Consortium for Educational Communication

Module on

Fish Products

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Text

Fish - Structure

Fishes are vertebrate animals, that is they have a vertebral column or 'spine'. There are two main groups of fishes, bony fish (*Teleosts*) and cartilaginous fish (*Elasmobranchs*). As the common names imply, the skeletons of teleosts are made of bone while the elasmobranchs have cartilaginous skeletons. The elasmobranchs comprise sharks, rays and dogfish which differ from teleosts in many respects. The teleosts are far more numerous, with a greater diversity of species than the elasmobranchs. All fishes are aquatic and breathe by absorbing dissolved oxygen in the water using their gills. The bodies of both teleosts and elasmobranchs are covered with scales but those of elasmobranchs are spiky and project through the skin. This makes the skin feel very rough. The scales of the teleosts have a flattened, discoid shape and are covered by a thin layer of skin and mucus which probably reduces friction between the body and the surrounding water and makes them very slippery. The external features (Figure 1) that are used to describe the fish are explained below:

Fins: Fins are appendages used by the fish to maintain its position, move, steer and stop. They are either single fins along the centerline of the fish, such as the dorsal (back) fins, caudal (tail) fin and anal fin, or paired fins, which include the pectoral (chest) and pelvic (hip) fins. Fishes such as catfish have another fleshy lobe behind the dorsal fin, called an adipose (fat) fin. The dorsal and anal fins primarily help fish to not roll over onto their sides. The caudal fin is the main fin for propulsion to move the fish forward. The paired fins assist with steering, stopping and hovering.

Gills: The gills are the breathing apparatus of fish and are highly vascularized giving them their bright red cover. An operculum (gill cover) that is a flexible bony plate that protects the sensitive gills. Water is "inhaled" through the mouth, passes over the gills and is "exhaled" from beneath the operculum.

Nostrils*:* The nostrils of fish do not open into the back of the mouth as do those of mammals and are not therefore, for breathing. They lead into organs of smell which are as a rule very sensitive, so that a fish can detect the presence of food in the water at considerable distances.

Eyes*:* The eyes are rounder in fish than mammals because of the refractive index of water and focus is achieved by moving the lens in and out, not reshaping the lens as in mammals.

Hearing: Although fish have no ears visible externally they can hear by transmission of vibrations through the body to sensitive regions of the inner ear.

Mouth*:* The mouth's shape is a good clue to what fish eat. The larger it is, the bigger the prey it can consume. Fish have a sense of taste and may sample items to taste them before swallowing. Most freshwater fishes in Florida are omnivorous. Some are primarily piscivorous (eating mostly other fish). The imported grass carp is one of the few large fishes that are primarily herbivorous. Fish may or may not have teeth depending on the species. Fish like chain pickerel and gar have obvious canine-shaped teeth. Other fish have less obvious teeth, such as the cardiform teeth in catfish which feel like a roughened area at the front of the mouth, or vomerine teeth that are tiny patches of teeth, for example, in the roof of a striped bass' mouth. Grass carp and other minnows have pharyngeal teeth modified from their gill arches for grinding that are located in the throat.

Scales: Scales in most bony fishes (most freshwater fishes other than gar that have ganoid scales, and catfish which have no scales) are either ctenoid or cycloid. Ctenoid scales have jagged edges and cycloid ones have smooth rounded edges. Bass and most other fish with spines have ctenoid scales composed of connective tissue covered with calcium. Most fishes also have a very important mucus layer covering the body that helps prevent infection. Anglers should be careful not to rub this "slime" off when handling a fish that is to be released. In many freshwater fishes the fins are supported by spines that are rigid and may be quite sharp thus playing a defensive role. Catfish have notably hard sharp fins, of which anglers should be wary. The soft dorsal and caudal fins are composed of rays, as are portions of other fins. Rays are less rigid and frequently branched.

Lateral line: The lateral line is a sensory organ consisting of fluid filled sacs with hair-like sensory apparatus that are open to the water through a series of pores (creating a line along the side of the fish). The lateral line primarily senses water currents and pressure and movement in the water.

Vent: The vent is the external opening to digestive urinary and reproductive tracts. In most fishes, it is immediately in front of the anal fin.

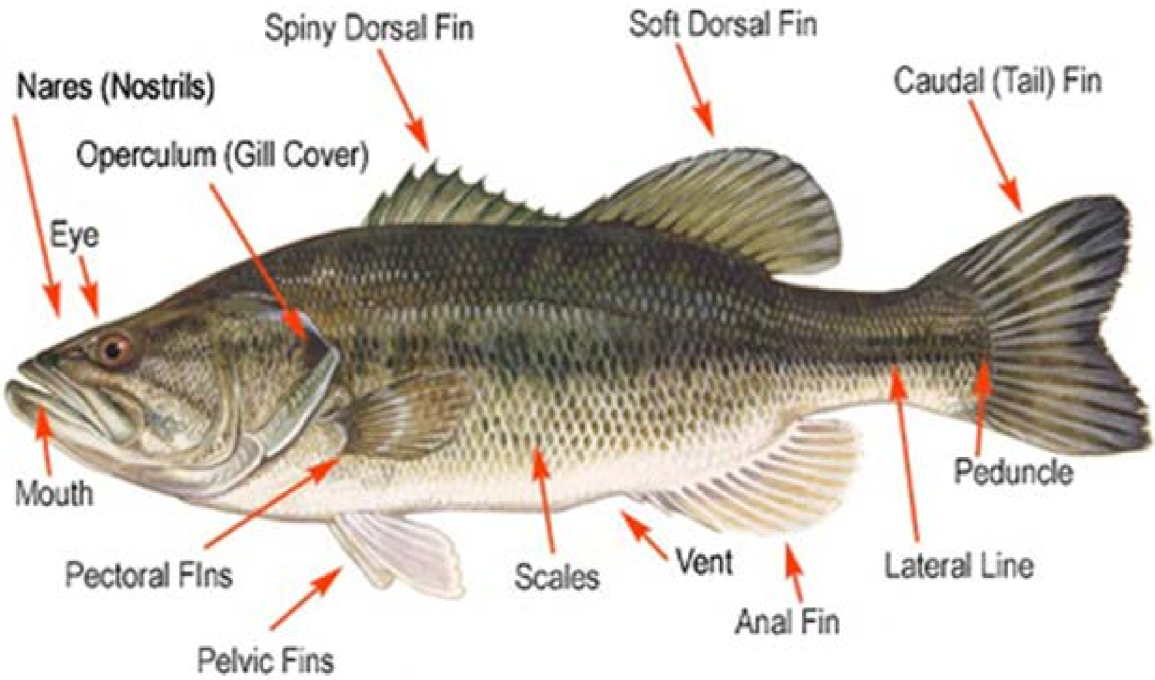

Figure 1: External morphology of fish.

