2. HYGIENIC HANDLING OF SEAFOODS AND LOW TEMPERATURE PRESERVATION

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Seafood plays a major role in human nutrition. Fish and shellfish form an important part of the human diet, both of the poor and of the wealthy. Good quality fish is an extremely safe food. The primary objective of seafood handling techniques is to preserve the quality of fish. However, factors such as delay in handling the catch, poor control of fish temperature, poor standards of gutting are often deleterious on the quality of fish and results in reduction of shelf life and loss of weight. Maintaining the quality of fish begins with harvest and transport of the fish products. Since fish is a highly perishable item of food, it is to be immediately processed to various products to preserve the quality and to increase the shelf life. Fish requires proper handling and preservation to increase its shelf life and retain its quality and nutritional attributes.

Handling of seafood

The earliest practice of fish handling in many parts of the world to avoid spoilage and loss of quality is to keep caught fish alive until cooking and consumption, particularly in China where live carp trade has been practiced for more than three thousand years. Till date, this remains to be one of the common fish-handling practices. A large number of fish species are usually kept alive in holding basins, floating cages, wells and fish yards. Holding basins, normally associated with fish culture companies, can be equipped with oxygen control, water filtering and circulation and temperature control. Simpler methods are also used viz., keeping fish in floating cages in rivers or simple fish yards constructed in backwaters. Also, the transportation of live fish ranges from very sophisticated systems installed on trucks that regulate temperature, filter and recycle water and add oxygen, to very simple artisanal systems of transporting fish in plastic bags with an atmosphere supersaturated with oxygen.

For harvested fish, the general handling operations after capture are: Transferring catch from gear to vessel, holding of catch before handling, sorting/grading, Bleeding/gutting/washing, Chilling, Chilled storage and unloading. These operations range from manual methods to fully automated operations. The number of operations and the order in which they are performed depend on the fish species, the gear used, vessel size, duration of the voyage and the market to be supplied. It is crucial to provide a continuous flow in handling and to avoid any accumulation of unchilled fish, thereby bringing the important time-temperature phase under complete control. Icing is the oldest method of preserving fish freshness by chilling and it is widely used. Mechanical refrigeration makes ice readily and cheaply available. In addition, ice keeps fish moist, has a large cooling capacity, is safe, and is a portable cooling method that can be easily stored, transported and used by distributing it uniformly around fish. Block ice is used in crushed form to chill fish. The use of ice at various stages of handling and processing require suitable insulated containers. These containers are designed and constructed locally, using natural or artificial insulating materials, with enough handling flexibility.

The most important factors to be considered in the initial handling and transport are the temperature, duration of storage/transport and the hygiene in all respects including that of the handlers. The important requirements are cleaning the fish from dirt and debris, chilling it immediately to prevent its temperature from rising and maintaining high standards of cleanliness at all stages. Fish, which has struggled for long in the net or onboard, is likely to spoil more quickly than a fish, which dies instantaneously or is killed quickly. Similarly fish with its stomach full while catching, will spoil more quickly and fish, which is bruised while catching or handling, will spoil more quickly than a physically sound fish.

Washing and sorting of fish

The harvested fish should be washed well with potable water to free it from dirt and other extraneous matter. Water chlorinated at 10 ppm level is ideal for initial cleaning. Most of the surface bacterial load is cleared by washing. In some freshwater species viz., eel carp and trout, slime constitutes 2-3% of the body weight(Venugopal,2006a) The excretion of slime which stops before rigor, creates a perfect environment for bacterial growth. Hence the carcass has to be thoroughly washed to remove slime. After washing the catch should be sorted species – wise and size – wise. Bruised, damaged and decomposed fish shall be separated from the catch during sorting.

Dressing

It is desirable to avoid the struggling of large fish by instant killing. The more the fish struggles, the faster will be the fall of pH after death. A pH of 6.0 encourages protein denaturation of muscle during frozen storage (Robb, 2001). The dressing operations of the catch include heading, bleeding and gutting have to be carried out as fast as possible without significant bacterial contamination. Gills and viscera harbour several spoilage bacteria in large numbers. Partially digested food in the viscera may become sour or putrid due to bacterial action. The powerful digestive enzymes in the viscera can bring about accelerated spoilage of fish. Therefore, wherever possible, it is advisable to remove the gills and viscera before the fish is preserved and stored. Gutting or evisceration should not cause any bruise on the exposed belly portion. Retention of any visceral parts can easily contaminate the soft belly and bruises can cause accelerated spoilage by permitting easy penetration of bacteria. The fish should be washed thoroughly after each operation. The larger fish are gutted by hand, washed and iced. Gutting helps to remove digestive enzymes and foul smelling compounds associated with gut. It also prevents accumulation of bloodstains and control haemoglobin catalyzed lipid oxidation in the fillets (Hultin, 1992).

