Technological Aspects of Fish Processing

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The world food situation requires continuing effort to increase and reserve the food materials, particularly protein foods from animal sources because of their value in up-grading the nutritional quality of the diet. The food materials get spoiled on storage and the type of spoilage depends on the composition, structure, types of microorganisms involved and the conditions of packaging and storage. The principal causes of spoilage in food are the growth of microorganisms, the action of naturally occurring enzymes in the food, chemical reaction and physical degradation and desiccation. The basic purpose of all food preservation is to prevent the above types of spoilage and make the food available at some future time or at distant locations.

There are several methods of preservation of foods. This article refers to the fundamental principles involved in different methods of fish processing with special emphasis on freezing and canning.

Freezing

Freezing means removal of heat from a body. Heat is a form of energy transferred by conduction, convection and radiation. The preservation of biological material by freezing depends upon the inhibitory effect of the low temperature upon the rate of growth of microbial organisms and the enzymatic and biochemical reactions which normally occur in unfrozen foods. Storage at low temperature is required to prevent the microbial spoilage of food. But, storage at such temperature has some adverse effect on many biological materials. The production of ice is responsible directly or indirectly for nearly all the undesirable side effects of low temperature storage. The mechanisms by which freezing injures biological materials are :

1. mechanical rupture of the structural components through the growth of ice crystals,

2. mechanical rupture of cells by growing ice crystals, releasing enzymes and substrates,

3. the effect of dehydration as liquid water is precipitated as ice which may cause (a) precipitation of proteins and other macromolecules from solutions and (b) changes in pH.

Changes during freezing

The physical changes which occur during freezing fish comprise formation of ice with expansion of volume and desiccation starting from the surface of the frozen fish with the consequent damage of muscle cells and concentration of minerals damaging the proteins and irreversibly altering them. During freezing, protein-water gel is completely altered because the water separates out as pure ice, leaving the proteins more or less dry. Freezing increases toughness which proceeds progressively during subsequent storage.

Formation of ice is initiated when the temperature of fish is lowered to about -1°C. At the same time, a concentration of various inorganic salts and organic compounds occurs. Consequently, freezing point falls. At -3°C about 70% of the water is frozen. At -5°C about 85% is frozen, at -25°C about 95% and between -50°C and -60°C almost all the water in fish is frozen. Thus the larger part of water is frozen between -1°C and -5°C and it is the rate of cooling during this temperature interval which determines the size of the ice crystals.

1. Slow freezing

Slow freezing forms big crystals rupturing the tissues more. Large crystals are able to penetrate the cell walls resulting in larger drip when the fish thaws.

2. Quick freezing

Quick freezing means generally that the temperature of every part of the product falls below the zone of 0°C to -5°C as rapidly as possible and within a certain limit. Quick freezing forms small crytals. There must be rapid rate of heat flow relative to a given temperature. So the problem is the speeding up of heat flow by reducing the resistance offered to heat exchange. For fish, this maximum time is given as two hours for the lowest region, that is the center of a package of fillets or the center of the thickest fleshy part of a whole fish. Freezing is complete only when the equilibrium temperature reaches -18°C. The product temperature is maintained at -18°C or colder during storage and transport with a minimum temperature variation. The advantages of quick freezing are the following :

a. Ice crystals formed are smaller.

b. As the freezing time is shorter, less time is allowed for the diffusion of salts and evaporation of water.

c. Decomposition is prevented during freezing.

Quick freezing can be effected in three ways :

a. Direct immersion of food in the refrigerating medium.

b. Indirect contact with the refrigerant, as by conduction through plates.

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

3. Drip formation

Excessive amounts of drip reflects degradation in the quality of frozen products. If the drip is discarded, water soluble nutrients and flavour are lost. Food that exudes a large amount of drip is usually dry and woody or tough in texture. A large amount of drip adversely affects the appearance of the product and causes a shrinkage or loss of weight. Accordingly, the amount of drip is often measured and used as one of the criteria for judging quality of frozen products.

General Methods of Freezing

Freezing is effected by the following :

1. Sharp freezer

Sharp freezer is a room which can be maintained at a low temperature usually -18°C or lower. This type of freezer takes considerable time for freezing food (air is a poor conductor of heat). This is slow freezing.

