Fish Processing and Value Addition – A Global Scenario

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Value addition is defined as any activity along the supply chain that increases the usability, culinary attribute or economic viability of a food item. Processing of fish into a wide variety of value-added products is now common with the increase in demand for food products that are ready-to-eat or require little preparation before serving. Usually, value added fish products are perceived to be those that have added ingredients such as a coating (breaded/battered) or a sauce, are prepared neatly or in some way provide more convenience to the user. Actually it indicates a measure of factors added to the total worth of a product at each stage of the production. Value addition ties in with consumer convenience. For example, value addition can be a process for transforming fish fillets into products that are perceived by the customer as having added quality and interest.

Fish is one of the healthiest foods available to man and there is an ever increasing demand for fish and fishery products. Being a highly perishable commodity, fish require immediate processing and various options are available for the value addition of fish. Fish processing, particularly seafood processing and marketing have become highly complex and competitive and exporters are trying to process more value added products to increase their profitability. Value can be added to fish and fishery products according to the requirements of different markets. These products range from live fish and shellfish to ready to serve convenience products. In general, value-added food products are raw or pre-processed commodities whose value has been increased through the addition of ingredients or processes that make them more attractive to the buyer and/or more readily usable by the consumer. It is a production/marketing strategy driven by customer needs and perceptions.

Fish and fish products have presently emerged as the largest group in agricultural exports of India, with 10.51 lakh tonnes in terms of quantity and Rs. 33,442 crores in value. This accounts for around 10% of the total exports of the country and nearly 20% of the agricultural exports. More than 50 different types of fish and shellfish products are exported to 75 countries around the world. In 2016-17 India exported 11,34,948 MT of seafood, principally frozen shrimp and frozen fish, worth Rs 37,870.90 crores. Provisional export figures for April-November 2017 have shown an increase of 18.72% and 15.16% respectively, in volume and value (in $) of seafood exports. The increased production of Vannamei shrimp, increased productivity of Black Tiger shrimp and better price realization of major items like Cuttlefish, Shrimp and Squid helped India to achieve significant export turnover.

Technology developments in fish processing offer scope for innovation, increase in productivity, increase in shelf life, improve food safety and reduce waste during processing operations. A large number of value added and diversified products both for export and internal market based on fish, shrimp, lobster, squid, cuttlefish, bivalves etc. have been identified.

Chilling

Chilling is an effective way of reducing spoilage by cooling the fish as quickly as - possible without freezing. Immediate chilling of fish ensures high quality products (Connell, 1995: Huss, 1995). Chilling by use of ice is the most important method employed commercially. The storage life of fish kept in ice depends on a number factors which include species, size, method of capture, fat content, breeding conditions, feeding regime and the method of killing. In general, the keeping quality of non-fatty fish is better than fatty fish in ice storage. The quality and quantity of ice used are important factors in determining the shelf life of iced fish. In tropical countries, a 1:1 fish to ice ratio is ideal for ice storage. It is recommended to add about 12-20% extra ice to the fish in order to compensate for water loss from melting and bad handling (Zugarramurdi *et al*., 1995). It is generally accepted that some tropical fish species can keep for longer periods in comparison to fish from temperate or colder waters. Up to 35% yield of high value products can be expected from fish processed within 5 days of storage in ice, after which a progressive decrease in the utility was observed with increase in storage days (Venugopal and Shahidi, 1998).

Transportation of Chilled Fish

Land transportation of chilled fish is carried out in insulated or mechanically refrigerated vehicles. The refrigerated vehicle used for chilled fish transportation should have a minimum inside temperature of 7 ^{0}C (Venugopal, 2006). Air shipment of chilled fish requires a lightweight and protective container. Pads of nonwoven fabric encapsulating synthetic absorbent powder are used for chilling of air shipped fish. Special thermal barrier films are used in combination with the pads to protect fish containers from heat (Subasinghe, 1996).

Transportation of live fish and shellfish

Transportation of fish, crustaceans and molluscs in live condition is the best method to ensure that the consumer is supplied with fresh product. In India, traditional mode of live transport in open earthen containers and metal containers was practiced (Jhingran, 1975). In terms of the range of species and the distance shipped, tropical fishes stand first in live fish transport. Waterless transportation of live fish is also practised for many species where the animals are kept in moist conditions under optimal cold temperatures.

