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Lecture Notes

Part 1

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INFLUENCE OF TEMPERATURE ON THE PRESERVATION OF FISH

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Introduction

Live fish muscle is relaxed and elastic. Immediately after death rigor mortis sets in, then the whole body becomes inflexible and rigid. The onset of rigor depends upon the temperature, particularly on the difference of temperatures between that of water and storage. If the difference is great, shorter is the time from death to rigor. Fish being the most perishable of human foods, they start spoiling the moment they are taken out of water and die. Temperature being a very important factor accelerating the process of spoilage, in a tropical country like India the ambient temperatures are very conductive for causing quick spoilage in fish. The spoilage reactions commencing on the death of the fish proceed at a very rapid pace. The rate of spoilage of fish at 2.5°C is twice as fast as that at –1.1°C. At 5.5°C, it is twice and at 11°C it is four times as fast as that at 0°C. The spoilage cannot be stopped completely. The best that can be done is to slow it down by means of some refrigeration technique, the simplest of which is addition of ice.

As fish become unfit for human consumption in about 8 to 12 hours after they are taken out of water, it is imperative to cool them down with crushed ice as early as possible after they are caught in order to retain their freshness for the maximum length of time. Once the rigor is resolved, the fish become soft and bacterial proliferation starts. Icing has to be done before this stage sets in, *i.e.*, when the fish is stiff. Method of icing plays a very important role in bringing about cooling. The ice should come in close contact with the fish. The best method of doing this is by putting ice and fish in alternative layers in the container, the bottom and top layers also being ice. Total height of the fish-ice mixture so stored should not exceed one meter, as otherwise the fish in the lower layers gets crushed due to the weight from the above. The thicker the layers of fish, the more the time required to cool down. A shelf life of one hour at room temperature (say 30°C) for fresh fish is comparable to a storage life of one day in a properly iced condition. That is to say, a fish which retains its edibility for 10 hours at room temperature does so for 10 days when properly iced. Retention of edible quality of fresh fish increases with decrease in temperature. For example a fish which keeps fit for human consumption for 8 to 10 hours at 30°C does so for one day at 20°C, 2 days at 15°C, three days at 10°C, 4.5 days at 5°C, 10 days at 0°C, 15 to 20 days at –5°C and 30 days at –20°C. Fish can be stored in good condition for 3 to 15 days in ice depending on the species and several other factors. Fatty fish like sardine has a relatively shorter life of 2 to 5 days in ice. Such fish will become easily rancid due to oxidation of its unsaturated fat. The belly portion becomes very soft and gets easily ruptured due to the action of enzymes and bacteria. It is also known that freshwater fish have longer shelf lives than marine fish in ice, so also the tropical species keeps longer in ice than cold water species.

Freezing

Commercial freezing involves cooling to very low temperatures such that the water in the fish is converted into ice. Lowering the temperature will reduce the chemical and enzymatic reactions which can lower the rate of autolysis, delay the breakdown of ATP consequently delaying the onset of rigor mortis, and also delay the bacterial spoilage. This forms the basis of preservation of foods by freezing. The freezing point of any food will be lower than that of pure water. Freezing begins in the fish usually at –1 to –2°c. Partial freezing or super chilling involves lowering the temperature of the fish to about –2 to –3°c. Storage life of the partially frozen fish is almost double that of the fish stored in ice. However some loss of sensory quality is experienced when the storage period extends to five days. This is considered to be caused by the fluctuations in the storage temperature. A change in temperature of less than 0.5°C can be instrumental in intermittent melting or freezing of water in the fish and can have pronounced influence on protein denaturation. Dehydration or freezer burn is the most common problem encountered in fish during cold storage. Though the fish is frozen to very low temperature of even upto –40°C, the cold storage is maintained only at about –20°C to –25°C. The problem of freezer burn arises principally from a change in the relative humidity in the cold store. The decrease in the relative humidity increases the risk of freezer burn in the product. An important defect in the cold storage atmosphere is non uniform distribution of temperature. Circulation of air will then cause the product to have varying temperatures at different locations leading to increased dehydration. Air circulation in the cold storage should be maintained at the minimum as excessive circulation can cause increase in the incidence of dehydration. Air, as it passes over the product, can pick up moisture and hence dehydration will be more with more air passing over it. Similarly the design should ensure that the heat ingress, though it is unavoidable, is minimized.