2. Air blast freezer

This differs from sharp freezer in that it is usually designed in the form of tunnel and takes full advantage of the heat - transfer effectiveness of rapidly circulating air. The temperature used in air blast freezing ranges from 0 to -30°C. Air velocity varies from 30 to 1050 metres / mt.

3. Contact plate freezer

Here the food, either packed or unpacked, is placed between metal plates and the heat extracted by direct conduction to the plates through which is circulated the refrigerant.

4. Vertical plate freezer

This freezer employs refrigerator plates to provide a series of vertical compartments or 'cans' into which the food is loaded for freezing.

5. Immersion freezing

In this method, the packed food is immersed in a low temperature liquid which absorbs heat from it.

The advantage of immersion freezing is that there is perfect contact with the refrigerating medium and therefore heat transfer is high. But there are some disadvantages also for this method of freezing such as : (i) the temperature has to be controlled carefully, (ii) it is very difficult to keep the medium from dirt and contamination, (iii) the refrigerating medium must be edible and capable of remaining unfrozen at -18°C and slightly below. Solutions of sugars, glycerol and sodium chloride are the ones usually employed.

6. Liquid freon freezing

In this case, the food is either immersed or sprayed by liquid freon.

7. Liquid nitrogen freezing

This affords the faster practical method of freezing and hence ensures the maximum possible preservation of initial qualities of food. The very low temperature and high refrigeration capacity of liquid nitrogen together with its inert characteristics which permit intimate contact with food, makes possible freezing rates many times faster than that which can be achieved using many other techniques.

8. Fluidized bed freezer

In a fluidizing freezer, the product to be frozen is individually suspended in the upward flowing cold air stream of the freezing tunnels and hence the best possible heat transfer is achieved between the air and the product. In this method, every fish is frozen individually and very quickly and there is no distortion of its shape by pressure. The freezing time for shrimp and similar small verieties is only a few minutes according to the size.

9. Cryogenic freezing

This name is applied for the freezing method where food is either immersed in or sprayed with very low temperature liquids such as nitrogen, air etc.

10. Sub - freezing

The application of negative temperature near -2°C ± -1°C is an advanced approach in the field of refrigerating technology. The sub-frozen fish has been found to keep its water holding capacity which favours the quality of products.

Canning

Canning may be defined as heat processing of food in a hermetically sealed container in order to reduce the population of bacterial contamination to a commercially safe level. For all practical purposes, it may be considered that fresh foods normally carry organisms which will cause spoilage if not restricted in their activity. The basis of canning process rests on the destruction of these organisms by heat and prevention of the entrance of others. The organoleptic and nutritive properties of the product are also retained to the greatest possible extent by canning.

Canning method

The basic method of canning operation consists of the following steps :

1. Preparation of raw materials
2. Pre-cooking / blanching
3. Filling
4. Exhausting
5. Sealing
6. Processing
7. Cooling
8. Labelling, casing and storing

1. Preparation of raw materials

Quality of any processed food depends on the quality of raw material. Therefore great care should be taken in selecting absolutely fresh fish for canning.

Once the raw material is received in good bacteriological condition, the general policy is to operate either under a cold or a hot schedule and avoid leaving the material at medium temperature for any length of time.

2. Pre-cooking / blanching

This is a process by which the raw food is heat treated before or after filling in cans but prior to sealing. The material is immersed in hot water / brine or exposed to live steam with or without pressure depending on the type of the material and pack.

Pre-cooking / blanching serves a number of purposes. One of the objectives is to shrink the raw product to permit adequate filling in the can. This step also expels respiratory gases from the cellular tissues which will improve the vacuum in the final product. It cleans the raw material and reduces bacterial contamination. The process inhibits enzymatic action and retards browning of some products. The extent of pre-cooking / blanching is determined by the characteristics of the individual food products.

3. Filling

Filling with correct weight of material has an important bearing in the canning process. For example, the efficiency of exhausting procedure is, in part, dependent on the amount of free space above the surface of the fish in the can, while the ratio of solid to liquid material markedly influences the rate of heat penetration into the container which affects the processing treatment.

4. Exhausting

Exhausting is to remove air and gas from the can. This procedure is necessary for the following reasons :

a. Minimisation of strain on the can through expansion of air during heat processing.

b. Removal of oxygen which accelerates internal corrosion of the can.

c. Creation of a vacuum when the can is cooled. Cans with bulging ends are regarded as unsound. It is necessary to ensure that the can ends remain flat or slightly concave throughout moderate storage temperature,

d. Oxidation of fat and consequent deterioration is prevented,

e. Vitamin C is preserved.

