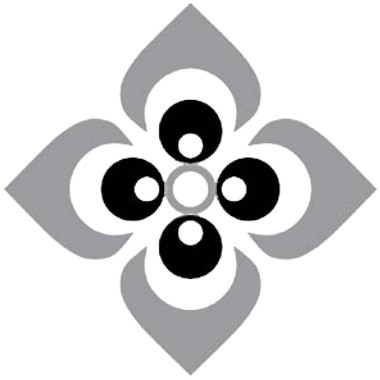

Consortium for Educational Communication

Module on

SPOILAGE OF FISH

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Text

Fishes are defined as aquatic vertebrates that use gills to obtain oxygen from water with fins consisting of a variable number of skeletal elements called fin rays. Fishes are different from all other food commodities as regards their method of harvesting, fragility of the product during transport to processing sites, and further in the chain, temperature dependency and variety of species. Fish is a highly perishable commodity. Freshly caught fish at a temperature of 16^0C remain good for hardly a day, on ice at 0^0C, finfish may remain good for periods of upto about 14 days, and however in contrast, beef may be stored at 1.7^0C for several weeks. Harvested fish and seafood materials undergo series of handling operations from catch sites until the product is delivered to the end user. Several factors predispose fresh fish to rapid quality degradation once they are harvested, and these include alteration of the surrounding environment due to removal from the marine or aquatic environment, high moisture content of fish, activities of microorganisms inside the gut and intestine, and physical damage resulting from the use of improper harvesting tools and procedures and rough handling practices. The Spoilage of fish beings as soon as fish dies. In tropical conditions, fish spoils quite rapidly, within a few hours of landing, if not properly cooled. The spoilage rate of fish may be reduced by good handling practices and effective temperature control from very beginning. In raw fish, spoilage takes place mainly due to three reason viz.,

1) Enzymic action

2) Microbial action

3) Chemical action

Enzymes and bacteria do not cause any deteriorative changes in the living cell because of the natural defensive mechanism. In dead fish, enzyme become involved in the autolytic changes and bacteria can invade the fish

muscle and proliferate there. The fish gut is rich in proteolytic enzymes and in dead fish it digests the gut and belly region making the fish very soft. Bacteria that are present on the surface, gills and gut of the fish invade the dead fish, decompose the tissue and bring about undesirable changes. Off odor and off flavor, slime, gas production, discoloration and soft texture are the obvious signs of spoilage. Component involved in spoilage process are protein, lipids, carbohydrates, nucleotides and other non-protein nitrogen compounds. The rate of spoilage is temperature dependent and lowering the temperature will reduce the rate of spoilage.

Factors influencing kind and rate of spoilage.

1. **The kind of fish:** The various kinds of fish differ considerably in their perishability. Thus some flat fish spoil more readily than round fish because they pass through rigor mortis more rapidly, but a flat fish like halibut keeps longer because of the low pH (less than 6) of its flesh. Certain fatty fish deteriorate rapidly because of oxidation of the unsaturated fats of their oils. Fishes high in trimethylamine oxide soon yield appreciable amounts of the "stale-fishy" trimethylamines.

2. **The condition of the fish when caught:** Fish that are exhausted as a result of struggling, lack of oxygen, and excessive handling spoil more rapidly than those brought in less adverse conditions, probably because of the less exhaustion of glycogen and hence smaller drop in pH of the flesh. "Feedy" fish, i.e., those fed of food when caught, are more perishable than those with an empty intestinal tract.

3. **The kind and extent of contamination of the fish flesh with bacteria:** The greater the load of bacteria on the fish, the more rapid the spoilage. This contamination may take place in the net, in the fishing boat, on the docks, or later in the plants. Fish in the round, i.e., not gutted, have not the flesh contaminated with intestinal organisms, but it may become odorous because of decay of food in the gut and diffusion of decontamination products into the flesh. Gutting the fish on the boat spreads intestinal and surface-slime bacteria over the flesh, but thorough washing will remove most of the organisms and adequate chilling

will inhibit the growth of those left. Any damage to skin or mucous membranes will harm the keeping quality of the product.