Contribution of fish to human nutrition

Fish represents a valuable source of micronutrients, minerals, essential fatty acids and proteins in the diet. The meat of fish and seafood products contains about 70-80% (w/w) water, 8%–25% proteins, 0.5%–30% fat, and 0.6%–1.5% mineral compounds. Fish meat contains abundant amounts of water-soluble vitamins, and fish oil (particularly from the liver) is rich in vitamins A and D. Also, it is commonly noted that one serving of seafood may meet the daily human requirement for B vitamins, and the biological value of seafood protein exceeds that of red meat proteins owing to the low proportion of collagen. Lipids contained in fish are rich in essential polyenoic fatty acids and particularly valuable nutritionally are the omega-3 polyenoic acids, which may reach up to 40% in the oil content of some fish. The nutritional value of fish differs considerably depending on the species, maturity and health status, type of the muscle or body part, processing technique, and duration after harvest. It is estimated that fish contributes up to 754 kJ per capita per day, but reaches such high levels only in a few countries where there is a lack of alternative protein foods, and where a preference for fish has been developed and maintained (e.g., in Iceland, Japan, and some small island developing states). More commonly, fish provides about 84–125 kJ per capita per day. Fish proteins are a crucial dietary component in some densely populated countries, where the total protein intake level may be low, and are significant in the diets of many other countries. For instance, fish contributes to or exceeds 50% of total animal proteins in some small island developing states and in Bangladesh, Cambodia, the Congo, the Gambia, Ghana, Equatorial Guinea, Indonesia, Japan, Sierra Leone, and Sri Lanka.

Fish and seafood in functional foods

Increasing realization of the positive link between fish consumption and good health has led to an upsurge in research and commercial exploitation of seafood biotechnologies to produce innovative functional marine food and medicinal products. The particularly low incidence of heart disease in fish-eating populations has been attributed to high ingested levels of the so-called omega-3 [eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA)] polyunsaturated fatty acids (PUFAs) in fish oil. For instance, in recent, researchers successfully incorporated omega-3 fatty acids into a range of products including bread, biscuits, soup, and an infant formula using spray-drying processes. These omega fatty acids reduce inflammation, and cardiovascular diseases by raising the plasma total high-density lipoprotein (HDL) cholesterol (the so-called good cholesterol). These are also the important components for brain development, immune modulation, and good vision and can help us from preventing type-2 diabetes.

Types of fish products

Cooked fish

Cooking provides short-term preservation of fish. A range of methods are used for cooking fish but the principle of the process remains the same. The flesh of the fish softens, enzymes become inactivated and the process kills many of the bacteria present on the surface of fish. The muscle fibres of fish are not tough and the amount of connective tissue is small, and therefore they are more easily cooked than the meat of warm blooded animals. When sufficiently cooked, the flesh of fish can be easily separated into flakes. Thus, fish is to be carefully handled during cooking so that it does not break easily. When over-cooked, fish meat shrinks excessively and becomes tough and dry. Fish is generally cooked by dry heat, such as broiling, baking and frying. Moist heat methods, such as steaming and poaching are also used. The fat content of fish also determines the cooking method. Fish low in fat is generally fried or basted with fat. Some fishes are rich in fat and such fishes require very little additional fat in cooking. Whole fish fillets and steaks may be baked. If the fish is thick fleshed it is scored here and there i.e., little slits are made in the flesh on each side, so that it will hasten the cooking of fish. The fish is then cooked at 177 ^{o}C. The fish may be brushed with oil before baking to prevent over-browning.

Broiling may also be used to cook whole fish or fish cuts. The dressed fish is placed on the broiler rack and cooked at a low broiling temperature. The temperature and time of cooking depends on the thickness of the fish to be cooked. The smaller the fish, the higher should be the temperature used. If the fish is large and thick, the cooking should be conducted at a lower temperature so that the heat gradually penetrates the flesh.

Frying is one of the most popular methods of cooking fish. This method is suitable for fillets, steaks and small whole fish. The fish may be shallow or deep fried. In shallow frying, fish is fried in a frying pan in hot butter. Before frying, the fish is soaked in lightly beaten egg or milk and rolled in flour or bread crumbs and shaken to remove the flour or crumbs not sticking to it. It is then fried till it becomes brown on each side. Next, it is removed from the pan and drained on absorbent paper. Deep fat frying is similar to shallow frying except that the frying medium is oil. The deep fryer should be no more than half filled with oil and heated to about 195 ^{o}C to 200 ^{o}C. Coated fish is plunged into the oil and when cooked it rises to the surface.

Cooking fish by steaming and poaching helps preserve its delicate flavour. For steaming, the fish is kept in a covered pan and placed on a rack over boiling water and cooked until done. In poaching, fish is placed in a kettle and covered with water. It is cooked with the liquid simmering.