Many bacteria are killed during freezing and the survivors die off slowly. Because of the long lag periods of bacterial growth at temperatures considerably below 0°C, the product may not undergo any serious deterioration in quality due to microbial growth. However the frozen fish is not free from viable bacteria and other microorganisms and is therefore subject to fast spoilage when defrosted and held at temperatures suitable for their growth. Food poisoning bacteria are known not to grow under conditions of freezing. *Enterotoxic stayphyococci* do not grow below 10°C and salmonella below 5°C. *Clostridium botulinum* types A and B do not grow and produce toxin below 10°C. However type E has been found to grow and produce toxin at temperature as low as 3°C. Storage of frozen fish at –10°C had been considered satisfactory. This will arrest microbiological activity. However the concentration of solutes in the unfrozen phase and consequent pH changes and enzyme activities can definitely accelerate some irreversible changes causing severe damage to the quality of fish. Frozen fish stored at –20°C has almost 4 times the shelf life compared to that stored at –10°C. Frozen fish stored at –30°C has almost double the shelf life than that obtainable at –20°C. For long time storage of frozen whole fish, fish or fish products, the ideal temperature is –20°C to –30°C or lower.

Modified atmosphere packaging (MAP)

In MAP, the air in the pack of food is replaced with a mixture of gases. Carbon dioxide, nitrogen and oxygen are the gases generally used in modifying the atmosphere. Among the different factors which influence the shelf life and keeping quality of fish packaged under carbon dioxide enriched atmosphere, storage temperature is one of the important factors, which influences the keeping quality of MAP products. The effectiveness of MAP decreases as the storage temperature increases due to the fact that the solubility of carbon dioxide also decreases at higher temperatures. For respiring products, increasing the temperature also increases the rate of respiration, resulting in a decrease in shelf life. The effects of temperature abuse are particularly important from the stand point of safety. Temperature abuse of MAP muscle foods may result in the rapid growth of both spoilage and pathogenic bacteria. The minimum reported temperature for *Salmonella* and *E. coli* inoculated in ground meat grew equally well at 12.5°C when the meat was packaged in low and high permeability film. *Staphylococus aureus* can grow and produce enterotoxin under anaerobic conditions at 10°C or less while *Yersina enterocolitica* has been reported to grow at temperatures as low as –2°C. Of major concern, with respect to safety of MAP fish is the growth and toxin production by *Clostridium botulinum* type E. Proper refrigeration is therefore essential in order to assure the effectiveness of carbon dioxide as an antimicrobial agent and to prevent potential growth of pathogenic organisms.

Drying

Over the years several improvements have been brought about in the process of drying keeping in view the consumer requirements. An important achievement in drying is the development of artificial driers where the important operational parameters like temperature, relative humidity and velocity of air can be controlled. This has led to dehydration which refers to a process of drying under controlled operational parameters like temperature, air velocity and relative humidity. Air temperature, RH of the air and air velocity are the parameters influencing drying rate of fish. The difference between dry bulb and wet bulb temperatures is related to the RH. When the difference becomes zero it implies that the air is saturated with water vapour (RH: 100%). A change in air temperature is usually accompanied by a change in RH. By increasing the air temperature, its moisture carrying capacity can be increased; however this may adversely affect the quality of the product. In the beginning of the drying cycle evaporation of water produces a cooling effect on fish and air around and hence the temperature of the fish tends to fall below the ambient. Difference in temperature does not show any appreciable influence on the drying rate at this stage. The influence of temperature on drying rate becomes more pronounced in the later stages of drying when the moisture content falls. In the low moisture range the drying rate is so slow that the cooling effect of evaporation is not appreciable. The fish being dried attains very nearly the temperature of the drying air. The internal distribution of water is the true factor which determines the drying rate in this phase. This can be accelerated by a rise in the material temperature. The recommended temperatures for drying fish of temperate waters is 25°C to 35°C whereas tropical fish is generally dried at 40 to 50°C. Higher temperature may cause cooking of fish flesh which will make the resultant dried product brittle. Therefore it is important that the temperature employed at any stage of drying is not high enough to result in cooking of fish flesh.