4. **Temperature:** Chilling the fish is the most commonly used method for preventing or delaying bacterial growth and hence spoilage until the fish is used or is otherwise processed. The cooling should be as rapid as possible 0 to -1°C, and this low temperature should be maintained. Obviously the warmer the temperature the shorter the storage life of the fish. Prompt and rapid freezing of the fish is still more effective in its preservation.

Types of spoilage in fish

A. Enzymatic spoilage

Autolytic spoilage is responsible for early loss of quality of fresh fish. The first enzymatic change in fish muscle is the gradual hydrolysis of glycogen to lactic acid which is known as glycolysis.

1) **Glycolysis:-**

After death, the blood circulation stops and the cells are no longer supplied with oxygen and hence glycogen will not be converted into the carbon dioxide and water unlike in the case of living cells. In the postmortem period, glycolysis proceeds via the anaerobic pathway where the end product is lactic acid. As the lactic acid accumulates, the pH of the muscle falls. In fish, glycolysis will continue until the supply of glycogen is completely used up. In general, fish muscle contain relatively low amount of glycogen compared with mammalian muscle and the final postmortem pH is consequently higher. This makes the fish meat more susceptible to microbial attack.

2) Flavor changes in fish (Nucleotide degradation):-

The most significant enzyme deterioration is the one that alter flavor. The nucleotide degradation in fish muscle produces many flavor bearing

compounds. These compounds are formed by the splitting of ATP by series of dephosphorylation and deamination reaction.

ATP□ADP□ AMP□IMP □ Inosine□ Ribose □ Hypoxanthine

Progressively it is hydrolyzed to ADP (Adenosine diphosphate), AMP (Adenosine monophosphate) and to IMP (Inosine monophosphate) and ammonia. At ambient temperature, ATP breakdown occurs rapidly and IMP accumulates in the fish tissue. In fresh fish, the rate of IMP is very high and it imparts a desirable sweet, meaty and characteristic flavor to fish. As autolysis proceeds further, the level of IMP decreases and neutral tasting Inosine or bitter tasting hypoxanthine accumulates in tissue. As a result, fish becomes more insipid. Some of these compounds increases with time and have been used as indices of fish freshness.

3) Belly bursting:-

Enzymic spoilage causes belly bursting in fish, especially during a period of high food intake. These fishes will have a large content of digestive enzymes in the digestive tract. Such fish will degrade quickly and spoil easily soon after they are caught. In the dissolve gut components, bacteria proliferate and produce gases such as CO_2 and H_2**.** This gas production leads to belly bursting after short storage period. Keeping the fish live for some time will retards this.

4) **Color changes in the fish:-**

Color is an important factor in seafood quality. Color change in seafood is caused by enzymic or non-enzymic action such as fat oxidation or by pigments. Color change in the seafood is an indication of spoilage. The important discoloration in seafood is caused by enzymes or fat oxidation and is illustrated below:

Black /blue discoloration

i) Shrimp:-

The development of black spot in shrimp is due to the presence of an enzyme, polyphenol oxidase (PPO). The black spot (melanin) is formed by the oxidative reaction of tyrosinase on tyrosine. Different species of shrimp undergo postmortem discoloration to different extents. The pigment is formed on the internal shell surfaces, or in advanced stages, on the underlying shrimp meat. This makes the shrimp unattractive for marketing. The shrimp phenol oxidase differs from that found in mussel or lobster in that it is not activated by trypsin. Sulphite preservatives can be used to prevent black discoloration resulting from phenolase reaction. Dipping shrimp in 0.2 – 0.5 % sodium bisulphite for one minute is usually adopted in industrial practice.

ii) Lobster:-

Black spot occurrence during icing and frozen storage of lobster is serious problem which results in significant commercial losses. Tyrosinase activity was identified in the blood with lesser amounts in other tissue. Discoloration at the butt of the tail, black spot between the segments and other deteriorations are more pronounced in moribund lobster. The tendency for blackening is also influenced by moulting cycle.

