marketing, the qualitative loss account for 2 -5 % while quantitative loss ranges from 3 - 17 %, being maximum during harvesting. Therefore, strengthening of the harvest practices by proper measures as well as post- harvest infrastructure facilities such as cold storage facilities, ice plants, freezing/processing units, roads and transportation, modern and hygienic wholesale and retail market outlets etc., as well as effective marketing system in identified areas are the key requirements for the development of this sector. There are, however, several constraints in handling the fish; the important among them are the bacteriological, chemical and physical processes that cause degradation of fish. Proper handling and preservation can increase its shelf life and retain its quality and nutritional attributes. The objective of handling, processing and preservation is to control or reduce the spoilage process so that the final product is wholesome and safe for the consumer. Fish and fishery products brought to market in a well-preserved condition will generally command higher prices, both at wholesale and retail levels, and thus give better returns to the fishing operation.

Effective handling and transportation can help to deliver the fish in the same condition as it is at the time of catch within the limits of practicability under good commercial practice. For this, the general and important rules to be followed include: Maintaining the fish at low temperature throughout the post-harvest chain by proper icing; Avoid mishandling of the fish; Sorting of fish, catch wise (species-wise, size-wise); Use of clean containers/surface for the holding/transportation of fish; Use of good quality water and ice; Personnel hygiene at every handling stage.

### **Hygienic onboard fish handling**

Handling of fish starts the moment they are harvested and refers to the conditions that fish are subjected to, after harvest till conveyed on-shore. Careful and hygienic handling of fish onboard the fishing vessel can ensure enhanced longevity of fish. These mainly include proper vessel design and maintenance, cleanliness of vessel premises, workers hygiene and maintenance of cold chain. For this:

1. Vessels must be designed and constructed so as to protect fish from contamination by bilge-water, sewage, smoke, fuel or other objectionable substances.
2. Equipment, materials, surfaces and surface coatings that come into contact with fish and fishery products must be corrosion-proof, durable, non-toxic as well as easy to clean and disinfect.
3. Fishing vessels should be designed and equipped with suitable holds, tanks or containers to preserve fresh fish and fishery products throughout the fishing period.
4. Chilling devices must allow easy monitoring of temperatures.
5. Ensuring availability of potable water for washing and cleaning of fish and fishery products retained on board as well as for ice that is used to chill the samples.
6. All vessels must be kept free of pests using pest control devices.
7. Sorting and heading and/or gutting of fish must be carried out hygienically as soon as practicable after capture and the eviscerated products must be washed immediately and thoroughly with either potable water or clean seawater.
8. Crew members must maintain a reasonable standard of hygiene and prevent contamination of fish or fishery products and where appropriate, wear suitable protective clothing, head covering and footwear.

### **Hygienic fish handling in harbour/market**

In the seafood supply chain, the first trade/sale point is the landing centres or harbours. These primary markets are the most crucial location which ensures the economic returns of fishermen as well as the availability of quality fish along the entire value chain. These domestic markets play a very crucial role in the development of fisheries sector in the country as about 85% of the total fish landing is distributed through domestic markets. They play a major role in strengthening the nutritional and food security. Ensuring hygienic handling practices in domestic market helps to minimize post-harvest losses and leads to food safety. Following minimum basic requirements can ensure good hygiene in domestic market:

- Cleanliness of the market premises
- Availability of potable water, ice facility and cold storage facilities
- Hygienic stalls with proper roofing and flooring and portable display unit with facility for cutting and storage of fish
- Maintenance of proper hygiene by workers
- Proper drainage and waste management system
- Transportation facilities that ensure maintenance of cold chain
- Communication facilities
- Restroom and toilet facilities

### **Hygienic fish handling in processing units**

Seafood Processing units are powerful economic drivers that has a major role in determining the domestic as well as international trade of aquatic produce. They mainly focus on value addition approaches of the fish thus improving the market value of the products. Following hygienic practices in these units will ensure improved fish quality which in turn is critical to increase marketing opportunities.