Freezing

Freezing is one of the better methods to preserve fresh fish. It may be either slow freezing or quick freezing. Slow freezing is accomplished by placing the product at a low temperature and allowing it to freeze slowly usually in still air. Quick freezing is accomplished in any one or combination of the following four methods:

- Air freezing
- Indirect contact freezing
- Liquid Immersion freezing
- Cryogenic freezing

Air freezing

Sharp freezing

Packaged or unpackaged marine products can be frozen in air at temperature from -18 to -40°C. If "sharp" freezing is employed, air is circulated slowly or not at all and the rate of freezing is very slow. It ranges from 3-72 hour or more depending on the conditions and size of the product. Sharp freezing is not common in modern freezing operations.

Air blast freezing

Circulating cold air at high speed enables freezing to proceed at a moderately rapid rate and this method is referred to as air-blast freezing. Air-blast freezing is usually accomplished by placing the products on a mesh belt and passing it slowly through an insulated tunnel containing air at-18 to -34°C or lower, moving counter current to the product at a speed of I to 20 meter/sec. Air at -29°C and at a speed of 10-12 meter/sec, is often satisfactory, although lower temperatures are preferred. Air blast freezing is economical and is capable of accommodating products of different sizes and shapes. It can result in (1) excessive dehydration of unpackaged products if conditions are not carefully controlled, and this in turn necessitates frequent defrosting of equipment and (2) undesirable bulging of packaged products which are not confined between flat rigid plates during freezing.

Spiral Belt Freezer

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

Carton freezer

This freezer consists of a number of carrier shelves which are automatically moved through the section of the unit. The operations are carried out hydraulic power with mechanical linkage to coordinate different movements. The boxes are fed automatically into the freezer on a feeding conveyor.

Fluidized Bed Freezing

Marine products of small size like prawns can be fluidized by forming a bed of prawns on a mesh belt and then forcing air upward through the bed at a rate sufficient to partially lift or suspend the particles. If the air used for fluidization is sufficiently cooled, freezing can be achieved at a rapid rate. An air velocity of at least 2 meter/sec. or more is necessary to fluidize the particles and an air temperature of - 35°C is common. The bed depth depends on ease of fluidization and this in turn depends on size, shape and uniformity of the particles. A bed depth of slightly more than 3 cm is suitable for small prawns where as a depth of 20 to 25 cm can be used for non-fluidizable products such as fillets. Fluidized bed freezing has proven successful for many kinds and sizes of products. The best results are obtained with products that are relatively small and uniform in size. Some fluidized-bed freezers involve a two stage freezing technique wherein the first stage consists of an ordinary air-blast freezing to set the surface of the product and the second stage consists of fluidized bed freezing.

The advantages of fluidized bed freezing are (1) more efficient heat transfer and more rapid rates of freezing and (2) less product dehydration and less frequent defrosting of the equipment. Dehydration loses of about 1% have been reported during fluidized bed freezing of prawns. The short freezing time is apparently responsible for the small loss of moisture. The major disadvantage of fluidized-bed freezing is that large or non-uniform products cannot be fluidized at reasonable air velocities.

Contact Plate Freezing

Fish products can be frozen by placing them in contact with a metal surface cooled by expanding refrigerants. Double contact plate freezers are commonly used for freezing fish/prawn blocks. This equipment consists of a stack of horizontal cold plates with intervening spaces to accommodate single layers of packaged product. The filled unit appears like a multi layered sandwich containing cold plates and products in alternating layers. When closed, the plates make firm contact with the two major surfaces of the packages, thereby facilitating heat transfer and assuring that the major surfaces of the packages do not bulge during freezing. Vertical plate freezers are also in use especially onboard fishing vessels. Contact plate freezing is an economical method that minimises problems of product dehydration, defrosting of equipment and package bulging. In this method the packages must be of uniform thickness. A packaged product of 3 to 4 cm thickness can be frozen in I to 1.5 hour when cooled by plates at -35°C. Freezing times are extended considerably when the package contains a significant volume of void spaces.