iii) Crab:-

Phenolase has been implicated in blue – black coloration of crab. The enzyme is present in the blood. Various additives have been shown to prevent blue discoloration (e.g. organic acid, sodium bisulphite and EDTA). The haemocyanin induced blacking is also prominent in crab and is non-enzymic.

b) **Yellowing of fish flesh:-**

Frozen storage of some fish may result in yellowing of flesh below the skin. Freezing or other processes disrupt chromatophores and release Carotenoids and their migrations to the subcutaneous fat layer causes

yellowing. Yellowing associated with lipid oxidation and carbonyl –amine reaction is observed during frozen storage.

c) **Brown discoloration:-**

Brown or yellow discoloration is caused by the reaction of the protein or the amino acids with product of lipid oxidation. Brown discoloration is observed in variety of processed products including white pomfret, sardine, jack mackerel, salted shark, marine eel, etc. Discoloration due to protein – lipid browning is greater in fatty fish than lean fish.

Table 1: Summary of the enzymatic changes in fish spoilage.

		Changes	Prevention
a) Glycolytic en-		Production of lactic acid, pH of tissue drops, loss of WHC in muscle, high temperature rigor may result in gaping	Allowed to pass through rigor at
b) Autolytic en-		Loss of fresh fish flavour, gradual production of bitterness with hydroxyl xanthenes.	Same as above rough handling or crushing
c) Ca-		Softening of tissue making processing difficult.	Avoid rough handling during storage.

		Autolysis of visceral cavity in pelagics (belly-bursting)	Problem increased with freezing/ thawing or long-term chill storage
e) Cal-pain		Softening molt-induced softening, in crustaceans.	Removal of calcium thus preventing activation
f) Col-la-ge-nas-es		Gaping of fillets softening of muscle tissue	
			Store fish at

B) Microbial spoilage:-

Fish spoilage is mainly due the action of bacteria. Bacteria are present on the surface slime, skin, gills and intestine of fish. In dead fish bacteria begin to invade the tissues causing spoilage and production of undesirable compound. The type of bacteria on the fish is very much depending on the microbial flora of the environment. However, in the fish processing industries two types of micro-organism are of concern.

1) Saprophytic or spoilage type bacteria:-

These organisms are responsible for the spoilage of the fish. The important classes of spoilage organisms found in tropical species are *Pseudomonas, Flavobacteria, Acinetobacter, Aeromonas and Moroxella.* The spoilage bacteria are characterized by their ability to produce H_2S, reduce Trimethlyamine oxide (TMAO) to Trimethlyamine (TMA) and convert urea to ammonia. Many volatile sulphur compounds are also produced by *Pseudomonas.*

A quantitative measurement of these compounds indicates the degree of spoilage. Fish flesh starts visibly to spoil when bacterial level rises to above 10^7 organisms per gram.

The flesh losses its culinary qualities like juiciness, firm texture, etc. changing it into a product that becomes soft with loss of flavor, discoloration and off flavor. The major deteriorative changes brought about by microorganisms in fish are the following.

a) Formation of ammonia:-

Spoilage organisms convert many nitrogen compounds into off smelling volatile bases. Non-protein compound present in fish are good substrate for spoilage organisms. The free amino acid pool in the muscle of fish is readily utilized by typical spoilage organism by the process of deamination. This result in the formation of ammonia which is the primary compound produced during decomposition of fresh fish. Ammonia is the major component in the total volatile nitrogen (TVN) fraction which often is used as a quality indicator for fresh fish. Urea present in elasmobranches like shark and rays is degraded to ammonia by bacterial action. Thus, high level of ammonia in these species is an indication of spoilage.