- Appropriate design and layout comprising sufficient working space under adequate hygienic conditions, an area for machinery, equipment and storage, separation of operations preventing cross-contamination, adequate natural or artificial lighting, ventilation and protection against pests.
- All food contact surfaces shall be smooth, durable, non-absorbent type, easy to maintain and clean and non-toxic.

- Availability of uninterrupted supply of portable water throughout for all processing operations.
- Availability of suitable facilities for temperature, humidity and other controls.
- All pre-processing and processing activities should be scheduled under HACCP system with proper documentation.
- Regular monitoring of processing unit for plant sanitation with an in-house laboratory and an in-process product quality check.
- Effective maintenance and sanitation systems including cleaning and sanitation procedures, pest control systems, waste management and monitoring effectiveness.
- All fish handlers should follow the recommended hygienic handling practices such as periodic medical examinations, regular cleaning and disinfection procedures prior and post to processing activities.

Strictly following these simple but important hygienic practices can definitely ensure high quality and safe fish to the consumers.

### **Low temperature preservation**

Proper preservation of fish assumes greater importance so that this nutritious source is delivered in prime quality to the seafood consumers. Among the various preservation methods available, low temperature preservation viz., chilling as well as freezing has attracted interest of many researchers on account of its minimal changes in the texture and other characteristics of fish upon proper processing and storage.

### **Chilling**

Shelf stability of fish is very important for ascertaining its availability to a wide range of customers across the globe. This can be assured only by proper handling and preservation techniques. Among the various preservation techniques, chilling assures effectiveness in delaying bacterial growth and prolong the shelf life of fish. Although chilling is effective in delaying the spoilage, it will not inhibit the spoilage completely as the enzymes and bacteria will be active at the chilled temperature. The objective of chilling is to cool the fish as quickly as possible to as low a temperature as possible without freezing. The storage life of chilled fish in different forms of ice like flake ice, slurry ice, ozone-slurry ice range from almost 4 to 20 days depending on the species. Studies have indicated that for every 10<sup>0</sup>C reduction in temperature,

the rate of deterioration decreases by a factor of 2-3. Hence higher and faster rate of temperature reduction upon capture assures better and prolonged stability of the seafoods.

The most common and cheapest means of chilling seafood is icing. Other means of chilling include: Air chilling; Use of alternative methods like chilled water viz., Refrigerated sea water (RSW), Chilled sea water (CSW), Chilled fresh water (CFW); Chilling of fish by dry ice (solid carbon dioxide), liquid nitrogen, cold ammonia or other refrigerants, etc. Chilling is a relatively short-term means of preservation when compared to other techniques like freezing, canning, salting or drying etc.

Icing is widely employed for chilled storage of marine as well as fresh water fishes as well as shell fishes. Fishes are kept in a chill store in insulated boxes with proper icing prior to pre-processing. The major advantage of using ice for chilling the fish is its high latent heat of fusion which facilitates the removal of large amount of heat from the object to be cooled. During transition from ice to water, 1 kg of ice absorbs 80 kcal of heat and this will be sufficient to cool about 3 kg of fish from ambient temperature of 30°C to 0°C. Hence theoretically about 30% of ice is needed to bring down the temperature from ambient conditions to 0°C. However, ice is needed to maintain the temperature as well as to accommodate the heat from the environment and hence in tropical conditions, a 1: 1 fish to ice ratio is ideal for ice storage. Icing of fish is very easy as it does not involve sophistication or high level of skill. Further it's easy availability is an added advantage. However, due to lack of knowledge icing is not properly practiced during fish handling and preservation. The proper use of ice can substantially reduce post-harvest losses and improve the quality of fish. In general, icing of fish is done in three stages during the post-harvest supply chain: on board fishing vessel immediately after harvest; after landing in the landing centre or before transportation; during retail sale. For icing to be effective, standard protocols like use of good quality ice, cleaning, dressing and sorting of fish for icing, proper layering of ice and fish etc. should be ensured.