The blood in the fish can clot and turn black or brown in colour adversely affecting the colour and appearance of the meat. Therefore bleeding is done to preserve the quality of the meat. Bleeding and evisceration can be done only to fish of reasonably large size. Slitting the throat followed by hanging the fish by tail or slitting the throat and immersing in cold water are the methods for bleeding.

Hygiene Requirement for Equipment on Fishing Boats

- ✓ Conduct thorough, regular cleaning of the boat and equipment to prevent bacterial build up.
- ✓ Cleaning with clean water and detergent should be done just before and immediately after each fishing trip.
- ✓ All equipment used for handling should be constructed from smooth, easy to clean materials
- ✓ Clean all equipment and fishing gear thoroughly after each operation
- ✓ Allow to dry in the sun and store in clean and dry place

Good handling practices on fishing boats

It is advisable for the fisher-folk to carefully handle their fish products on canoe/boat during transport. This will allow the fisher-folk to maintain high quality of the fish product. There are several factors affecting fish handling on canoe/boat, mostly the biological, chemical and physical factors that cause degradation of fish products. The surfaces of dead fish are ideal growth habitats for bacteria contributing to the spoilage process. Hence, it is important for the fisher-folk to control the temperature of fish. Bacteria growth implicates chemical breakdown due to oxidative and enzymatic reactions leading to off odour; flavor and rancidity. Good handling practices on fishing boats are listed below;

- ✓ Clean seawater should be used to clean boats and equipment.
- ✓ Do not use water that may be contaminated with sewage;
- ✓ Ensure that all fishers maintain a high standard of personal hygiene;

- ✓ Hands and other exposed body parts should be thoroughly washed before handling the catch;
- ✓ Cover cuts and wounds with waterproof plasters;
- ✓ Wash hands with soap and clean water after going to the toilet;
- ✓ Do not cough or sneeze on seafood or ice;
- ✓ Use only good quality ice, made of potable water by an approved supplier
- ✓ Always store ice in clean containers.
- ✓ Avoid large and sharp-edged pieces of ice which can damage the fish;
- ✓ Ice the fish immediately after capture
- ✓ Use at least 1kg of ice to preserve 1 kg of seafood;
- ✓ Ice and seafood should be placed in layers in an insulated container;
- ✓ Ensure proper drainage of melted ice water from boxes;
- ✓ Sort the catch as early as possible in order to protect seafood on the fishing boat from sun and wind.
- ✓ Fish caught at different time, have to be kept apart since they will be at different stage of spoilage
- ✓ Small fishes have to be kept separate from large fishes, as they tend to spoil more rapidly than the latter
- ✓ Soft-bellied fishes are to be kept separately, if the guts are being removed or the belly has burst, the body cavity has to be washed to remove any traces of the gut.

Hygiene requirements for landing sites

- ✓ Landing sites should be washed with safe water and detergents at least once a day;
- ✓ Waste products should be stored in covered containers and disposed of hygienically;
- ✓ Seafood contact surfaces should be free of all type of contaminants like oil, grease, etc;
- ✓ Cutting, cleaning and processing seafood should be done in areas designed for that purpose;
- ✓ Seafood should be stored with ice in clean plastic containers to reduce spoilage and contamination;
- ✓ Landing sites should be fenced and unauthorized access forbidden;
- ✓ Clean and safe water must be available for cleaning the site and equipment;
- ✓ Hand washing facilities, clean water and soap should be present;

Handling of seafood at Landing Sites

- ✓ All boat workers who handle the fish at the landing site should practise good personal hygiene;
- ✓ Persons suffering from contagious diseases should not enter the landing site
- ✓ Chilling should be commenced as soon as possible;
- ✓ Handling should not cause physical damage;
- ✓ Handlers should avoid eating, drinking, using tobacco, chewing gum in production areas, and sneezing and coughing over unprotected food;
- ✓ Seafood handlers should wash and sanitize their hands at the start of food handling activities and immediately after using the toilet;
- ✓ Before handling any seafood, wristwatches, necklaces, rings or other jewellery should be removed. This will reduce the potential for physical contamination.