Vacuum is the condition where the pressure in a system is reduced from the atmospheric pressure. It is one of the indications of a sound packing procedure. It reduces the strain on the container during processing thereby preventing the buckling of the ends.

Biologically, a vacuum is important in that it restricts the growth of organisms requiring air for growth. Chemically, it is important to remove the oxygen from the air in the head space of containers. Vacuum in fish containers helps protect colour and flavour of products, assists in retaining vitamins, prevents rancidity due to oxidation and helps retard the corrosion of the plate and the corrosion of the closures of the glass containers. Physically, vacuum is of value in holding the closures on glass jars, keeping of ends concave in cans and reducing the pressure within containers while being heat treated.

5. Sealing

The objective of this process is to obtain air tight seal between the cover and the body of the container so that spoilage agents connot enter the sealed container after the canned fish has been sterilised.

6. Processing

Objective of this step is to apply heat to the container and its contents at a temperature and for a length of time sufficient to kill or inactivate potential spoilage agents without overcooking the fish. This process is the most important step in the canning operation.

Processing time and temperature required for each food depends on :

a The type and number of spoilage agent in or on the product.

b. The consistency of the product. Solid pack and thick liquid require larger periods of processing.

c. The acidity of the products. Most spoilage agents are less resistant to heat in the presence of acids and usually, the more the acid in the product the less is the processing time required.

The complete elimination of air from the retort is a vitally important factor in steam processing. Air reduces the retort temperature. Air being heavier than steam, tends to form a layer below the steam. A mixture of air and steam at any temperature is not as efficient as saturated steam at the same temperature. From these considerations it will be clear that sole reliance in processing should not be placed on pressure guage reading alone; there must be agreement between the readings of both pressure guage and thermometer, the accuracy of which is, of course, important and should be checked periodically.

7. Cooling

Objective of this process is the rapid removal of heat from the canned fish after processing to prevent overcooking. Also, rapid cooling of the canned fish tends to inhibit the growth of any spoilage agent that may not have been killed by the heat processing. The cans should be cooled to a temperature of 35°C and this will result in their retaining sufficient heat to ensure rapid drying of the can surface and thus protecting against rusting. Chlorinated water (5 ppm) can be used for cooling purpose.

8. Labelling, casing and warehousing

Every label must bear the name of the product, net contents and other specific information as required. Object of storing is to hold the canned fish under conditions that do not alter the quality of the fish or the appearance of the container. The processed cans must not be cased hot, because the loss of heat by radiation from the cases is slow and this will cause injury to quality.

In order to keep chemical change to a minimum, temperature of storage room for foods should be held just above the freezing point of the canned products. Glass packed foods should be protected from light. Light catalysed reactions include bleaching of colour, destruction of vitamins and flavour deterioration.

Spoilage of canned products

The chief causes of spoilage are the following:

1. under-processing, 2. inadequate cooling, 3. infection resulting from leakage through seams, 4. pre-process spoilage, 5. improper seaming.

1. Under-processing

Any pack which suffers spoilage as a result of the activities of organisms surviving the heating process can be termed under-processed. In under-processed packs the activity of the surviving organisms may result in gas production which causes the can to 'swell' or the contents may undergo acidification or some other undesirable change affecting quality; but no gas is produced. When growth of micro-organisms occurs without gas production, the affected cans have a normal appearance externally and spoilage is only detectable after the can has been opened.

2. Inadequate cooling

Some bacteria (thermophiles) multiply rapidly in a high range of temperature and failure to cool cans immediately after processing to a temperature of about 35°C may lead to serious spoilage.

3. Leakage through seams

The micro-organisms infecting canned fish as the result of post-process leakage of the containers may be of widely varying types. The main source of the organisms is the cooling water.

4. Pre-process spoilage

Spoilage of this type is an example of faulty canning practice whereby bacterial development in the fish is permitted during the preparation period. Processing may subsequently sterilise the pack, but the liberation of gas produced by the organisms during the lag period before processing may cause swelling or flipping of the cans.