Fish protein hydrolysates

The production of fish protein hydrolysates (FPH) involves the process that relies on proteolytic enzymes as in fish silage except that for FPH the enzymes are deliberately added commercially available sources from a wide range of plant, microbial and animal origins. Examples of such enzymes are bromelain (pineapple), papain (papaya), trypsin (bovine or porcine), and alcalase and neutrase from bacterial sources, among many others. In this context the production of FPH is a higher technology process compared to fishmeal production. Although any raw material suitable for fish meal production can be used for FPH, it has found best use in treating the off-cuts from white fish processing – cod frames, for example, where the mineral content of bones is reduced and the protein recovery from adhering flesh is maximized. Typical composition for FPH is moisture (3–8%), protein (70–87%), protein solubility in water (75–85%) and crude fat (1–23%), where the wide ranges are dependent on the raw material used. Figure 2 shows a process scheme for FPH production from fish or fish wastes.

Fish or fish wastes

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Mincing

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Water → Incubation← Enzyme or starter addition

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Heat to 90°C to inactivate Enzyme

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Separation (oil, residues)

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Liquefied fish protein

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Concentrate

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FPH powder

Figure 2: General process for the production of FPH

Fish meal

Fish meal can be made from almost any type of seafood, but is generally manufactured from wild-caught, small marine fish that contain a high percentage of bones and oil, and are usually deemed not suitable for direct human consumption. Fish meal is made by cooking, pressing, drying, and grinding of fish or fish waste to which no other matter has been added. It is a solid product from which most of the water is removed and some or all of the oil is removed. Of the several ways of making fish meal from raw fish, the simplest is to let the fish dry out in the sun. This method is still used in some parts of the world where processing plants are not available, but the end product is poor quality in comparison with ones made by modern methods. Now, all industrial fish meal is made by the following processes:

Cooking: A commercial cooker is a long, steam-jacketed cylinder through which the fishes are moved by a screw conveyor. This is a critical stage in preparing the fish meal, as incomplete cooking means the liquid from the fish cannot be pressed out satisfactorily and overcooking makes the material too soft for pressing. No drying occurs in the cooking stage.

Pressing: A perforated tube with increasing pressure is used for this process. This stage involves removing some of the oil and water from the material and the solid is known as press cake. The water content in pressing is reduced from 70% to about 50% and oil is reduced to 4%.

Drying: If the meal is under-dried, moulds or bacteria may grow. If it is over-dried, scorching may occur and this reduces the nutritional value of the meal. The two main drying methods are used:

Direct: Very hot air at a temperature of 932°F is passed over the material as it is tumbled rapidly in a cylindrical drum. This is the quicker method, but heat damage is much more likely if the process is not carefully controlled.

Indirect: A cylinder containing steam-heated discs is used, which also tumbles the meal.

Grinding: This last step in processing involves the breakdown of any lumps or particles of bone. Figure 3 shows a process scheme for fish meal production from fish.

Fish

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Cooking

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Pressing

↓

Drying

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Grinding

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Fish meal

Figure 3: General process for the production of Fish meal

Uses

Fish meal in diets increases feed efficiency and growth through better feed palatability, and enhances nutrient uptake, digestion, and absorption. The balanced amino acid composition of fish meal complements and provides synergistic effects with other animal and vegetable proteins in the diet to promote fast growth and reduce feeding costs. High-quality fishmeal provides a balanced amount of all essential amino acids, phospholipids, and fatty acids required for optimum development, growth, and reproduction. The nutrients in fishmeal also aid in disease resistance by boosting and helping to maintain a healthy functional immune system. It also allows for formulation of nutrient-dense diets, which promote optimal growth.

Fish oils

Recent developments in the recognized importance of fish oils as a source of omega-3 (n-3) fatty acids for humans and animals have altered the conceived value of fish oils as a by-product for various fish processing operations. Fish oils are of two kinds, liver oils and fish body oil. Liver oil is the principal natural source of vitamin A and to a lesser extent vitamin D. Fishes such as cod, halibut, tuna and shark are good sources of fish liver oils. The oil and vitamin A content vary in different fishes. Body oil is obtained from fishes such as sardine, herring and salmon. Liver oil is obtained by different methods. One method is by cooking good quality minced fish liver at 85-95°C. This results in the disintegration of liver cells and freeing of oil. The oil floating on the steam condensate can be skimmed off or separated by centrifugation. Fish body oils are produced along with fish meal. Fishes are first ground to a pulp and steamed. The oil and water get separated from the protein. The cooked flesh is then pressed. The presscake is worked up for fish meal. The press liquor or stick water is concentrated and oil recovered.

Preservation techniques of fish

Conservation is necessary to keep the dead fish in fresh condition for quite a long time. This is achieved by employing any one of the methods like chilling, freezing, curing and canning.

Chilling Fish

Fish begins to spoil immediately after death. This is reflected in gradual developments of undesirable flavours, softening of the flesh and eventually substantial losses of fluid containing protein and fat. By lowering the temperature of the dead fish, spoilage can be retarded and, if the temperature is kept low enough, spoilage can be almost stopped. Fish can be kept cool by placing it in the shade. Although this method is simple and requires no special equipment, the fish still begins to deteriorate within a few hours. An alternative is to pack the fish with ice. This is an effective method and fishes are chilled in ice when they are to be stored for a few days. Ice is put inside the body cavity in large fishes. The fishes are arranged in tiers in shelves or boxes and stacked, and should not be dumped in heaps in cold storage.

Uses of ice:

- Fish preservation time can be extended by using ice.
- Ice reduces fish body temperature and keeps the body cool for more time.
- Water, formed due to ice melting, cleans the mucous and other material of the fish body.
- Ice is useful as good preservative due to its melting point 0°C and latent heat 80

cal/g.

- Due to high relative humidity of ice, it is very good for preservation.
- Ice is cheap and very effective preservative.