b) Formation of TMA:-

Marine fish is characterized by the presence of an odorless compound called Trimethlyamine oxide (TMAO). Marine flat fish and teleost contain low level of this compound (0.1-0.5%) while elasmobranches (shark, rays, etc.) and gadoids contain very high level(1 to 1.5%). Spoilage bacteria convert this substance into foul smelling Trimethlyamine (TMA). TMA is produced in fish muscle slowly at first then at greater speed in fish stored at ambient temperature, in ice or in refrigerated seawater. The fishy odor is produced when it reacts with fat.

c) Histamine formation:-

Microbial spoilage of fish produces the toxin, histamine in certain fishes. Histamine poisoning or scombroid fish poisoning is very frequent in

many countries. Scombroid fishes and other dark muscle fishes contain high level of free amino acid, histidine in their muscle. During spoilage histidine is converted into histamine by bacteria. Over fifty species including popular species such as Tuna, Bonito, Mackerel, Blue fish, Dolphin fish (*Mahi mahi*), sardine, carangids, herring, and anchovies were shown to be potential threat of histamine poisoning. Histamine production increases with temperature and 37^0 C is the optimum temperature for the microbial activity. *Morganella morganii, Hafnia alvei*, etc. are the main spoilage organisms producing histamine. Low temperature storage, right from catch, reduces histamine production.

d) Indole production:-

Conversion of tryptophan to indole is another result of amino acid decomposition by bacteria. The FDA uses indole level along with sensory evaluation for measurement of shrimp decomposition**.**

e) Other compounds formed during bacterial spoilage:-

A number of extractives are available in fish for bacterial action such as free amino acids, sugars, peptides, creatine, as well as lipid and proteins. Chemical examination of spoiling fish muscle has shown that organoleptically the most important constituents are the volatile sulphur compounds such as hydrogen sulphide (H_2S), dimethyl sulphide$(CH_3)_2S$ and methylmercaptan (CH_3SH). Ester of lower fatty acid such as acetic, Propionic, butyric, hexaenoic acid etc. are also produced. Volatile sulphur compounds influence the organoleptic characters, especially odors; in spoiling fish. The overall qualitative chemical picture of spoiling fish is summarized below:

Substrate	Compounds produced by bacterial action
Inosine	Hypoxanthine
Carbohydrate and lactate	Acetic acid, CO_2 & H_20
Methionine & Cysteine	H_2S, CH_3SH and $(CH_3)_2S$
Tryptophan	Indole

Glycine, Leucine & Serine	Esters of acetic, Propionic, butyric and hexaenoic acids
Trimethlyamine oxide	Trimethlyamine
Urea	Ammonia
Lipids	Carbonyls
Proteins	Tyrosine, Indole, skatole, putrescine, cadaverine
Histidine	Histamine

Some of the spoilage bacteria proteolytic and undoubtedly contribute to the ammonical odor by producing ammonia from the protein breakdown.

2) Pathogenic bacteria:-

The pathogenic bacteria associated with seafood's are of two types:

a) Indigenous bacteria:-

They are widely distributed in the aquatic environment. These pathogens occur in minimal numbers and are not a serious problem in fresh fish. However, their growth and multiplication in seafood is a serious problem and can cause illness.

Eg. *Clostridium botulinum, Vibrio sp., Aeromonas sp.*

b) Non-indigenous bacteria:-

They occur in seafood as a result of contamination. The source include polluted aquatic environment, sewage, excreta from animals, birds, human being, workers handling the material as well as the surface and environment where the seafood is processed.

Example *Salmonella sp, Shigella sp., E. coli, and Staphylococcus aureus*

C) Chemical spoilage (oxidation of the fish lipids):-

Fish lipid is characterized by a high level of polyunsaturated fatty acids (PUFA) and hence undergoes oxidative changes. With fatty fish in particular, fat oxidation give rise to problem such as rancid flavour and odor as well as discoloration. Lipid oxidation is by two process (a) Auto oxidation – action of O_2 on the unsaturated fatty acids and (b) Lipid hydrolysis – an enzymatic

hydrolysis with free fatty acids (FFA). Oxidative rancidity is of great concern in the fatty fish storage. In pelagic species like sardine, mackerel and herring, rancidity has been detected during spoilage. At first hydro peroxide are formed, which further degrade to form aldehyde and ketones with typical rancid flavor. The oxidation is initiated and accelerated by heat, light (UV radiation), presence of several organic or inorganic compounds (e.g. Cu and Fe), moisture content, large surface area, presence of air etc. Antioxidant such as tocopherols, ascorbic acid, citric acid or Carotenoids can inhibit oxidation.