Hygiene Requirements for seafood during Transport

- ✓ Seafood storage rooms containers / compartments must be designed to avoid contamination of fish and spoilage
- ✓ Containers / compartments must be insulated, and lined with strong, smooth, easy to clean materials;
- ✓ Storage containers / compartments must be closable to keep the seafood at a low temperature during transport;
- ✓ The weight of ice should be equal to the weight of seafood being transported;
- ✓ Seafood should be handled carefully to avoid being damaged;
- ✓ Transporters should be washed with clean water and approved detergents;
- ✓ Transporters must only be used for the transport of fish;
- ✓ Seafood temperatures should be recorded at the start, during, and at the end of transport.

Good fish processing practices: Good fish processing practices refers to appropriate skills and knowledge being used by the fisher-folk and fish processors in processing fish products after harvesting. Hence good fish processing ensure a higher quality fish products. The required condition for good fish processing includes the followings:

- ✓ Fish should be washed in clean water thoroughly to remove blood, slime and scales;
- ✓ Fish are sorted/graded accordingly, large fish are separated from small fish;
- ✓ Fish processing should be done in a proper place where there is no chance for bacteria growth;
- ✓ Equipment and utensils used for fish processing should be kept clean in good condition;

- ✓ Waste fish products should be kept in a closed place that does not allow flies, rats and other pests to breed and be a nuisance;
- ✓ Any waste products from processing must be disposed of in way which does not harm the environment either the water or land;
- ✓ Finished products must be packaged and handled in a careful way to avoid contamination and so they remain safe to eat

Good practices in fish processing area: Specific procedures must be followed to minimize the risk of such hazards causing illness to consumers:

- ✓ The processing area should be closed: have a compound wall and gate to prevent the entry of wandering animals to the premises;
- ✓ Clean the processing area regularly to ensure that there is no rubbish lying around attracting flies, rats and other pests;
- ✓ Use clean equipment and utensils at the fish processing area;
- ✓ The processing area should have a separate washing facility for utensil ;
- ✓ Floor and walls of the peeling shed should be tiled to enable easy washing;
- ✓ The processing area should have a raised receiving area for the unloading of fish products;
- ✓ Make sure that there are good toilet facilities and these are kept clean;
- ✓ Ensure that there are no trees or vegetation near the processing place as these are good places for insects and vermin to live

Low temperature preservation

Low temperature preservation is the best method to retain the quality and freshness of fish and fish products for a long time. Among them, chill storage i.e., keeping the fish in the unfrozen condition has only limited shelf life and it will vary between 4 and 20 days depending on the condition and species of fish. In frozen storage also the shelf life is restricted but it varies from few weeks to years. The various factors that affect the frozen storage shelf lives are condition of fish at the time of catch, handling, processing and product development, packaging and glazing of the product, freezing method adopted, frozen storage temperature, stacking methods and transportation techniques. These factors can be put together and can be termed as ‘Product, Processing and Packaging’ (PPP) and ‘Time Temperature Tolerance’ factors (TTT).

Chilling

Chilling is an effective way of reducing spoilage in fish if it is done quickly and if the fish are kept chilled and handled carefully and hygienically. Immediate chilling of fish ensures high quality products(Connel, 1995: Huss, 1995) .For every 10 ^{0}C reduction in temperature, the rate of deterioration decreases by a factor of 2-3 (Hardy,1986) . The objective of chilling is to cool the fish as quickly as possible to as low a temperature as possible without freezing. Chilling cannot prevent the spoilage together but in general, the colder the fish, the greater the reduction in bacterial and enzyme activity.

The important chilling methods of fish and fish products at non-freezing temperature are:

- Iced storage.
- Chilled seawater (CSW) storage.
- Chilled freshwater (CFW) storage.
- Mechanically Refrigerated seawater (RSW) storage.
- Cold air storage.