Freezing

Freezing is an alternative method for cooling fish. This technique provides long-term preservation. Fish contains higher amount of water, normally 60-80 percent depending on the species, and the freezing process converts most of this water into ice. Freezing requires the removal of heat, and fish from which heat is removed falls in temperature in the manner shown in Figure 4. During the first stage of cooling, the temperature falls fairly rapidly to just below 0°C, the freezing point of water. As more heat requires to be extracted during the second stage, in order to turn the bulk of the water to ice, the temperature changes by a few degrees and this stage is known as the period of "thermal arrest". When about 55% of the water is turned to ice, the temperature again begins to fall rapidly and during this third stage most of the remaining water freezes. A comparatively small amount of heat has to be removed during this third stage. As the water in fish freezes out as pure crystals of ice, the remaining unfrozen water contains an ever increasing concentration of salts and other compounds which are naturally present in fish flesh. The effect of this ever increasing concentration is to depress the freezing point of the unfrozen water. The result is that, unlike pure water, the complete change to ice is not accomplished at a fixed temperature of 0°C, but proceeds over a range of temperature. The variation of the proportion of water (which is converted to ice) in the muscle tissue of fish against temperature is shown in Figure 5. The figure shows that by the time the fish temperature is reduced to -5°C about 70% of the water is frozen. It also shows that even at temperatures as low at -30°C, a proportion of the water in the fish muscle still remains in the unfrozen state.

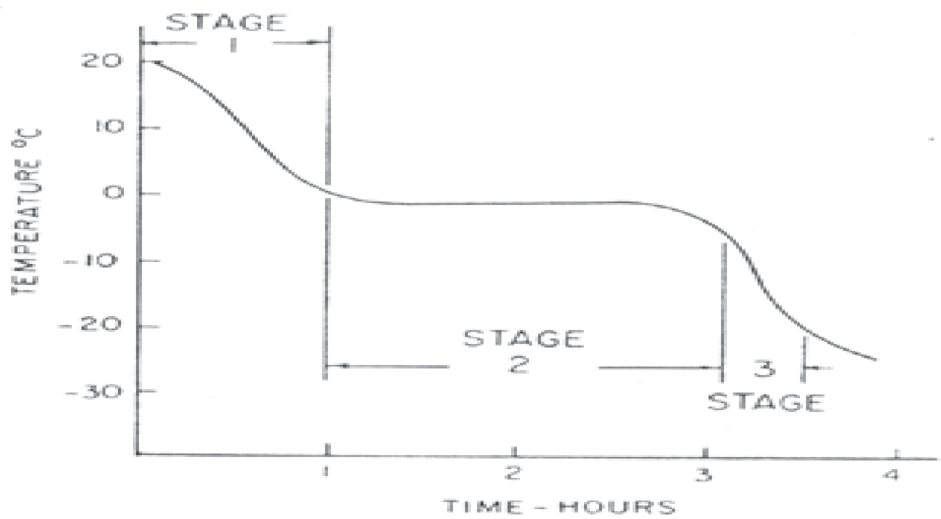

Figure 4: Temperature-time graph for fish during freezing.

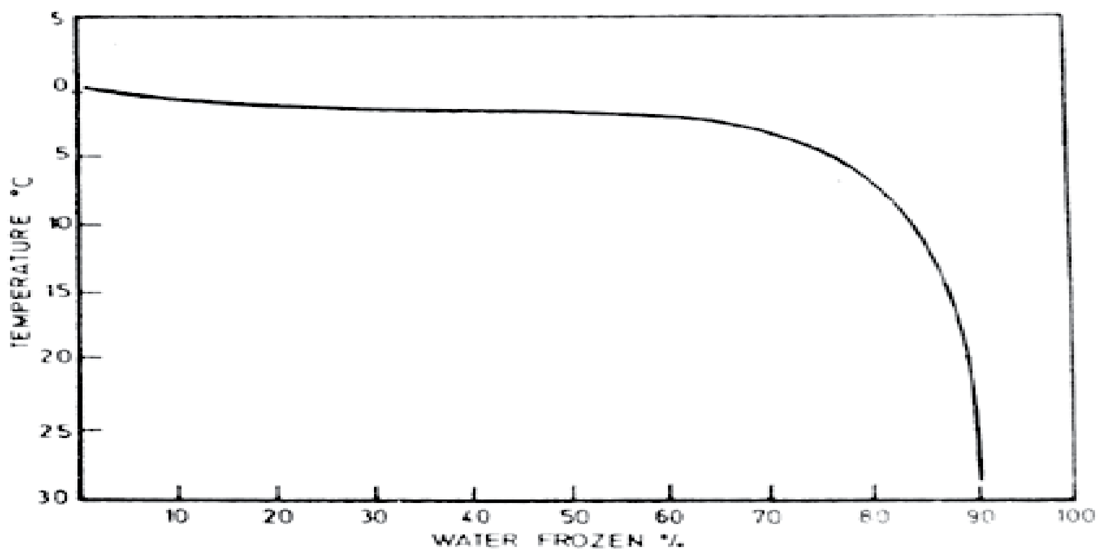

Figure 5: Freezing of fish muscle and the percentage of water frozen at different temperatures.

Deep or quick freezing

When fish is intended to be stored for a long period, quick freezing is preferred which inhibits bacterial action. During quick freezing every part of the product comes within the range of 0° to -5°C. Properly frozen fish at -20°C retains its physical properties and nutritive values for a year or more and is almost as good as fresh fish. Smaller sized crystals, shorter time taken for freezing less time allowed for diffusion of salts and evaporation of water and prevention of decomposition are some of the advantages in quick freezing. There are three ways effecting quick freezing:

a) Direct immersion of fish in the refrigerating medium

b) Indirect contact with the refrigerant through plates

c) Forced convection of refrigerated air directed at heat transfer surfaces.