Liquid Immersion Freezing

Liquid immersion freezing or direct immersion freezing is accomplished when a product is frozen by immersing or by spraying with a freezant that remains liquid throughout the process. This technique is occasionally used for fish and prawns. Liquid immersion freezing can result in moderately rapid freezing. Freezants used for liquid immersion freezing should be non-toxic, inexpensive, stable, reasonably inert, and should have a low viscosity, low vapour pressure and freezing point and reasonably high values for thermal conductivity. Freezants should have a low tendency to penetrate the product, little or no undesirable effects on organoleptic properties and require little effort to maintain desired standards for sanitation and composition. Aqueous solutions of propylene glycol, glycerol, sodium chloride, calcium chloride and mixtures of sugars and salt have been used as freezant.

Cryogenic Freezing

Cryogenic freezing refers to very rapid freezing by exposing food products to an extremely cold freezant undergoing change of state. The fact that heat removal is accomplished during a change of state by the freezant is used to distinguish cryogenic freezing from liquid immersion freezing. The most common food grade cryogenic freezants are boiling nitrogen and boiling or subliming carbon dioxide. Boiling nitrous oxide also has been considered, but at present it is not being used commercially. The rate of freezing obtained with cryogenic methods is much greater than that obtained with conventional air-blast freezing or plate freezing, but is only moderately greater than that obtained with fluidized bed or liquid immersion freezing. For example, shrimp freeze in about 9 min in a commercial liquid nitrogen freezer and in about 12 min in a fluidized bed freezer. Currently liquid nitrogen is used in most of the cryogenic food freezers. Usually liquid nitrogen is sprayed or dribbled on the product or alternatively very cold gaseous nitrogen is brought into contact with the product. Freezing with carbon dioxide usually involves tumbling the product in the presence of powdered or liquid carbon dioxide. Carbon dioxide is absorbed or entrained by the product in this method. This entrapped CO_2 should be removed before it is packaged in an impervious material.

Crusto Freezer

This is a combination of cryogenic freezing system and air blast freezing system. The equipment utilizes the possibility of a fast and efficient crust freezing of extremely wet, sticky products which can then be easily handled in a spiral belt freezer or a fluidized bed freezer without deformation or breakage.

Pre-freezing and Freezing Consideration

The quality of frozen-thawed cooked fish is influenced by a number of factors including species, composition, size, how and where caught, elapsed time between harvest and freezing, the state of rigor and quality when frozen and the details of freezing process and frozen storage.

The major problems encountered during the freeze-processing of fish are oxidative deterioration, dehydration, toughening, loss of juiciness, and excessive drip. Effective pre freezing and freezing techniques are available for controlling many of these problems except toughening and loss of juiciness. Reasonable control of toughening and loss of juiciness can be accomplished only by storing fish for a minimal time and / or at temperatures at -18°C or lower. Undesirable oxidative changes in fish can be minimized by (1) eliminating oxygen (2) avoiding contamination with heavy metals (oxidative catalysts) (3) adding antioxidants and (4) by using low storage temperature. Dehydration can be avoided by applying glaze and suitable protective coatings.

Individually Quick Frozen Products (IQF)

Lobster, squid, cuttlefish, different varieties of finfish etc. are processed in the individually quick frozen style. IQF products fetch better price than conventional block frozen products. However, for the production of IQF products raw-materials of very high quality need to be used, as also the processing has to be carried out under strict hygienic conditions. The products have to be packed in attractive moisture-proof containers and stored at –30°C or below without fluctuation in storage temperature. Thermoform moulded trays have become accepted containers for IQF products in western countries. Utmost care is needed during the transportation of IQF products, as rise in temperature may cause surface melting of the individual pieces causing them to stick together forming lumps. Desiccation leading to weight loss and surface dehydration is other serious problem met with during storage of IQF products.

Some of the IQF products in demand are prawn in different forms such as whole, peeled and de-veined, cooked, headless shell-on, butterfly fan tail and round tail-on, whole cooked lobster, lobster tails, lobster meat, cuttlefish fillets, squid tubes, squid rings, boiled clam meat and skinless and boneless fillets of white lean fish. IQF products can be easily marketed as consumer packs, which is not possible with block frozen products. This is a distinct advantage in marketing.

Canning

Canning is a method of food preservation in which preservation is achieved by the destruction of micro-organisms by the application of heat of food packed in a sealed container. Since the canned foods are sufficiently cooked products and free from micro-organisms they offer consumer safety besides being ready to consume. Canning has the unique distinction of being an invention in the field of food processing/ preservation whereas all other methods can be considered as adaptation of natural processes or their modifications. Because of their very long shelf life and ready to consume feature canned products have become very popular and a variety of food stuffs, both plant and animal origin and their combinations are produced and distributed.