The most common means of chilling is by the use of ice. Although ice can preserve fish for some time, it is still a relatively short-term means of preservation when compared to freezing, canning, salting or drying, for instance. When used properly it can keep fish fresh so that it is attractive in the market place.

Ice is available in several forms such as blocks, plates, tubes, shells, soft and flakes . Of these, flake ice is the most popular form 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. It also cause minimum damage to the flesh To ensure maximum contact of ice with the fish, proper selection of the size of ice particles and good stowage practices are needed. The rate of chilling is governed by:

- The size, shape and thickness of fish;
- The method of stowage;
- Adequate mixing of ice, water and fish (in ice slurries);
- Adequate contact of ice with the fish;
- The size of the ice particles.

Icing is widely employed for chilled storage of freshwater fish in the country. The dressed and cleaned fish is kept in a chill store in insulated boxes with proper icing prior to preprocessing. The major advantage of using ice for chilling the fish is that it has a high latent heat of fusion so that it is capable of removing large amount of heat as it melts without changing the temperature at 0 ^{O}C. During transition from ice to water 1 kg of ice absorbs 80 k cal of heat and this will be sufficient to cool about 3 kg of fish from 30 ^{O}C to 0 ^{O}C. Hence theoretically about 30 % of ice is needed to bring down the temperature from ambient conditions to 0^{o}C. However, ice is needed to maintain the temperature as well as to accommodate the heat from the environment. Hence in tropical conditions a 1: 1 fish to ice ratio is ideal for ice storage. Fish of the same size and species are placed in the same boxes. It is always recommended to add about 12-20% extra ice to the fish in order to compensate for water loss from melting and bad handling (Zugarramurdi, *et. al,*1995)

Freezing

Freezing Characteristics

The water present in fish products are converted to ice during freezing i.e., a change from the liquid phase to the solid phase. The change of water from liquid to solid phase results in increase in volume and a consequent decrease in density, increase in thermal conductivity and thermal diffusivity, and decrease in heat capacity. The volume increase on freezing of water is by about 9%, thermal conductivity 4 times and thermal diffusivity 11 times. Heat capacity is found to reduce from one cal/g to 0.5 cal/g. A proportional change in these properties may also observed in food products.

Freezing Curve for Pure Water

The freezing curve of pure water is given in Fig. 1. During the early stages of cooling i.e. cooling from ambient temperature to 0°C (T1 to T2) the sensible heat amounting to 1cal/g° C is removed. Point S represents super cooling. Super cooling is needed to remove sufficient quantity of heat so as to get stable ice nuclei for crystal growth. On crystallization of ice at S the heat of crystallization is released and the temperature of the system rises to 0°C (T2) from S. The temperature remains at 0°C until all the water is converted to ice. This period is called thermal arrest period. 79.8 cal of heat must be removed for each gram of ice formed. The water-ice transformation usually involves a long period. On completion of solidification further heat removal is faster and about 0.5cal/g of heat is removed for the decrease by every 1°C.

Freezing Techniques

There are a number of methods by which fish can be frozen. It may be either sharp (slow) freezing or quick freezing. Slow freezing is accomplished by placing the product at a low temperature and allowing it to freeze slowly usually in still air. Quick freezing is accomplished in any one or in any combination of the following four methods:

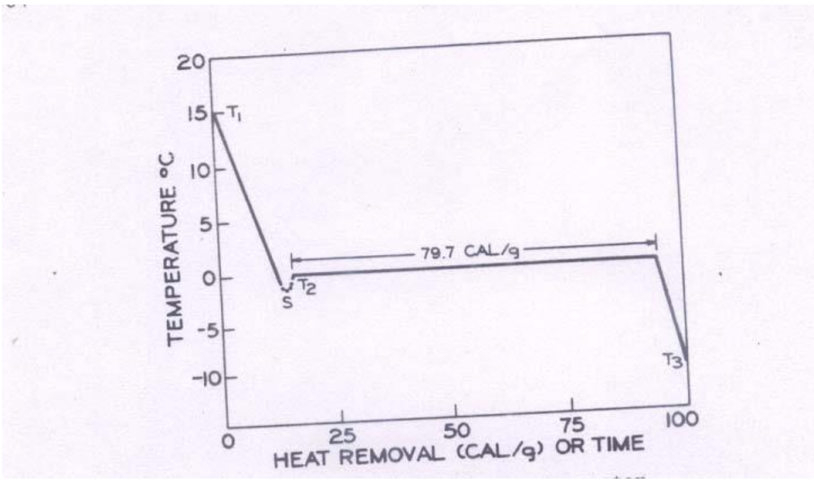


Fig.1. Freezing curve for pure water

1. Immersion freezing
2. Indirect contact freezing
3. Air blast freezing and
4. Cryogenic freezing:

Tunnel freezing

Circulating cold air at high speed enables freezing to proceed at a moderately rapid rate and this method is referred to as air-blast freezing. Air-blast freezing is usually accomplished by placing the products on a mesh belt and passing it slowly through an insulated tunnel containing air at-18 to -34°C or lower, moving counter current to the product at a speed of I to 20 meter/sec. Air at -29°C and at a speed of 10-12 meter/sec, is often satisfactory, although lower temperatures are preferred.

Spiral Belt Freezer

Modern designs of belt freezers are mostly based in the spiral belt freezer concept. In these freezers a product belt that can be bent laterally is used. The present design consists of a self staking and self-enclosing belt for compactness and improved air flow control. The number of tiers in the belt stack can be varied to accommodate different capanlies and line layouts. The belt is continuous. The products are placed on the belt outside the freezer where it can be supervised. As the belt is continuous it is easy for proper cleaning. Both unpacked and packed 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 used. Vertical airflow is more efficient.

Fluidized-Bed Freezing

Marine products of small size like prawns can be fluidized by forming a bed of prawns on a mesh belt and then forcing air upward through the bed at a rate sufficient to partially lift or suspend the particles. If the air used for fluidization is sufficiently cooled, freezing can be achieved at a rapid rate. An air velocity of at least 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. In this instance since fluidization is not involved a more proper name is "through-flow air freezing. It will take about 30-35min to bring down temperature from 30°C to –18°C for fish fillets up to 3 cm thick. Fluidized bed freezing has proven successful for many kinds and sizes of 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 as compared to air- blast freezing are (1) more efficient heat transfer and more rapid rates of freezing and (2) less product dehydration and less frequent defrosting of the equipment. Dehydration loses of about 1% have been reported during fluidized bed freezing of prawns. The short freezing time is apparently responsible for the small lose of moisture.

The major disadvantages of fluidized-bed freezing is that large or nonuniform products cannot be fluidized at reasonable air velocities.

Plate Freezing

Fish products can be frozen by placing them in contact with a metal surface cooled by expanding refrigerants. Double contact plate freezers are commonly used for freezing fish/prawn blocks. This equipment consists of a stack of horizontal 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. Contact plate freezing is an economical method that minimises problems of product dehydration, defrosting of equipment and package bulging. In this method the packages must be of uniform thickness. A packaged product of 3 to 4 cm thickness can be frozen in I to 1.5 hour when cooled by plates at -35°C. Freezing times are extended considerably when the package contains a significant volume of void spaces.

Liquid Immersion Freezing

Liquid immersion freezing or direct immersion freezing is accomplished when a product is frozen by immersion in or by spraying with a freezant that remains liquid throughout the process. This technique is occasionally used for fish and prawns. 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 values of vapour pressre and freezing point and reasonably high values for thermal conductivity. Freezants should have a low tendancy 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 solution of propylene glycol, glycerol, sodium chloride, calcium chloride and mixtures of sugars and salt have been used as freezant.

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 carbondioxide. Boiling nitrous oxide also has been considered, but at present it is not being used commercially. Boiling CCl2F2 (freon-12) does not have sufficiently low boiling point to qualify as a true cryogenic fluid, but it is included in this category since it can provide, by the change of state principle, rates of freezing comparable to those obtained commercially with true cryogenic freezants.

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 moderoately greater than that obtained with fluidized bed or liquid immersion freezing. For example, shrimp freeze in about 9 min in a commercial liquid nitrogen freezer and in about 12 min in a fluidized bed freezer.

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. None of the current commercial liquid nitrogen freezers employ the technique of direct immersion. It should be noted that the final product temperature is usually not different from that obtained during conventional methods of freezing. The following are some of the advantages of liquid nitrogen freezing.