Ice is available in several forms such as blocks, plates, tubes, shells, soft, chip and flakes. To ensure maximum contact of ice with the fish, proper selection of the size of ice particles and good stowage practices are needed. Flake ice is the most popular form of ice for industrial use because of its cooling efficiency. It is also relatively dry and will not stick together to form clumps when stored. Cooling capacity is more for flake ice due to a large surface area for heat

exchange. On being smaller in size and less thickness with smooth edges, it also causes minimum damage to the flesh.

### **Shelf life of iced fish**

Shelf life of food is defined as the maximum length of time a given product is fit for human consumption. It is the time period during which the food can be stored and displayed whilst still maintaining an acceptable quality or specific functionality. For fish, shelf life is the time from when it is taken from the water until it is no longer fit to eat. Shelf life of chill stored fish range from 4 to 20 days. The stability of fish is dependent on various intrinsic as well as extrinsic factors. Various research carried out in this aspect has derived a few general observations which reports that in ice storage:

- Non-fatty fishes can be kept longer than fatty fishes
- White fleshed fishes can be kept longer than dark fleshed fishes
- Freshwater fishes can be kept longer than marine fishes
- Tropical fishes can be kept longer than temperate fishes
- Smaller species can be kept longer than big fishes
- Flat fishes can be kept longer than round fishes
- Thick skinned fishes can be kept longer than thin skinned fishes

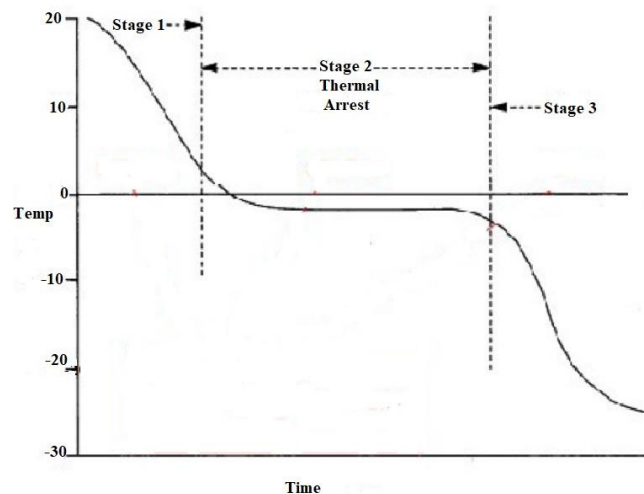
### **Quality Changes in fish during the chilling/icing**

- *Weight loss:* The fish chilled with ice shows gradual weight loss upon storage. Losses which occur in iced fish are largely or entirely due to formation of free liquid drip. This is on account of quality changes viz., protein denaturation associated with the chilling and associated storage. Drip water carries with it a considerable percentage of soluble proteins, salts, other flavouring and nutritive components of the fish.
- *Discolouration:* Improper icing/chilling results in bruising, damage and consequent discolouration of flesh. Improper and delayed gutting of fish facilitate the powerful digestive enzymes to attack the viscera and belly walls resulting in belly burn or disruption at iced temperature which also cause discolouration. It is well known that pelagic fishes with filled digestive tract may develop torn or burst bellies well before the signs of spoilage sets in.

- *Rancidity*: In case of fatty fishes, even at low temperature of 0 to 2°C, rancidity may develop on account of fat oxidation and the rancid flavour becomes a limiting factor affecting its keeping quality during storage.
- *Shrinkage*: Shrinkage is a common phenomenon in fish packed with ice, particularly in the upper layers. The shrinkage in lean fishes are higher than that of fatty fishes as the subcutaneous layer of fat serves to reduce the evaporation of tissue moisture.
- *Weight gain*: Fish stored in refrigerated and chilled seawater exhibits the tendency to gain weight and uptake salt thereby limiting the application of this chilling system in seafoods.