Methods used to assess fish quality

Several methods are used to determine the quality of fish. These can be classified into sensory and instrumental methods. The latter comprise chemical, physical and microbiological methods.

Sensory evaluation of fish quality is the scientific discipline used to evoke, measure, analyze and interpret reactions to characteristics of food as perceived through the senses of sight, smell, taste, touch and hearing. Sensory methods have the advantage of being simple, cheap and rapid. However, they can be very subjective, as they are based on the assessment of individuals, their likes and dislikes. The subjectivity and bias can be reduced significantly by proper training and the use of proper descriptors and structured scaling. Also, advances are being made in the development of instruments capable of measuring parameters such as texture and other rheologic properties, and microscopic methods combined with image analysis are used to assess structural changes and "the artificial nose" is now used to evaluate odour profile.

Chemical methods rely on the measurement of metabolite(s) produced during fish storage or distribution to obtain a quantitative fish index. The most widely used chemical test is Total volatile bases (TVB), which measures the content of trimethylamine (TMA) + dimethylamine + ammonia + other basic nitrogenous compounds associated with seafood spoilage. Other tests target the separate measurement of TMA, DMA, nucleotide catabolites (known as the K-value) or biogenic amines contents (BA). The K or "freshness" index gives an indication of fish freshness during the early

stages after capture, whereas TMA, TVB or BA gives this indication at later stages when the bacterial spoilage starts. DMA is used to measure the quality of frozen fish. Also, oxidative rancidity is measured by evaluating the peroxide value (PV) during the early stages or the thiobarbituric acid-related substances (TBA-RS) during later stages. Fish authentication relies on electrophoretic or DNA sequencing methods. Chemical methods are rapid, quantitative and reproducible. However, no one test is capable by itself of providing a picture of the full spectrum of changes that take place in fish and lead to its spoilage.

Physical methods involve the measurement of fish pH, texture or electrical properties. These methods are rarely used because they are either not sufficiently reliable or require calibration depending on the fish species.

Microbiological examination of fish aims at evaluating hygienic quality of fish, including temperature abuse, and the possible presence of pathogenic microorganisms in the fish. They consist in the measurement of total aerobic bacteria also called total plate count (TPC), spoilage bacteria, and various pathogenic bacteria. They should be kept to the minimum as they are time consuming, costly and require technical skills. Several new rapid methods are being developed and marketed. They are based on immunological reactions (ELISA, monoclonal antibodies) or genetic engineering (PCR, DNA-probes).

Principles of various 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 freezing, drying, salting, smoking and canning.

Freezing

Freezing means removal of heat from the body. To check the enzymytic, bacterial action and putrefaction it is preferred to store the fish under lower temperatures. The 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. It is preferred to store at a temperature below 6.6°C to prevent microbial spoilage of fish. The formation of ice to some extent causes damage to the biological material, like growth of crystals of ice ruptures the structural components, releasing the enzymes and precipitation of liquid water and thereby causing precipitation of proteins effecting the change of pH making it more or less dry. The ice formation is initiated when the temperature of fish is lowered to about -1°C with a change in the concentration of inorganic and organic compounds. Freezing continues to fall with the lowering of temperature. At - 50°C to -60°C the entire water in the fish is frozen. The maximum freezing of water is between -10°C and -5°C with different sized crystal formation of ice.