1. Dehydration loss from the product is less than 1%.

2. Oxygen is excluded during freezing.
3. The individually frozen products undergo minimal freezing damage. Fish/prawns frozen cryogenically exhibit minimum thaw exudate and minimum damage to texture. These quality advantages are retained if the frozen storage is minimised and / or the temperature is -23°C or lower.
4. The equipment is simple, suitable for continuous flow operations, adaptable to various production rates and product sizes, or relatively low initial cost, and capable of high production rates in a minimal space.

The only disadvantage is the high operating cost and this is attributable nearly entire to the cost of liquid nitrogen.

Freezing with carbon dioxide usually involves tumbling the product in the presence of powdered or liquid carbon dioxide. This method provides most of the advantages cited for liquid nitrogen freezing. Carbon dioxide is absorbed or entrained by the product in this method. This entrapped CO2 should be removed before it is packaged in an impervious material.

In freon -12 as cryogenic freezant the material is placed on stainless steel mesh belt and conveyed through an insulated freezing chamber. Freezing is accomplished either by spraying the product with food grade CCI2F2 or by a combination of initial immersion of the product followed by spraying. In both procedures vapours are collected for reuse. Advantages for freezing in liquid freon-12 are essentially the same as those cited for liquid nitrogen. This method has an advantage of lower operating costs.

Crusto Freezer

This 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 fludized bed freezer without deformation or breakage.

Chilling versus freezing of fish

There are many factors to be taken into account when considering the differences between chilling and freezing of fish products for various markets. Both chilling and freezing operations can produce stable products and the choice of one or the other depends on many factors.

Advantages and disadvantages of chilling and freezing *

Chilling	Freezing

Short-term storage (up to one month maximum for some species, only a few days for others)	Long-term storage (a year or more for some species)
Storage temperature 0 °C	Storage temperature well below zero, e.g. -30 °C
Relatively cheap	Relatively costly
Product resembles fresh fish	If poorly done can badly affect quality
Relatively low-tech	Relatively high tech
Low skills required	High skills required
Portable refrigeration	Generally static operations

QUALITY DEFECT IN CHILLED AND FROZEN PRODUCTS

Quality changes during chilled storage

Belly bursting

Enzymatic spoilage causes belly bursting of fish, especially during a period of high food intake. These fish will have large content of digestive enzymes in digestive tract. Such fish will degrade quickly & spoil easily soon after caught. In the dissolved gut components, bacteria proliferate and produces gases such as Co2 & H2. This gas production leads to belly bursting after short storage period.

Gaping of fillet

Phenomenon observed in fish which are well fed at the time of capture and are frozen before or during rigor is called gaping. Gaping of fillet occur due to weakening of the connective tissues which bind together the muscle segments in the fish flesh.

Pink / Yellow discolouration in squid and cuttle fish

Pigment released from the disrupted chromatophores localized in the skin most likely stains the mantle during the handling or storage. Insufficient ice as well as under the stacking condition

Black discolouration

Black discolouration in shrimp lobster etc. occurs when stored fresh. Bruises and rough handling increase the occurrence of this discolouration, which is caused by polyphenolase enzyme, acting on polyphenolic compounds of aminoacids like Tyrosine and

Phenylalanine. Sulphite preservatives are used to prevent black discolouration. Shrimps are dipped in 0.2-0.5 % sodium bisulphite for one minute