However, the fish canning industry in India is declining due to the high cost of cans. Recent innovations like polymer coated Tin Free Steel (TFS) cans provide a cheaper alternative. Studies conducted at CIFT showed that polyester-coated TFS cans are used for processing ready to serve fish products, which can be stored at room temperature for long periods. The industry can utilize these cans for processing ready to eat fish and shell fish products for both domestic and export markets. This will help in reviving the canning industry in India (Mallick *et al.,* 2006; Sreenath *et al.,* 2007)

Unit Operations in a canning process are:

1. Selection and preparation of raw material.
2. Pre-cooking / blanching
3. Filling in to containers.
4. Addition of liquid medium
5. Exhausting
6. Seaming
7. Heat Processing / Retorting
8. Cooling
9. Drying, warehousing, labelling and casing

Retort Pouch Processing

Reportable flexible containers are laminate structures that are thermally processed like a can, are shelf stable and have the convenience of keeping at room temperature for a period of more than one year without refrigeration. The most common form of pouch consists of a 3 ply laminated material. Generally, it is polyester / aluminium foil / cast polypropylene. See-through pouches made of polyester/aluminium oxide or silicon dioxide/nylon/cast polypropylene is also available. The manufacture of retort pouch packs involves a series of lengthy operations viz., filling, air removal, sealing, traying and heat processing in an over pressure autoclave

The pouches are heat processed in an over pressure autoclave. Work carried out CIFT has shown that oil sardines packed in retort pouches having composition polyester / aluminium foil / cast polypropylene remained in excellent condition even after a period of 3 years (Ansar Ali et al., 2005). Mackerel in curry packed in indigenous retort pouch and processed to an F_0 value of 8.43 can be kept at room temperature for 18 months in acceptable condition (Gopal *et al.,* 2001). Seer fish in curry medium packed in locally manufactured retort pouches, having a three-layer configuration of thickness 12.5 μm polyester /12.5 μm aluminium foil / 80 μm cast polypropylene with a F_0 value of 11.5 remained in good condition for up to 24 months at room temperature(Ravi

Shankar *et al.,* 2002). The flexible pouches manufactured indigenously employing the configuration recommended by CIFT has opened the way for commercialization of fish curry in retortable pouches. The process relies on heat sterilization and in many respects is analogous to canning with the imported tin can being replaced by a cheaper indigenous heat resistant flexible pouch. In comparison with frozen foods, the retort pouch provides a longer shelf life and does not require refrigeration, energy, expensive methods of distribution and storage. No chemical additives are added as most of the bacteria are killed by heat sterilisation. Test marketing of mackerel curry conducted by MPEDA have shown that the product had good acceptability and there is good demand for fish curry in flexible pouches.

Curing

Traditional methods of processing fish by salting, drying, smoking and pickling are collectively known as curing. Cured fish consumption is more in areas where the availability of fresh fish is comparatively limited, namely interior markets and hilly areas. This is also the cheapest method of preservation, since no expensive technology is used. In India roughly 20 % of the fish caught is preserved by curing. Considerable quantities of cured fish are also exported, mainly to Singapore, Sri Lanka and to the Middle East. Simple sun drying was the widely practised traditional method of fish preservation. By this, preservation was achieved by lowering of water content in the fish, thereby retarding the activity of bacteria and fungi. The heat was able to destroy the bacteria to a certain extent. Later on, a combination of salting and drying or salting, smoking and then drying were developed.

Methods of Drying

There are basically two methods of drying fish. The common one is by utilizing the atmospheric conditions like temperature, humidity and airflow. This is traditional sun drying. The other is dehydration or artificial drying, by using artificial means like mechanical driers for removal of moisture from the fish under controlled conditions.

Sun drying depends heavily on the natural weather conditions since the fish is dried by heat from the sun and the air current carries the water away. Here there is no control over the operations and many a time the losses cannot be substantiated. Hence it is necessary that the operations be controlled to get a product, which has an extended shelf life, but at the same time the texture, taste and flavour is maintained. It is here that artificial driers where processing parameters are controlled gain a lot of importance. Such processes are carried out in a controlled chamber or area. Such products have advantages over sun-dried products since they have better keeping quality and longer shelf life.