### **Freezing**

Low temperature preservation like freezing is the best method to retain the quality and freshness of fish and fish products for a long time. Freezing reduces the spoilage activity and extends the shelf life of the product. It represents the main method of processing fish for human consumption, and it accounted for 55.2% of total processed fish for human consumption and 25.3% of total fish production. Freezing involves the cooling down of food materials from ambient temperature conditions to a temperature below the freezing point. Generally, the freezing process has three stages; first stage (pre-freezing stage) corresponds to removal of heat from the food, when the temperature is reduced from ambient to freezing point. The second stage which is the freezing stage, is the period of transformation of water to ice through the whole mass of food. The second stage is also referred to as the zone of maximum crystallization. Between the first and second stages there is a transitory super cooling period when the temperature falls below the freezing point which is not observed in all cases. In the third stage nearly 75% of the water in the muscle turns into ice which leads to further rapid drop in temperature, as the thermal diffusivity of ice being much higher than water.



### Freezing Curve of fish

As the water in fish freezes out as pure crystals of ice, the remaining unfrozen water contains higher concentration of salts and other compounds which are naturally present in the fish muscle. The increasing concentration of the salts will depress the freezing point of the unfrozen water. Hence unlike pure water, conversion to ice will not occur at  $0^{\circ}\text{C}$  but proceeds over a range of temperature. Thus, even at  $-30^{\circ}\text{C}$ , a portion of water in the fish muscle will remain in unfrozen state. Slow freezing produce ice crystals of comparatively larger size and few in numbers which may cause rupture of the cell walls and result in fluid loss and textural changes on defrosting. In contrast fast or quick freezing produce large number of small and uniform crystals, thus reducing the possibility of shrinkage or rupture.

The drip loss on thawing of fish occurs mainly due to denaturation of protein during freezing which result in the loss of water binding capacity of the protein. The optimum range of temperature for denaturation is  $-1^{\circ}\text{C}$  to  $-2^{\circ}\text{C}$ ; thus, in order to reduce the thaw drip to minimum, the time spent in this temperature zone should be minimum. If the temperature of fish/fishery product is reduced from  $0^{\circ}\text{C}$  to  $-5^{\circ}\text{C}$  in 2 hours or less, then it can be termed as a quick frozen product. During freezing process, the temperature of the fish should be lowered to  $-30^{\circ}\text{C}$  such that the thermal centre of the fish attains  $-20^{\circ}\text{C}$  prior to its removal from the freezer. The time taken to lower the temperature of the thermal centre to  $-20^{\circ}\text{C}$  is termed as the freezing time. Based on this, most of the commercial freezers operate at temperatures of  $-35^{\circ}\text{C}$  to  $-40^{\circ}\text{C}$ . The major factors which affect freezing time include: Freezer type, Freezer operating temperature, Refrigeration system and operating condition, Air velocity in an air blast freezer, Product



temperature, Product thickness, Product shape, Product contact area and density, Product packing, Species of fish

### **Freezing systems**

Freezing techniques have evolved with different modes of operation and the first man made freezing system was reported to be freezing using ice-salt mixture; followed by the developments in mechanical refrigeration. Mechanical refrigeration can broadly be classified into two: direct and indirect system wherein the direct system, the refrigerant absorbs heat directly from the material to be cooled while in indirect/ brine system, the refrigerant absorbs the heat that brine absorbs from the material to be cooled.

Based on this mode of operation, they are further classified as:

- *Freezing in Air*
- *Indirect contact freezing*
- *Spray or Immersion freezing*
- *Cryogenic freezing*

### **Air freezing**

Seafoods can be frozen in air at temperatures ranging from  $-18^{\circ}$  to  $-40^{\circ}$  C.

#### *Sharp Freezing*

Sharp freezers are cold storage rooms especially constructed to operate at and maintain low temperatures. Freezing time generally ranges from 3-72 hours or more depending on the conditions and the size of product. In this method, the product to be frozen is placed in a very cold room, maintained at temperatures in the range of  $-15^{\circ}\text{C}$  to  $-30^{\circ}\text{C}$ . In this system, the air within the room will circulate by convection, with little or no provision for forced convection. Hence foods placed at these low temperatures are frozen comparatively slow, taking several hours or even days for complete freezing.