Ice formation occurs at a place where heat is extracted and then spread to warmer areas from where heat is conducted to refrigerating medium. The size of the crystals depends upon the nature of freezing in slow or quick freezing. Large crystals formed in slow freezing, rupture the tissues more since it penetrates the cell wall easily and forms the drip. Drip is the flow of tissue fluids from the frozen fish or muscle during freezing of the fish or muscle. This drip is due to the cell damage caused in freezing. This drip leaches along with soluble protein, vitamins and minerals and gives an undesirable appearance. The formation of drip affects the appearance of the product and results in the loss of weight. Hence, drip is considered as one of the criteria for judging the quality of the frozen products.

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./gr.
- Due to high relative humidity of ice, it is very good for preservation.

- Ice is cheap and very effective preservative.

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.

There are several methods of quick freezing. Among the various types of quick freezing plants installed in India the carrier air blast type is widely used. Oil sardines, mackerel and seer are the three commercial important food fishes used in the application of refrigerated sea water for preservation. These fishes are stored in artificial sea waters prepared by dissolving common salt to give a sodium chloride content 3.5% at a temperature of -1.1 to 0°C. In general the fishes stored in refrigerated sea water had firmer texture and better appearance than ice-stored ones.In general different methods of freezing are adapted through sharp freezer. 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 in use in India.

Freeze drying

This is modified deep freezing, completely eliminating all chances of denaturation. The deep frozen fish at -20°C is then dried by direct sublimation

of ice to water vapour with any melting into liquid water. This is achieved by exposing the frozen fish to 140°C in a vacuum chamber. The fish is then packed or canned in dried condition. Any loss of flesh contents by way of leaching during melting of ice is thus avoided. The product is quite fresh looking in appearance, flavour, colour and quality.

Filleting and freezing of fish

The processing industry also adopted freezing of fish in the form of fillets at times when prawns are not available. Fillets are nothing but the strips of flesh cut parallel to the backbone of the fish. Fishes like milk fish, cat fish, perches, mullets, carps, eel, etc., are suitable for filleting and freezing. Filleting can be done by hand which is economical or by using a filleting machine. Fillets may be with or without skin and it fetches a much higher price in the luxury market.

Fillets are dripped in brine to enhance their appearance and to reduce the amount of drip and it also gives a salty flavour. The freezing of fillets can be an individual quick freezing of block freezing. After dropping in brine, the fillets wrapped in polythene sheet are frozen in contact plate freezer at -35°C to -40° C and stored at -23° C.

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.

Salting

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 picked. In some fishes like seer, black pomfret, Indian salmon etc., the gut is removed and filled with salt in 1 : 3 proportion. 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.

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 38^{o}C is raised from a smokeless fire. After this heating, cold smoke at a temperature below 28^{o}C is allowed to circulate past the fish. In case of hot smoking, first a strong fire produces a temperature around 130^{o}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 phenol content of the smoke acts as an antiseptic and it also imparts 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.

Canning

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 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. 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 nonacidic. 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.

Methods of canning

Filling:

Empty cans should be packed carefully by employing the manual labour

or through mechanical device. While packing, care should be taken to see that no air pockets are left which cannot be removed by exhausting. At the same time too tight packing should be avoided. It is always better to leave some space at the top for accommodating gas released while processing. Fatty fishes (salmon, herring, mackerel, etc.) results in acceptable products when salt is added. Non-fatty fishes call for special additives to improve flavour and texture. Brine is used when fish is not salted properly as an additive for enhancing flavour. Monosodium glutamate is used as additive for canned fish at a concentration of 1.6 gm / Kg fish. Vegetable oil and olive oils are also used for filling the cans.

Exhausting:

The air and gas from the can should be removed before its sealing process. This can be done by using exhausting which minimizes the strain on the can through expansion of air during heat processing. Removal of oxygen to avoid internal corrosion and creation of vacuum when the can is cooled are indication of sound packing since it protects colour and flavour of products and retains vitamins, etc. Further it checks the growth of organisms which requires air for growth. Later sealing is done to obtain air tight seal between the cover and the body of container so that the spoilage agents cannot enter the sealed container after the canned fish has been sterilised.