In mechanical driers, removal of water from the fish is achieved by an external input of thermal energy. This is an expensive method since there is need for fuel for heating and maintenance of the temperature. The drying chamber consists of a long tunnel in which the washed and cleaned fish is placed on trays or racks. A blast of hot air is passed over the material to be dried. After the required degree of drying the product is removed from drier and packed.

Salting

This is one of the oldest methods of preservation of fish. Salting is usually done as such or in combination with drying or as a pretreatment to smoking. During salting osmotic transfer of water out of the fish and salt into the fish takes place, which effect fish preservation. It is based on different factors like diffusion and biochemical changes in various constituents of the fish. Salting amounts to a process of salt penetration into the fish flesh. Penetration ends when the salt concentration of the fish equals that of the surrounding medium. Loss of water during salting limits bacterial growth and enzyme activity, thus preserving the fish. The high salt content prevents the growth of normal spoilage microflora in the fish; but halophiles, which can survive 12-15% of salt, will survive.

Smoking

Smoke curing is another traditional method of preservation of fish. It is generally a combination of salting, smoking and drying. Smoking is usually done in a specially designed kiln or a room. The source of smoke is wood, sawdust or coconut husk, depending on the particular flavour required. The fish that is salted and partially dried is used for smoking. Smoking can be done at temperatures below 35 ^{0} C (cold smoking) or at higher temperature (hot smoking). Liquid smoking by immersion in smoke liquor and electrostatic smoking is also practised in different countries.

Irradiation

Irradiation treatment involves controlled exposure of the food to radiation sources such as isotopes of cobalt (^{60}Co) or cesium (^{137}Cs), which emit gamma rays, and also X-rays and electron beams (Lagunas-Solar, 1995). Radiation processes that can be applied to fishery products include radurization (pasteurization of chilled fish), radicidation (sanitization of fresh and frozen products including fish mince by elimination of non-spore forming pathogenic bacteria) and disinfestation.

Radurization of fresh fish at 1 to 3 kGy reduces initial microbial loads by 1 to 3 log cycle, essentially reducing spoilage causing bacteria and extends their chilled storage life 2-3 fold. The treatment is effective for the extension of shelf life of most of the marine and freshwater fish species. Radicidation is sanitation of frozen products including fish minces by elimination of non-spore forming pathogenic bacteria such as Salmonella, Vibrio and other species at a dose of 4 to 6 kGy. The treatment, however, is limited in its ability to eliminate viruses and *Clostridium botulinum* type E spores, which jeopardize the safety of seafood through production of lethal botulinum toxin. Several studies have established the feasibility of low dose gamma irradiation at a dose of 1kGy for the disinfestations of dried fish. Irradiation at doses in the range of 0.1 to 1.0 kGy can prevent development of beetle larvae and adults in packaged, salted, dried fishery products (Rodrick, 1999; Venugopal 1990; Venugopal and Shahidi,1998; Venugopal *et al.,* 1999).

Battered and Breaded Products

The most prominent among the group of value added products is the battered and breaded products processed out of a variety of fish and shellfish. Battered and breaded products offer a ‘convenience’ food widely valued by the consumer. These are products, which receive a coat or two each of a batter followed by coating with breadcrumbs, thus increasing the bulk and reducing the cost element. The pick-up of coating can be increased by adjusting the consistency of the batter or by repeating the coating process. By convention, such products should have a minimum fish component of 50%. Coated products viz., fish fingers, squid rings, cuttlefish balls, fish balls and prawn burgers form one of the major fish and shellfish based items of trade by the ASEAN countries (Chang et al., 1996).

The production of battered and breaded fish products involves several stages. The method varies with the type of products and pickup desired. In most cases it involves seven steps. They are portioning/forming, pre-dusting, battering, breading, pre-frying, freezing and, packaging and cold storage.

The first commercially successful coated product is 'fish finger; or 'fish stick'. Later several other products particularly the coated fish fillet, fish portions, fish cakes, fish medallions, fish nuggets, breaded oysters and scallops, crab balls, fish balls, coated shrimp products, coated squid rings etc. became prominent in most of the developed countries with the advent of the fast food trade. The present day production of coated seafood items involve fully automated batter and breading lines which start from portioning and end with appropriate packaging of the product (Suderman & Cunningham, 1983; Dikhoof, 1990; Hutchison *et al.,* 1992; Joseph, 2003).A variety of battered and breaded products can be prepared from shrimp, squid, clams, fish fillets, minced meat from low cost fish etc. A brief profile of some important battered and breaded products is given below.