#### *Air blast freezing*

In an air blast freezer, fish is frozen by circulation of a stream of high velocity cold air either in a batch or continuously, typically in a duct or tunnel at  $-18$  to  $-34^{\circ}\text{C}$  or lower, moving counter current to the product at a speed of 1-20 meter/sec.

*Continuous air blast freezers/tunnel freezers:* In this type of air blast freezer, the fish are conveyed through the freezer (trolleys or they may be loaded on a continuously moving belt or conveyor) usually entering at one and leaving at the other.

*Batch air blast freezers:* Batch air blast freezers use pallets, trolleys or shelf arrangements for loading the product. The freezer is fully loaded, and when freezing is complete, the freezer is emptied and reloaded for a further batch freeze.

Air blast freezing is economical and is capable of accommodating products of different sizes and shapes. However, it can result in excessive dehydration of unpackaged products if conditions are not carefully controlled, as well as undesirable bulging of packaged products which are not confined between flat rigid plates during freezing.

Modern designs of belt freezers are mostly based on the spiral belt freezer concept. In these freezers, a conveyor belt that can be bent laterally is used. The design consists of a self-staking and self-enclosing continuous belt for compactness and improved air flow control. The number of tiers in the belt stack can be varied to accommodate different capacities and line layouts. The products are placed on the belt outside the freezer where it can be supervised. Both packed as well as unpacked products are frozen and the freezer gives a large flexibility both with regard to product and freezing time. Both horizontal and vertical air flow can be applied and the latter is observed to be more efficient.

Fluidized bed freezing is a version of air blast freezing wherein marine products like small sized prawns, uniform sized fillets etc. can be frozen by passing through meshed belts where they are fluidized by a stream of forced cold air moving upward through the bed at a rate sufficient to partially lift or suspend the particles. Freezing by this method is rapid and a minimum air velocity of 2 meter/sec. or more is necessary to fluidize the particles and an air temperature of - 35°C is common. The bed depth depends on ease of fluidization and this in turn depends on size, shape and uniformity of the particles. A bed depth of slightly more than 3 cm is suitable for small prawns where as a depth of 20 to 25 cm can be used for non-fluidizable products such as fillets. Fluidized bed freezing has proven successful for many kinds and sizes of food products. The best results are obtained with products that are relatively small and uniform in size. Some fluidized-bed freezers involve a two stage freezing technique wherein the first stage consists of an ordinary air-blast freezing to set the surface of the product and the second stage consists of fluidized bed freezing. The advantages of fluidized bed freezing include more efficient heat transfer and more rapid rates of freezing and less product dehydration and less frequent defrosting of the equipment. Dehydration losses of about 1% have been reported during fluidized bed freezing of prawns. The short freezing time is apparently responsible for the small loss of

moisture. The major disadvantage of fluidized-bed freezing is that large or non-uniform products cannot be fluidized at reasonable air velocities.

### **Contact Plate Freezing**

Plate freezers consist of a vertical or horizontal stack of hollow plates, through which refrigerant is pumped at - 40° C. Fish products can be frozen by placing them in contact with these metal plate surface cooled by expanding refrigerants. This equipment consists of a stack of horizontal or vertical cold plates with intervening spaces to accommodate single layers of packaged product. The filled unit appears like a multi layered sandwich containing cold plates and products in alternating layers. When closed, the plates make firm contact with the two major surfaces of the packages, thereby facilitating heat transfer and assuring that the major surfaces of the packages do not bulge during freezing. Vertical plate freezers are also in use especially onboard fishing vessels. In this method the packages must be of uniform thickness. A packaged product of 3 to 4 cm thickness can be frozen in one to two hours when cooled by plates at -35°C. Freezing times are extended considerably when the package contains a significant volume of void spaces. Double contact plate freezers are commonly used for freezing foods in retail packages. This equipment may be batch, semi-automatic or automatic. Advantages of this type of equipment include good economy and space utilization, relatively low operating costs compared with other methods, little dehydration of the product and therefore minimum defrosting of condensers, and high rates of heat transfer.