5. Improper seaming

In ideal seaming, the edges of the cover and the body are properly folded to form five folds of metal. In improper seaming, the cover hook is compressed against the folded body hook creating an opening between the body and the cover for a portion of the perimeter through which spoilage agents enter the can.

Drying

Drying is a process by which water from a moist substance is removed. If air is used to carry away the water vapour formed, the process is called air drying. This can be 'natural drying' (exposed to outdoors to the effect of sun and wind) or 'artificial drying' (inside a dryer).

To be efficient, the outdoor drying requires a dry atmosphere, sunlight and also a slight breeze. Under unfavourable atmospheric conditions, artificial drying is advantageous. Artificial drying allows the process to be continuous (day and night) and permits the standardised production of a product of high and uniform quality.

During the initial stages of drying, the surface of fish muscle behaves like a saturated surface. During this period, the rate of evaporation is uniform and is the maximum. This stage of drying is known as the 'constant-rate period'. In practice, the constant-rate period is terminated when the rate of diffusion of water from the interior of the muscle cannot maintain a sufficient flow to the surface. The termination of constant rate period is followed by a rapid decline in the drying rate. The rate of drying continues to decrease and becomes negligibly small as the water content of the fish muscle approaches an equilibrium value. This period is known as 'falling-rate period'.

In the process of drying fish, the constant-rate period is very short whereas the falling-rate period lasts much longer. These two periods are critical because the surface layer of the fish is still moist, therefore perishable and susceptible to bacterial decomposition. To avoid this, drying operation during these two periods should be conducted at the highest possible rate.

The influence of air temperature in drying is considerable. Even a small increase of only a few degrees may appreciably improve the overall efficiency of the operation. The danger of cooking the fish is most pronounced and can be eliminated only by keeping the temperature below the tolerance limits of fish. The relative humidity of the drying air is also important. It regulates the drying rate and greatly influences the appearance of the final product. The drier the air, the higher the drying rate. The effect of air velocity is more or less similar to the effect of relative humidity. Good velocities also favour the distribution of the drying air circulating over the fish and increase the coefficient of heat transfer between the air and the fish.

Salting

Salting is a method of preservation based on the penetration of salt into the tissues and governed by the various physical and chemical factors such as diffusion, osmosis and a series of chemical and biochemical processes associated with changes in various constituents of fish. Salting starts the moment fish surface comes into contact with salt. The end of the salting process is the moment when all of the fish have reached the required salinity and acquired the appropriate taste, consistency and odour.

There are three basic methods used in the salting of fish. They are (1) dry salting, (2) wet salting and (3) mixed salting. Dry salting is characterised by the fish being salted with dry salt. A solution of salt is formed in the water extracted from the fish. The salt as a result of its hygroscopic ability and osmosis absorbs water from the fish and is then dissolved by it. Wet salting is a process by which the fish is put into a previously prepared solution of salt. The basic deficiency of wet salting is a rapid decrease in the original concentration of brine in the preservation process. Mixed salting is the method by which the fish is salted simultaneously with salt and with brine. In this method, the salt on the surface of the fish prevents the brine from becoming diluted. Thus the brine remains saturated.

Salting as such amounts to a process of salt penetration into the fish flesh. This period ends when the salt concentration of the fish tissue becomes equal to the concentration of salt in the surrounding solution. The method of salting has a great influence on the structural and mechanical features of the muscle tissue of the fish and considerable changes in shape may result.

In salting of fish, it is important to take into consideration the following factors: (1) purity of salt, (2) amount of salt, (3) duration of salting and (4) weather conditions. To reduce the accessibility of oxygen, fish must be completely covered by the brine.

Smoking

Smoking or smoke curing of fish is a method of preservation effected by a combination of drying and deposition of smoke constituents. When fish is smoked it is subjected to four basic treatments viz. brining, drying, smoking and heat treatment.

This type of preservation is effected either by 'hot smoking' or 'cold smoking'. During hot smoking, the temperature of smoke may rise, at times, to above 100°C while the flesh reaches 60°C and gets cooked. The heat treatment also results in partial sterilization, although subsequent reinfection and spoilage of the cooked flesh is still quite rapid. During cold smoking, the temperature is not more than about 30°C and the fish is not even partially cooked.

Formaldehyde, acids and phenols are the important constituents of smoke involved in smoke curing of fish. Among these, phenolic constituents are supposed to be the most effective in preserving fish.