Salt curing

Salt curing, though is an important method of preservation by itself, with or without subsequent drying, is one of the most widely practiced methods of fish preservation throughout the world. When introduced in sufficient quantities in the fish flesh, salt can delay the activity of bacteria or even inactivate them by reducing the water activity. This forms the basis of preservation by salting. Temperature affects the salting process. With increase in temperature, salt penetration into fish flesh increases. Increase in temperature intensifies the thermal motion of particles and also causes a reduction in the viscosity of water. But increase in temperature also may increase the rate of spoilage. If the fish is salted at lower temperatures, the rate of penetration will be reduced, but the rate of spoilage will be reduced even more.

Smoking

It is an ancient method of preservation of fish. The principle involved in this method is to expose the fish, dressed and salted in the usual manner, to smoke generated by smoldering saw dust, coconut husk etc for various durations depending upon the degree of smoke flavour desired, followed by drying in the sun or artificially. Smoke imparts a pleasant and agreeable flavour to the fish besides exercising preservative action through its several chemical constituents. Two types of smoking, *viz*., cold smoking and hot smoking are popular. Cold smoking is a mild process where temperature is not raised enough for the fish flesh to undergo even a partial cooking (below 40°C). In hot smoking the temperature of smoke is high and the fish flesh is cooked even to the extent of partial sterlisation (above 70°C).

Canning

Canning is a method of preservation of food in which spoilage is averted by killing the microorganisms present by application of heat and prevention of subsequent contamination, the product being enclosed in a hermetically sealed container.

High acid foods like fish marinades and pickles containing acetic, citric or lactic acid do not support the growth of bacteria and hence spore forming pathogenic microorganisms will not grow in them. Such foods need heat processing only at 100°C or below. Generally the organisms that can grow in such acidic conditions can be destroyed in the temperature range 90-95°C. Fish packaged in tomato sauce is a medium acid food. Such foods will require heat processing sufficient to make them safe against *Clostridium botulinum*. Canned fish in general, except when packed in medium like tomato sauce, is a low acid food often with pH close to neutral. Therefore canned fish will require heat processing as do low acid foods to ensure safety against *Clostridium botulinum*. All foods likely to have the presence of *Clostridium botulinum* are processed on the assumption that this organism is present in the food and should be eliminated. However some heat resistant spore forming bacteria like *Bacillus stearothermophilus* which are responsible for the flat sour spoilage in canned fish will survive heat processing sufficient to eliminate the spores of *Clostridium botulinum*. Heat treatment sufficient to ensure their complete elimination will result in over cooking of the fish. Therefore in developing the heat processing requirements for low acid canned foods like fish, the golden rule is to avoid the contamination of the foods with such bacteria by resorting to hygienic handling practices. Only safety against *Clostridium botulinum* is ensured in such cases. This is the principle based on which thermal processing requirements of canned fish are generally arrived at. Generally heat processing is done at 115°C or 121°C depending on the product and medium.

High Temperature Short Time processing (HTST)

The relatively long time at temperatures upto 121°C employed to destroy the spoilage organisms in the conventional heat processing may affect the quality of food in appearance, flavour and nutritive value. One of the major achievements in the efforts to overcome this problem is the development of a High Temperature Short Time (HTST) processing technique. The basic approach in this technique is to achieve more rapid heating of foods so that higher processing temperatures and reduced time of heating can be employed. For every increase of 10°C in temperature beyond the maximum conditions of growth, there occurs a 10 fold increase in destruction of microorganisms resulting only in doubling the rate of chemical reactions responsible for product deterioration. Therefore, heat treatment at higher temperatures for shorter periods of exposure results in greater retention of the natural characteristics of this product than a process of equal lethality attained by heating at a lower temperature for longer periods. A temperature of 130-135°C is being used for HTST for thermal processing low acid products.

Conclusion

Temperature influences the spoilage rate and shelf life of fish in chilled, frozen, modified atmosphere packaging, drying, smoking and thermal processed products. High temperature short time processing is having good effect on the retention of nutrients. Among the different methods of preservation, drying and chilling are the cheapest methods of preservation. Freezing and canning are the expensive methods of preservation.

Suggested Reading

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