Quality changes during frozen storage

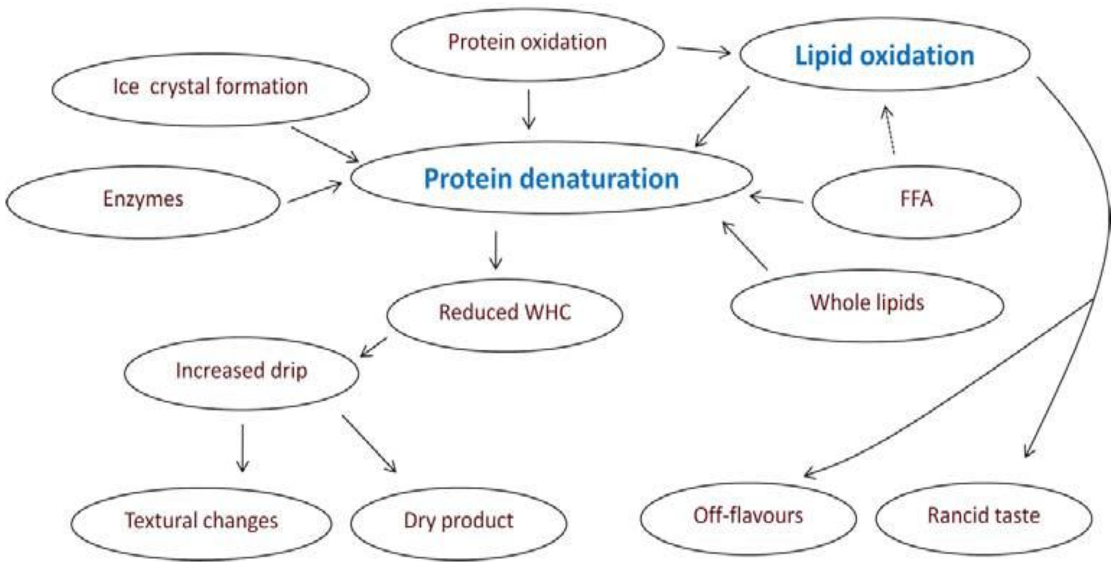
Physical changes The physical changes which occur during freezing and storage of frozen products comprise crystallization of ice with expansion of the volume, and desiccation starting from the surface of the frozen fish.

Ice formation

The crystallization of ice is initiated when the temperature of the fish is lowered about -1°C. At the same time, concentration of various inorganic salts and organic components present in

the fluid of the fish occurs and consequently, the freezing point falls. There is also an increase in the volume of the fish when the water is converted to ice. The larger part of the water consequently freezes between -1°C to -5°C and it is the rate of cooling and this temperature interval determines the size of the ice crystals. It is well known that slow freezing results in the formation of large ice crystals. These may cause the tissue of the fish to become so porous and perforation of the tissue can often be seen after the fish is thawed. It may even become even spongy. Rapid freezing on the other hand, results in small ice crystals, and the quality of quick frozen fish may be practically equivalent to that of fresh unfrozen fish.

Physical and chemical changes during frozen storage



Freezer burn/Desication

Freezer burn is a condition that occurs when frozen food has been damaged by dehydration and oxidation, due to air reaching the food. Change in fluctuation in storage temperature influences the desiccation, loss of weight and quality of the fish contributes to a poor appearance or results in “freezer burn”. If the desiccation is pronounced, the fish surface may become dry and fibrous. In some cases the skin may change the colour, several other factors influence the loss are, the kind of wrapping, it’s sealing and moisture transmission characteristics.

Discolouration

When frozen fish is in contact with air, oxidation of fat or oil in the fish takes place and these results in “rusting” or discolouration of the flesh and development of rancid odours and flavours.

Green/Brown discolouration

Frozen tuna and sword fish may exhibit green and brown discolouration. Uncooked fish meat contains three derivatives of myoglobin. The pigment responsible for the pink colour in normal cooked meat of tuna is hemochrome, derived from the reaction of myoglobin with non-heme constituents. Greening is due to pigments resulting from the oxidation of hemechrome that occurs when the meat is unduly exposed to oxidative condition during and after cooking. Greening of frozen sword fish may be related to up take of H2S produced by putrefactive bacteria. Proper evisceration and removal of blood immediately after the catch reduce the risk of discolouration.The undesirable discolouration in yellow fin tuna meat can be averted , if the fish is frozen at full rigor,stored at a temperature of -23°C to -27°C,and defrosted by still air at 10°C.

Yellow discolouration

Frozen storage of some fish (cod) may result in yellowing of flesh below skin. Freezing process disrupt chromatophores and release carotenoids and their migration to the S/C fat layers causes yellowing. Cuttlefish muscle has very high phospholipid content and is susceptible to oxidation. Since phospholipids contain amine groups, their oxidation can lead to aldehyde–amine interactions that produce yellow colour. In crustaceans,like lobster, pigment is limited to the surface of the meat, the changes during frozen storage lead to yellow discolourations.

Summary

Hygienic handling of fishes is the very basic requirement to be followed for better maintenance of quality and safety of fish and fishery products. Low temperature preservation particularly icing is the most practiced preservation method in countries like India for a short term shelf-life extension.