In general different methods of freezing are adapted through sharp freezer such as air blast freezer, contact plate freezer, vertical plate freezer, immersion freezing, liquid freon freezing, liquid nitrogen freezing, fluidized bed freezer, cryogenic freezing, sub freezing, etc. All the methods of freezing shall help in absorption of heat and in preserving the initial qualities of fish. Among the various methods of freezing the blast freezer is mostly used. Individually quick frozen (IQF) products are frozen as single units which need not be thawed for sub-division or perhaps even for cooking purposes. The demand for IQF products has increased with the upsurge in the number of low temperature “freezer” cabinets both in catering establishments and in the home. IQF freezing allows for the purchase of a frozen product in bulk and the selection from storage of only sufficient quantities to meet immediate requirements. Other products such as blocks of fish and fish portions usually packaged in cartons are also produced for direct consumption without the need for reprocessing. The consumer will purchase this type of product from the retailer, still in the frozen state, and either cook it in the frozen state or thaw it for immediate consumption. Products frozen in bulk can be unprocessed, such as blocks of whole fish frozen in contact freezers. Blocks of frozen fish may weigh up to 50 kg; they are usually glazed or wrapped after freezing and are then stored until required for further processing. In some cases, fish are bulk frozen, stored and finally thawed all in one place. This is usual when there is a short seasonal fishery and fish are preserved for processing over a longer period. Bulk frozen fish may also be distributed in the frozen state. This enables the fish to be sold to a larger home market and also allows the product to be exported. In this case there are additional requirements for low temperature transport and a more extensive cold chain. Fish frozen in bulk may also be fully processed before freezing and only the skinless, boneless portion used. One particular process of this type worth special mentioning is the production of frozen fillet blocks. A frozen fillet block is a regular shaped block of fish flesh frozen in a horizontal plate freezer within a treated cardboard carton and a metal retaining frame. The filling process ensures that there are no voids in the block. After freezing, the blocks are stored in bulk and at a later date cut into smaller portions of different shapes. The fish portions may then be packaged and sold in this form or they may be coated with a flour batter and breadcrumbs. Coated fish portions should be returned to the freezer and rehardened before packaging and storing.

Curing of fish

Cured fish refers to fish which has been cured by subjecting it to salting, drying, pickling, fermentation, smoking, or some combination of these before it is eaten. These food preservation processes can include adding salt, nitrates, nitrite or sugar, can involve smoking and flavoring the fish, and may include cooking it. The earliest form of curing fish was dehydration. Other methods, such as smoking fish or salt-curing also go back for thousands of years. The term "cure" is derived from the Latin *curare*, meaning *to take care of*.

Salt curing

Salting is a process where the common salt, sodium chloride is used as a preservative which penetrates the tissues, thus checks the bacterial growth and inactivates the enzymes. Salting commences as soon as the surface of the fish comes in contact with common salt and the end product shall have the required salinity with taste and odour. Some of the factors involved in salting of fish which play an important role are purity of salt, quantify of salt used, method of salting and weather conditions like temperature, etc.

During the process the small fishes are directly salted without being cleaned. In the medium and large sized fish the head and viscera are removed and longitudinal cuts are made with the help of knives in the fleshy area of the body. Then the fish is washed and filled with salt for uniform penetration through flesh. Large fishes like sharks are cut into convenient sized pieces. Generally, sardines, mackerels, seer fishes, cat fishes, sharks and prawns are used for salting.

The salt used should be pure common salt so as to keep the quality of the fresh fish. Traces of calcium and magnesium caused whitening and stiffening of the flesh and gives bitter or acid flavor to the product. In addition it does not allow the easy penetration of common salt. Dry salting, wet salting and mixed salting are the three methods employed in salting of fish.

Dry salting

In this process the fish is first rubbed in salt and packed in layers in the tubs and cemented tanks. The salt is applied in between the layers of fishes in the proportion of 1:3 to 1:8 salt to fish. The proportion of salt to fish varies with the fish since the oily fish require more salt. At the end of 10 - 24 hours the fishes are removed from the tubs and washed in salt brine and dried in the sun for 2 or 3 days. Large fish lose about one third and small fish about one half of their dressed weights.

Wet salting

The cleaned fish are put in the previously prepared salt solution. It is stirred daily till it is properly pickled. In some fishes like seer, black pomfret, Indian salmon etc., the gut is removed and filled with salt in 1:3 proportions. First the salt is filled in the gut region of the fish and stacked, on the following day further addition of salt is done since the salt settles down at the bottom. Finally the process is repeated to ensure the proper filling up of salt and left undisturbed for 7 - 10 days allowing the liquor to flow off. The fishes preserve in wet salting process are to be consumed before the rain sets in and the fishes are marketed without drying.

Mixed salting

In this process, simultaneous use of salt and brine is followed. The salting process is continued till the concentration of salt in the surrounding medium equalizes with the concentration of salt in the fish tissue. The salting process may affect the shape, structure and the mechanical features of muscle tissue.

Pit curing

It is another process employed in south and south east of our country. In this process the fish treated with salt are buried in pits lined with leaves. After 2-3 days they are removed and marketed directly.

Use of Nitrates and nitrites

Nitrates and nitrites have been used for hundreds of years to prevent botulism and ensure microbial safety. Nitrates help kill bacteria, produce a characteristic flavor and give fish a pink or red color. The use of nitrates in food preservation is controversial. This is due to the potential for the formation of nitrosamines when the preserved food is cooked at high temperature. The use of either compound is carefully regulated. For example, the FDA Code of Federal Regulations states that sodium nitrite may be safely used: “As a color fixative in smoked cured tuna fish products so that the level of sodium nitrite does not exceed 10 parts per million (0.001 percent) in the finished product. As a preservative and color fixative, with or without sodium nitrate, in smoked, cured sable fish, smoked, cured salmon, and smoked, cured shad so that the level of sodium nitrite does not exceed 200 parts per million and the level of sodium nitrate does not exceed 500 parts per million in the finished product.

Smoking

In this method, landed fish is cleaned and brined. It is then exposed to cold or hot smoke treatment. In cold smoking, first a temperature of 35°C is raised from a smokeless fire. After this heating, cold smoke at a temperature below 28°C is allowed to circulate past the fish. In case of hot smoking, first a strong fire produces a temperature around 130°C. This is followed by smoking at a temperature of 40°C. The smoke has to be wet and dense. Good controls are necessary over density, temperature, humidity, speed of circulation, pattern of circulation and time of contact with fish of the smoke. The organic acids of the smoke acts as an antiseptic and phenols impart a characteristic colour and flavour. Some condensation of tars and resins also adds to the taste. Strict hygienic conditions are maintained throughout this operation. For best results, fishes are hanged on special structures in special installations called smoke houses. For making fire and smoke, only hard wood (Conifer wood, Saw dust etc.) are used. Smoke house has a chimney at the top for exit of smoke. It also has a number of galleries for hanging fishes. The smoke house is made of fire proof material and is very well insulated to retain heat. Fish can be smoked in a variety of ways, but as a general principle, the longer it is smoked, the longer its shelf-life will be.