Fish Mince and Mince Based Products

Mechanically deboned fish meat is termed as fish mince. Fish mince is more susceptible to quality deterioration than the intact muscle tissue since mincing operation cause disruption of tissue and exposure of flesh to air, which accelerates lipid oxidation and autolysis. The quality of the mince is dependent on the species, season, handling and processing methods (Babitt, 1986). Also, low bone content in the mince (01-0.4%) is desirable for better functional and sensory properties (Grantham, 1981). Depending on the type of raw material, fish mince can have a frozen storage life up to 6 months without any appreciable quality deterioration (Ciarlo *et. al.,* 1985). Generally minced fish is frozen as 1-2 kg blocks at -40 ^{0} C in plate freezers and stored in cold store at -18 ^{0} C. Lipid oxidation and protein denaturation during frozen storage of mince can be prevented by the incorporation of spices, cryoprotectants and hydrocolloids (Joseph, *et.al.,* 1992; Jiang, *et. al*.,1986)

Fish mince is a major source of raw material for the preparation traditional products such as patties, balls, wafers, loaves, burgers, fish fingers, dehydrated fish minces, cutlets and pickled products (Regenstein,2004; Grantham,1981; Venugopal and Shahidi, 1995; Venugopal, e*t. al.*,1992; Joseph, *et.al*., 1984). The mince from different species could be combined to prepare composite fillets (Venugopal, 2006).

Surimi

Surimi is stabilized myofibrillar protein obtained from mechanically deboned flesh that is washed with water and blended with cryoprotectants (Park, 2005). Washing not only removes fat and undesirable matters such as blood, pigments and odoriferous substances but also increases the concentration of myofibrillar protein, the content of which improves the gel strength and elasticity of the product. This property can be made use of in developing a variety of fabricated products like shellfish analogues. India produces about 40.000 MT of surimi per annum ,70% of which comes from thread fin bream.

Kneaded products

Several kneaded products like kamaboko, chikuwa, hampen, fish ham and sausage are processed using surimi incorporating other ingredients. The ingredients used in most of these preparations are identical; however, the classification is principally based on the manufacturing process involved. The ingredients employed other than surimi include salt, monosodium glutamate, sugar, starch, egg white, polyphosphate and water. The method of processing all these products involves grinding together of the various ingredients to a fine paste and some sort of heat treatment at some stage.

Fibreized products

Fibreized products are in great demand among the surimi based imitation shellfish products. The ingredients used in the formulation of fibreized products includes, besides surimi, salt, starch, egg white, shellfish flavour, flavour enhancers and water. All the ingredients are thoroughly mixed and ground to a paste. The paste is extruded in sheet on the conveyor belt and is heat treated using gas and steam for partial setting. A strip cutter subdivides the cooled sheet into strings and is passed through a rope corner. The rope is coloured and shaped. The final product is formed by steam cooking the coloured and shaped material.

Fish sausage

Fish sausages are surimi or fish mince mixed with additives, stuffed in suitable casings and heat processed. The surimi or fish mince is mixed with salt (3-4%), sugar (2-3%), sodium glutamate (0.3%) starch and soy protein in a silent cutter and stuffed in casings by an automatic screw stuffer. The stuffed sausage is heated in hot water at 85-90°C for 40-60 min. After heating, it is cooled slowly to avoid shrinking of the tube and then stored at refrigerated temperature. The production of fish sausage in India is rather insignificant, although market potential for this product is good (Hassan & Mathew, 1999). Sausages prepared from rohu mince treated with potassium sorbate had a shelf life of 16 days at refrigerated temperatures (Sini *et. al.*, 2008).