### **Spray or Immersion freezing**

Immersion freezing is a method of commercially preparing frozen foods so that the product remains suitable for consumption over a long period of time. The process helps to lock in moisture as well as maintain the flavour and taste of the processed food. Liquid immersion freezing or direct immersion freezing is accomplished when a product is frozen by immersing or by spraying with a freezant that remains liquid throughout the process. Liquid immersion freezing can result in moderately rapid freezing. Freezants used for liquid immersion freezing should be non-toxic, inexpensive, stable, reasonably inert, and should have a low viscosity, low vapour pressure and freezing point and reasonably high values for thermal conductivity. Freezants should have a low tendency to penetrate the product, little or no undesirable effects on organoleptic properties and require little effort to maintain desired standards for sanitation and composition. Aqueous solutions of propylene glycol, glycerol, sodium chloride, calcium

chloride and mixtures of sugars and salt have been used as freezant. The major advantages of liquid immersion freezing are rapid heat transfer, lower operating and investment costs and easy adaptability to continuous operations. Quick freezing preserves the texture of tissues more successfully and causes less dehydration during the freezing process. However, it is difficult to derive freezants with suitable properties.

### **Cryogenic Freezing**

Cryogenic freezing refers to very rapid freezing by exposing food products to an extremely cold freezant undergoing change of state. The fact that heat removal is accomplished during a change of state by the freezant is used to distinguish cryogenic freezing from liquid immersion freezing. The most common food grade cryogenic freezants are boiling nitrogen and boiling or subliming carbon dioxide. The rate of freezing obtained with cryogenic methods is much greater than that obtained with conventional air-blast freezing or plate freezing, but is only moderately greater than that obtained with fluidized bed or liquid immersion freezing. Currently liquid nitrogen is used in most of the cryogenic food freezers. Usually, liquid nitrogen is sprayed or dribbled on the product or alternatively very cold gaseous nitrogen is brought into contact with the product. Freezing with carbon dioxide as well as using freon are all other means employed. Carbon dioxide is absorbed or entrained by the product in this method. This entrapped CO<sub>2</sub> should be removed before it is packaged in an impervious material. Further use of refrigerants like freon, though economic is being withdrawn by the industry on account of the concerns with regard to its role in ozone depletion.

Advantages of cryogenic freezing include: improved baseline production rates by reducing the amount of time required to remove heat from a product; marked increase in product yield due to less product dehydration; improved product safety and minimum product degradation due to the short freezing time; better texture retention due to formation of smaller internal ice crystals; low labour costs through reduced product handling and quicker cleanup and consistent production rates.

Crusto Freezing is a combination of cryogenic freezing system and air blast freezing system. The equipment utilizes the possibility of a fast and efficient crust freezing of extremely wet, sticky products which can then be easily handled in a spiral belt freezer or a fluidized bed freezer without deformation or breakage.

### **Quality changes during freezing and frozen storage**

The quality of frozen-thawed cooked fish is influenced by a number of factors including species, composition, size, harvesting conditions, elapsed time between harvest and freezing, the state of rigor and quality when frozen and the details of freezing process and frozen storage. The major problems encountered during the freeze-processing of fish are oxidative deterioration, dehydration, toughening, loss of juiciness, and excessive drip. Effective pre freezing and freezing techniques are available for controlling many of these problems. Reasonable control of toughening and loss of juiciness can be accomplished by storing fish for a minimal time and / or at temperatures at -18°C or lower. Undesirable oxidative changes in fish can be minimized by (1) eliminating oxygen (2) avoiding contamination with heavy metals (oxidative catalysts) (3) adding antioxidants and (4) by using low storage temperature. Dehydration can be avoided by applying glaze and suitable protective coatings.

Cooling seafoods is among the most effective methods for preserving their quality. From a choice refrigerants, it can be chilling which facilitates short term preservation to freezing at sub-zero temperatures leading to extended storage life for months and even years, depending on temperature employed. Application of these preservation techniques with standard operating protocols can ensure superior quality seafoods to the customers.

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