Smoking can be categorized as:

Cold smoking: In this method, the temperature is not high enough to cook the fish. It is not usually higher than 35°C.

Hot smoking: In this method, the temperature is high enough to cook fish.

Hot smoking is often the preferred method. This is because the process requires less control than cold processing and the shelf-life of the hot-smoked product is longer, because the fish is smoked until dry. Hot smoking does, however, have the disadvantage that it consumes more fuel than the cold-smoking method. Traditionally, the fish would be placed with smouldering grasses or wood. Alternatively, fish may be laid or hung on bamboo racks in the smoke of a fire.

Drying

Drying involves dehydration i.e. the removal of moisture contents of fish, so that the bacterial decomposition or enzymic autolysis does not occur. When moisture contents reduce upto 10%, the fishes are not spoiled provided they are stored in dry conditions. Fish drying is achieved either naturally or by artificial means.

Natural drying

In natural drying the fishes after being caught are washed and dried in the sunshine. They are suspended or laid out flat on the open ground. The process, however, has a number of disadvantages. It is slow and results in much loss, through putrefaction. It can be carried out only in dry, well aerated climate receiving sunshine which is not too hot. It thus depends upon the environmental factors and availability of space. Lastly only the thin fishes can be preserved by this method, because the fat fishes have much flesh allowing bacterial decomposition to continue in deeper parts of their body. An additional disadvantage is that dried fishes require a long soaking period to restore water and that the sun dried fishes are not usually relished.

Artificial drying

In artificial drying the killed fishes are cleaned, gutted and have their heads removed. They are then cut lengthwise to remove large parts of their spinal column, followed by washing and drying them mechanically.

Fermented fish

Fermentation is a process by which beneficial bacteria are encouraged to grow. These bacteria increase the acidity of the fish and therefore prevent the growth of spoilage and food-poisoning bacteria. Additionally, salt is used to prevent the action of spoilage bacteria and allow the fish enzymes and the beneficial acid-producing bacteria to soften (break down) the flesh. Fermentation is therefore the controlled action of the desirable micro-organisms such as *Lactobacillus* in order to alter the flavour or texture of the fish and extend shelf-life. The use of fermentation as a low-cost method of fish preservation is commonly practiced all over the world. There are many different types of fermented products and their nature depends largely on the extent of fermentation which has been allowed to take place. Essuman (1992) defined fermented fish as any fishery product which has undergone degradative changes through enzymatic or microbiological activity either in the presence or absence of salt. Traditionally the term ‘fermented fish’ covered both enzyme-hydrolysed and microbial fermented fish products and a clear distinction has not been made between these products. Most of the traditional products involve salting and occasionally smoking, marinating and drying; therefore, although some products are only involved in one type of processing method (salted, marinated or smoked) some involve combinations and can also be called fermented fish products.

Principles of the fermentation process

The complex ripening process consists of chemical and biochemical reactions that change the characteristics of the fish tissue and thus the sensory properties of the fish. Ripening is believed to be caused mainly by enzymic actions which split macromolecules such as protein and fat in the fish musculature into low molecular weight compounds, e.g. peptides, amino acids and free fatty acids. The texture of the salted fish becomes softer and tenderer during the ripening phase and a pleasant, typical taste is formed. The enzymes responsible for ripening are reported to be endogenous proteolytic enzymes from the internal organs and muscle tissue of the fish. The other source of enzymes is known to be bacterial, mainly lactic acid bacteria (LAB) derived either from fish, or other ingredients used in the process. LAB are found as the dominant micro-organisms in many fermented fish products where their primary role is to ferment available carbohydrates and thereby cause a decrease in pH. The combination of low pH and organic acids (mainly lactic acid) is the main preservation factor in fermented fish products. Generally, pH should be below 5–4.5 in order to inhibit pathogenic and spoilage bacteria. In addition, salt and spices (such as garlic, pepper or ginger) may add to the safety of products and, in some products, garlic may serve as a carbohydrate source for the fermentation. Table 1 gives examples of species from these genera which are important in fish fermentation.

Table 1: Classical genera of LAB for fish fermentation

Genus	Typical species
Lactobacillus	*L. acidophilus*
	L. brevis
	L. casei subsp. *Casei*
	L. delbrueckii
	L. plantarum
Pediococcus	*P. halophilus*
	P. parvulus
Lactococcus	*L. lactis* subsp. *Lactis*
	L. lactis subsp. *Cremoris*
Leuconostoc	*L. mesenteroides* (various subspecies)
	L. lactis
Bifidobacterium	*B. bifidum*
	B. longum
	B. breve
Carnobacterium	*C. piscicola*
	C. funditum
	C. alterfunditum

Issues relating to fermentation process of fish

Fermentable carbohydrates: The presence of fermentable carbohydrates (mono- and disaccharides) is essential and is usually provided by the addition of rice (or cassava). However, starchy substrates must be broken down and enzymes with amylolytic activity have been demonstrated.

Presence of salt: The presence of salt inhibits spoilage bacteria and promotes LAB and halophiles generally by lowering the water activity, although LAB are inhibited by low water activity affecting the fermentation. The effect varies depending on the phase in which salt is found, being highest in the solid state and less in solution.

Initial pH: The initial pH of the raw material will vary and hence the pH drop due to any specific LAB activity will depend on this value. A rapid drop in pH demands the presence of easily fermentable carbohydrates.

Temperature: This has an enormous effect on fermentation and in traditional products ambient temperatures alone, in the range of 25–35°C, promote a vigorous ferment-promoting tissue breakdown and favour sauce production.

Preservation effects of LAB

The preservation of fish through LAB fermentation is due to the inhibition of a wide range of spoilage and pathogenic organisms by the various end products of the fermentation.