Accelerated Freeze Drying

Accelerated freeze-drying is now being increasingly used for the preservation of high value food products. The product has the advantages like absence of shrinkage, quick re-hydration upto 95%, minimum heat induced damage etc. In India this technique is now applied for processing shrimp, squid rings etc. The possibilities for various ready-to-eat products based on fish and shellfish employing this technique are immense. In this, there is a speeding of the freeze drying process, as a result of modification in the heating mechanism. Food is arranged in single layers between metal sheets or grids held in a tray. This is kept between the heating plates. When the required pressure and temperature is attained in the chamber, fluid contained within the hollow plates is heated to temperature of 60 to 100° C. The heat is conducted through the metal mesh, and trays to the product while allowing the water vapour to escape through the mesh channels to the side of the heating plates from where it is removed. Otherwise the pressure at the food surface would increase and the ice will melt. When the ice is melted from the surface the pressure is applied to the plates using a hydraulic mechanism so that the mesh will be pressed against the surface of the fish giving more direct heat contact to the product. At the same time the temperature of the heating material is reduced since, after sublimation the surface temperature of the fish will be the same as that of heating plates (Balachandran, 2001). This method appeared to reduce the freeze-drying time appreciably from 10-12 hours to 6-7 hours, depending on the thickness of the food, temperature and pressure, and hence it is termed as accelerated freeze drying.

Extrusion technology

It is a technique used to form shapes by forcing a material through a region of high-temperature and/or pressure, and then through a die to form the desired shape. Food Extrusion is the process of cooking moistened, starchy, proteinaceous food material by the combined action of pressure, temperature and mechanical sheer. CIFT has worked on the production of extruded products by incorporating fish mince with cereal flours. The fish mince is mixed with cereal flours, spices and vegetable oil and extruded using a twin-screw extruded. The product obtained is finally coated with spice mix to provide a delicious snack that has been christened as "Fish Kure".

Hurdle technology

The concept of hurdle technology is based on the application of combined preservative factors to achieve microbiological safety and stability of foods (Leistner, 1978). The most important hurdles used in food preservation are temperature, water activity, acidity, redox potential, antimicrobials, and competitive microorganisms. A synergistic effect could be achieved if the hurdles hit at the same time at different targets that disturb the homeostasis of the microorganisms present in foods (Leistner, 2000).

For the fish products manufactured in industrialised countries, hurdle technology has been employed for two groups of products (Leroi, 2008). These are:

- Convenience products based on traditional products, like rehydrated salt-cured or dried fish. The raw material is a preserved semi-finished product but as the preservative is removed during processing, surviving pathogens in the raw material may recover. Minimising the survival of pathogens in this product is therefore, beside the hygienic process conditions, necessary to ensure product safety.
- Lightly preserved fish products which are uncooked or mildly cooked products, with low level of preservatives (NaCl < 6% WP, pH >5), such as cold-smoked salmon, carpaccio, slightly cooked shrimp. These products are usually produced from fresh seafood and further processing involves one or a few additional steps that increase risk of cross contamination. The treatments are usually not sufficient to destroy pathogens, and, as several of these products are eaten raw, minimising the presence and prevent growth of pathogens is essential for the food safety.

Innovative packaging Technologies

Modified Atmospheric Packaging (MAP)

Modified Atmospheric Packaging (MAP) is a process by which the shelf life of fish is increased by enclosing it in an altered atmosphere such that it slows down the degradation by microorganisms and development of oxidative rancidity. In practice fish/fish products are packed in an atmosphere of carbon dioxide and other gases like oxygen and nitrogen. MAP chilled fish is an attractive proposition both to the retailer and to the consumer. A number of authors have reported considerable increase of up to two or even three-fold in the shelf-life of fish packed in modified atmosphere compared to that of fish packed in air. (Shalini, 2000; 2001; Ozogul *et al*.,2000,2004; Jeya Shakila et al.,2003; Reddy *et al.*, 1995,1996; Yesudhason *et al.*, 2010).

Active Packaging

Active packaging refers to the incorporation of certain additives into packaging systems to alter the packaging atmosphere and to maintain it throughout the storage period with the aim of maintaining or extending product quality and shelf-life. There are two types of active packaging systems viz., scavenging systems (O_2, CO_2, H_2O, ethylene, taints) and releasing systems (CO_2, H_2O, antimicrobials, antioxidants). Studies conducted at CIFT on the active packaging of fishery products have demonstrated a significant extension of shelf life over air packed samples (Mohan *et al.,* 2008; 2009a; 2009b; 2010)