Processing:

Removal of air as completely as possible is an important factor in steam processing. The container along with the contents is heated in a retort at a temperature which is sufficient to kill the potential inactive spoilage agents without any damage to the fish inside. The retort systems can be operated continuously or in batches. The retort shall have an inlet at the top through which steam enters. The weight of the steam that entered the retort and the incoming steam both put together drives the air out from the bottom without mixing. Air pockets if present in a retort may give rise to uneven processing and lead to under processing while interfering between pressure and temperature. The processing time and temperature required for each food depends on various factors like types of pack, size of cans

retort system, etc. By adopting the above heating process the majority of the spoilage agents or bacteria are killed. If any bacteria remains unkilled they can be eliminated by subjecting it to rapid cooling immediately after processing. The can should be cooled to a temperature of 35°C which is sufficient for rapid drying of the can surface. It protects against rusting. Chlorinated water of 5 ppm can be used for cooling purpose. Even after careful regulation of pressure during and after processing, the cans are sometimes exposed to temporary leaks. Through these leakages the bacteria may enter-after processing. Hence, to minimise this, chlorinated water is used for cooling. The canned product should not be transported immediately since the salt pellets and others additives used may take some days for equal distribution throughout the can contents. It is advised to store for 3 months before final quality control. During this period all cases of leak contamination would show up.

Irradiation Treatment

Gamma radiation is considered an innovative and interesting method to preserve chilled, stored fish and also reduce microbial populations in fresh fish and fish products. Several researchers have reported increases in storage times of 1–3 weeks for fresh and cooked product and doubling of storage times for frozen products. Several authors have noted that irradiation doses of 2–7 kGy can reduce important pathogens in food such as *Salmonella*, *Listeria*, and *Vibrio* spp., including many of the fish-specific pathogens like Pseudomonadaceae and Enterobacteriaceae, which can be significantly reduced in number. The application of irradiation treatment in fish and seafood must be viewed as part of an integrated quality and safety management, incorporating good manufacturing practice (GMP) and hazard analysis and critical control points (HACCP). Irradiation doses between 0.75 and 1.5 kGy for fresh products and cooked products and between 2 and 5 kGy for frozen foods have been recommended Marcotte did not consider these doses to be sufficient enough to control spore-forming bacteria such as *C. botulinum* type E. Furthermore, it has been noted that irradiation does not eliminate the toxins produced by *S. aureus* and others, and consequently, it has been cautioned that whether irradiated or not,

fish and shellfish must be properly processed and stored cold (-3ºC) or in ice, or frozen. Other researchers have reported that fish may be irradiated at doses of 3–4 kGy, without appreciable increase in temperature during irradiation, and without affecting odor and taste, thus increasing the storage life of the product by two to threefold.

The Role of Packaging Technology

Proper packaging plays a crucial role in preservation of quality and delivery of safe, wholesome fish, and seafood products to the end user. Packaging performs three main functions, namely containment, protection, and information. With regard to fresh fish and seafood, packaging must be carefully selected to cope with the presence of water on fish skin, a condition that could contribute to breakdown of paper-based packaging as well as rapid microbial contamination. Packaging must also be selected to protect against adverse environmental and atmospheric condition as well as penetration of physical and chemical hazards. To facilitate supply chain management and marketing operations, adequate labeling of the package is essential to inform and educate the end user about the content and utility. Given the high perishability of fish and seafoods, only blemish-free and top-quality produce should be contained in the package. Innovative packaging technologies based on manipulating the gas-exchange characteristics of packaging material to control the oxido-reduction potential have been developed and applied to preserve and extend the storage stability of fish and seafood products. The application of vacuum packaging, CA or MA packaging around fresh fish is based on the following premise: some spoilage bacteria and lipid oxidation require oxygen—thus, reducing the oxygen around the fish will increase storage and shelf life. Depending on the fish species and intended end use, specific combinations of O2, CO2, and N2 determine the level of CA or MA. In practice, vacuum packaging, CA storage, and MA packaging are used in combination with refrigerated storage for preservation of fish and seafood products. The combination of methods must be optimized and closely evaluated to match specific requirements.