Acid production: Lactic, and other organic acids generated by LAB, reduces the pH of the environment with an inhibitory effect on Gram-positive and Gram negative bacteria.

Hydrogen peroxide and carbon dioxide: LAB (in the presence of oxygen) can generate hydrogen peroxide, which, in turn, can generate hydroxyl radicals causing the peroxidation of membrane lipids and microbial cell susceptibility. These effects are well known for many organisms. Carbon dioxide is an end product of heterolactic fermentation and, on occasions, by

decarboxylation of amino acids by LAB, promotes an anaerobic environment, reduces pH and can help to destroy the integrity of the microbial cell wall.

Bacteriocins: These are 'antibiotic-like' molecules, usually protein in nature, of varying molecular weight, mode of action and specificity of action. They are produced by many LAB, either naturally or induced, with some LAB producing a single form whilst others produce two or three forms. Nisin (produced by *Lactococcus lactis*) shows activity against Gram-positive bacteria but not pathogenic Gram-negative bacteria such as *Escherichia coli* and *Salmonella*.

Canning of Fish

Canning is a method of preservation in which spoilage can be averted by killing micro-organisms through heat in hermetically sealed containers. It is generally well known that food carries micro-organisms which cause spoilage if left unchecked. These micro-organisms are to be eliminated and the entry of other is restricted. The raw material should be processed properly since it contains most dangerous pathogenic microbe *Clostridium botulinium* which should be destroyed. This is found in protein rich food such as fish which has pH 6- 7 and is non-acidic. There are some other heat resistant bacteria like *Clostridium sporogenes* which needs longer time-temperature treatments than *Clostridium botulinlum*. It needs a temperature of 120°C for 4 minutes or at 115°C for 10 minutes to kill them in large numbers.

Processing operations

The canning process involves pre-treatment of fish, preparation of can, filling and closure of the can, technique of heating the filled cans to kill micro-organisms without damage to fish, finally cooling, cleaning and storage of the product (Figure 6).

Washing and grading are often carried out in conjunction with de-icing if the fish is supplied in this form. In a de-icing tank the fish sink and the floating ice is skimmed off – the tank may be topped up to replenish the volume of water lost with the ice. Fish is sorted by size, and water is used to transport them through the sloping flume system, which gives rise to some contamination. The level of contamination depends to some extent on the condition of the fish – poor quality leads to more slime and blood on the equipment. Water usage can be reduced, as in the previous stage, by monitoring the need for top-up water and using the minimum for fish transport – using shut-off valves and sprays rather than constant flows and the use of gravity flow.

Skinning and scaling are alternatives which can be employed as a first operation in fish preparation and should be done with care to prevent losses in later operations. If the fish are skinned there is no need for scaling to be done. Scaling is normally done using a rotating perforated drum which removes the scales as the fish are pressed up against it and the scales are washed off by a stream of water. Skinning can be done manually or mechanically with knives or drums and again water is used for lubrication and washing away the skin. The wash water is contaminated with skin, scales and subcutaneous oil from fatty species and also torn flesh if the fish flesh quality is poor.

Deheading can also be done manually or mechanically and if water is used for transporting the heads there is a significant pollution load from blood and flesh. Water transport is not necessary if gravity systems are correctly designed but the heads are heavy and may need moving manually. For canning, the simultaneous removal of the head and guts (called nobbing) is done for larger species followed by removal of the tail. These operations also generate a pollution load in the waste water and although vacuum removal of guts reduces the volume and load considerably it is an expensive option.

Filleting is not associated with all canned fish, such as salmon and sardines, as their bones are soft enough to eat after retorting or for species when the filleting weakens the physical structure such that the fish falls apart on retorting. Filleting oily fish is also difficult and leads to considerable damage as the lipid and fish flesh are closely related and this arrangement is destroyed by the filleting process. All these issues affect the aesthetic appeal of the product when the can is opened and so impinge on product quality. The filleting process will vary for white fish and for oily fish. White fish are often beheaded and gutted and cleaned before filleting but this is not always the case for oily fish so these processes are included at this point. Mechanical or manual filleting can be applied for white and oily fish but in both cases water usage is a major factor and used, often in continuous flow, for removing offals, cleaning out belly cavities and general cleaning and can even be used to orientate the fish in the mechanical process. Filleting machines should be checked regularly for correct adjustment and knife sharpness, and fish alignment prior to filleting can be done with rotating brushes rather than water jets. Finally, the fillets can be further trimmed manually to remove bones, blood and membranes and any flesh recovered can go directly for fish mince or even surimi production. The move from manual to mechanical filleting was driven by a need to cut costs and improved product consistency.

Filling the cans involves a series of operations very dependent on the species of fish being processed, particularly its size: for example, are the fish to be canned whole or as fillets, steaks or chunks? Sauces, oil or brine can also be added at this stage and if this is not done carefully the cans overflow and must be washed to remove debris which would stick to the can in the retort. Water usage can be reduced by proper adjustment of the sauce/brine filler and by using water recovered from elsewhere in the plant to wash off any spillage.

Exhausting and sealing are the final operations prior to retorting, and entail the removal of gases in the headspace above the can contents and the reduction of oxidation and internal corrosion by excluding oxygen. The pressure differences in the can during retorting can lead to strain on the can seams and leakage, and this is the commonest cause of spoilage as organisms gain ingress – such effects are not always easy to spot once the cans have cooled down. Large cans also need a headspace to allow for the expansion of the contents in the retort, which is not usually the case with small cans. There are three ways to achieve a good headspace vacuum:

Hot filling/sealing of the can with hot sauce, oil or brine expels air from the headspace and will prevent further expansion in the retort. With hot filling the can must be sealed immediately to prevent contraction and ingress of air on cooling. Hot filling can also be achieved by combining a pre-cook followed immediately by the injection of hot sauce or oil and sealing. Another, rather slow, technique is to fill the cans, then 'clinch' the lids (the first operation of can sealing only being applied) and hold them in a hot water bath to expel air prior to the second sealing operation. Vacuum sealing is very reliable but requires an evacuated chamber and can slow down the process line. It is considered essential for laminated foil pouches to prevent pressure build-up in retorting stage. Steam sealing involves passing the cans through a steam chamber which expels air and condenses once the can is sealed.