Intelligent Packaging

Intelligent packaging systems monitor the condition of packaged foods and communicate information about quality of the packed food during transportation and storage (Brody *et al.,* 2001; Kerry *et al.,* 2006). This consists of an external or internal indicator which can indicate whether the quality of the packed food has decreased before the product has deteriorated. Examples are Time Temperature Indicators (TTI) and Freshness Indicators. Time Temperature Indicator is simple devices which can show an easily measurable, time-temperature dependent change that reflect the full time temperature history of a food product. It is attached to the packaging material externally and activated by adhesion of the two materials. Freshness indicators indicate the spoilage or lack or freshness of the product, in addition to temperature abuse or package leakage. This is based on the reaction with volatile metabolites produced during ageing of foods which gives a visible colour change as an indicator. The U.S. Food and Drug Administration (FDA) recognize TTI in the 3rd edition of the Fish and Fisheries Products Hazards and Control Guidance.

Future scenarios for the global seafood industry

The prevailing consumer attitude towards the benefits of seafood are:

Functional: The focus is on the benefit of seafood to be convenient. Seafood is perceived to be just another source of protein with little differentiation, as its status as a healthy food is under greater competition from other categories. As a result consumers want their seafood to convenient with enhanced health benefits, and affordable.

Experiential: Seafood is perceived to be a superior source of protein with its own distinct benefits and rituals of consumption compared to other proteins. As a result consumers want their seafood to be an experience and are willing to pay more for it. Consumers have relatively high levels of education and interest.

Positioning seafood on future market scenarios

The following factors can play a major role in determining the seafood demand in future market situations.

Reframing seafood as a healthier substitute to other protein sources

Targeting individual dietary needs and aspirations through seafood

Creating seafood experiences that deliver moments of healthy pleasure

Redefining long-life seafood as a smart shortcut for busy gourmands

Using preservation technologies to lock in and maximize the benefits of fresh seafood

Making new trends instantly accessible to all

Extracting the essence of seafood to reinvent recipes

Extracting the vital essence of seafood from offcuts
Unlocking the power of seafood by pairing with marine and land 'super foods'
Diversifying out-of-home and portable solutions by blurring meal and snack formats
Creating high engagement with seafood through no contact preparation
Providing universal building blocks that can be easily customized to local tastes

The drivers of change for the Global seafood industry will be:

Growing disposable incomes in emerging markets
Rising and more volatile fish prices
Increasing scope of fishing regulations
Growth of high-end and premium seafood
Rising consumer awareness about healthy nutrition
Growing demand for traceability and transparency
Increasing desire for convenience
Depleting wild fish stocks
Growing exports of cheaper farmed fish from emerging markets
Rising oil prices
Growing Population: 7 billion mouths to feed
Rapid aging of the global population
Growing concern about processed foods and additives
Stagnant to moderate growth in Europe
Growing concern about the negative environmental impact of consumption
Growth of climate change impacts and extreme weather
Rising levels of sea pollution
Rise of 'quantified self' and data driven diets
Development of unconventional protein sources
Growing development of aquaculture technologies
Development of marine biotechnology
Continuing challenge of cold chain distribution from Ireland
Growing consolidation of the global seafood industry
Growing resurgence of 'from scratch' cooking
Increasing sophistication of food culture
The rising popularity of supplements and nutraceuticals
Growing interest in 'mood food'
Continuing negative attitudes towards fish preparation
New retail models combining foodservice

Growing influence of NGOs

Growth of fast casual foodservice

Conclusion

Consumers want a healthy, trusted protein source they can rely on. In this world the seafood industry adds value through innovation that optimizes health and builds trust. As people became more conscious about the benefits of good health and wellbeing in the face of a growing 'lifestyle disease epidemic' globally, they looked for foods that demonstrated enhanced nutritional and wellness benefits. The perceived healthiness of seafood meant that consumers naturally gravitated to the category. Yet as concepts of 'health' evolved, so too did consumer expectations of the seafood category - people increasingly expected seafood to be managed in a way that 'optimizes' its health benefits. The result was that seafood marketed as 'healthy 'was no longer enough to keep consumers engaged – people wanted seafood that would reliably improve their brain health, their mood, their skin, their fitness etc. However the higher levels of standardization in seafood production and processing enabled by new technologies meant that seafood became increasingly perceived by consumers as a functional source of protein. Consequently seafood increasingly had to compete against new categories of alternative protein sources, such as supplements and vegetable-based proteins.

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