Heat-processing operations

As the central operation in canning, the nature of the equipment used and the mode of operation will have profound effects on the energy/water usage of the overall canning process. Retorts can be batch or continuously operated usually under saturated steam and pressure and should reflect the nature of the fish being processed, scale of operation and the technical expertise available to manage the plant.

Batch retorts can be operated in a horizontal or vertical axis and the choice often depends on batch size. Horizontal retorts can be loaded with cans on walk-in trolleys (for large batches) whilst vertical retorts are filled by block and are therefore more time-consuming in filling and unloading. However, vertical retorts tend to give better steam/heat distribution and the larger horizontal systems even need multi-entry ports along the length of the vessel for even distribution of steam. Both systems are inefficient of energy and water as the system must be heated and cooled for each batch operation. Batch retorts do offer the advantage of unique product identification, which is essential if there is a need for subsequent product recalls incident analysis and process remediation.

Continuous retorts give higher throughputs as there is no downtime between batches. Continuous rotary cookers move the cans along the (horizontal) vessel at a predetermined speed for the required heat treatment and the movement helps in heat transfer. Pressure-secure valves introduce and remove the cans, and transfer valves allow movement from heating to cooling vessels. Continuous agitating retorts roll the cans on conveyors up and down a single vessel, again achieving good heat transfer.

Hydrostatic retorts move cans vertically up and down the vessel in towers which may be several storey's high (thus saving space) with heating, holding and cooling sections which determine the heat treatment achieved. Entry and removal is through a water lock maintained by the steam pressure in the holding section of the vessel, which in turn is kept at a constant temperature by the head in the heating/cooling sections.

Post-processing operations

The post-processing operations are cooling with chlorinated water; drying cans before handling, storage and bulk packing.

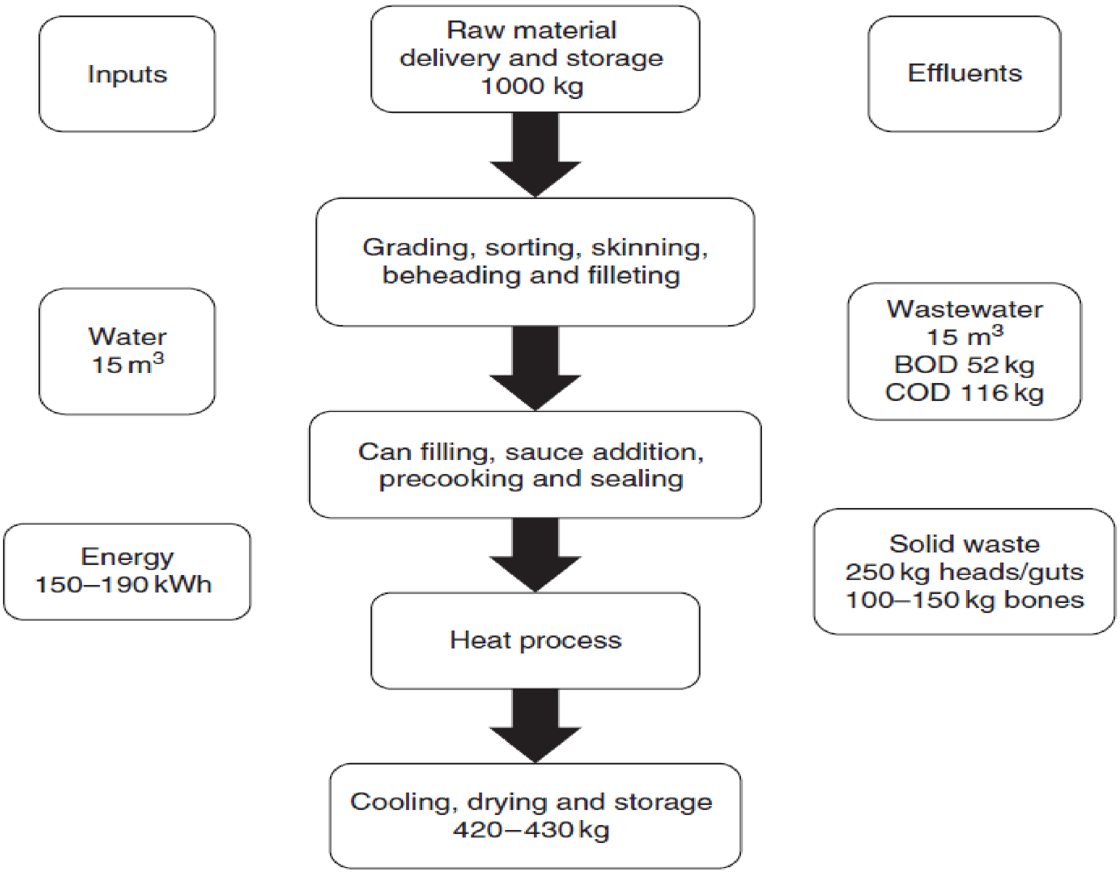

Figure 6: General process of fish Canning operation

Quality criteria for thermally processed fish

The canning process will cause changes in the texture and flavour of the fish product compared to the raw material but these are usually acceptable (and even desirable) for most species – but not for the delicately flavoured and textured white fish. Consequently, oily fish such as tuna and salmon, among others, are canned most successfully as are many shellfish species. Other quality factors which can be affected by canning include slight loss in the nutritional value of proteins and associated denaturation giving a curdled appearance, losses in vitamins and colour changes (particularly for salmon). Attempts to minimize these quality defects involve the prevention of overcooking by improved heat transfer – just the kind of effects which would ensure the destruction of organisms with reduced energy and water usage as mentioned above. Thus, good processing, product quality and sustainability go hand in hand once again.