Advances in Fish Processing Technologies

Bindu J & C.O. Mohan
Fish Processing Division
ICAR- Central Institute of Fisheries Technology, Cochin

Introduction

Worldwide there is a growing demand for fish and fish products. The increase in fish production is mainly from aquaculture species and wild caught. Responsible utilization of these resources by adopting suitable post-harvest technologies is equally important to prevent spoilage and post-harvest losses. Fishes have been one of the major sources of protein and forms an important diet whose demand is increasing globally. The awareness about its health benefits has resulted in recommendation of fish in the daily diet by many organizations including World Health Organization. Fish is highly rich in nutrients since it provides more than 20 % of the per capita animal protein for about 3 billion people of which more than 50% is under developed countries. Fish and fishery products are sources of protein containing almost all of the essential amino acids required for human health. The fishes are also an excellent source of omega-3 fatty acids, which contribute to visual and cognitive human development, Fishes also provide different types of essential minerals such as calcium, phosphorus, zinc, iron, selenium and iodine and vitamins A, D and B, thus helping to reduce malnutrition and non-communicable diseases which may co-occur when high energy intake is combined with a lack of balanced nutrition. Even though fish is highly nutritious, it is also highly perishable and it undergoes spoilage faster than any other muscle foods. Good handling practices coupled with proper preservation, packaging and storage will result in responsible management of this nutrient dense food commodity. Both conventional and advanced post-harvest technologies aim to preserve the quality of fish so that it can be transported to the distant locations under controlled storage conditions to offer quality products to the consumers. Conventional post-harvest interventions include technologies for chilling and freezing, curing and drying, thermal processing, smoking, extrusion, value added products and advanced packaging methods. Advanced technologies like High Pressure Processing, Irradiation, Pulsed light technology, Pulsed Electric Field, Microwave Processing, Radio frequency and Ultrasound have application in fish processing and preservation to offer quality products to consumers.

Conventional Processing Technologies

Live Fishery Products

It is believed that live fish is healthier and tastes better compared to the ones killed earlier or preserved, which is increasing the demand for live fish and shellfishes. These products fetches maximum price compared to all the other forms of value-added products as it maintains the freshness. Road transportation constitutes a major mode of transportation in many countries for fish products transport between regions. However, in India, marketing of live fish is very limited transportation and the candidate species include high value species, cultured grouper,

red snapper, seabreams, seabass, red tilapia, reef fish, air-breathing fishes, shrimp, crabs, lobster, clams, oyster and mussels. Basically, live transportation of fish is followed either by using water-filled containers with an oxygen source from outside or by using sealed plastic bags filled with oxygen. These methods are also called as open and closed systems of live fish transportation, respectively. Live transportation includes grading, crowding, netting, fasting, handling, and loading/packing, packaging at suitable medium and post-transport operations like unloading and handling which are potentially stressful to fish. Inappropriate handling, undue air exposure, food deprivation, poor water quality, inappropriate transport densities, sudden changes in water temperature, and rapid water movement are particularly stressful to the fish. Although live transportation looks very simple, it will have challenges for meeting the quality guidelines and health regulations of specified agencies. The stress induced during live transportation may result in mortality and globally around 10% of farmed fish die annually.

Chilling

Chilling is the most commonly used method for maintaining the freshness of freshly caught fishes. This is done normally by keeping fishes in melting ice or slurry ice so as to maintain the fish temperature around 1- 4 ºC, which delays the enzymatic action and microbial activity, thereby extending the shelf life of the products. Traditionally, chilling preservation is done by using melting ice, either flake ice or crushed block ice and 1:1 ratio of fish to ice. Slurry ice has been introduced for super chilling and lowering the core temperature of the fish quickly. A wide range of fish and shellfish products varying from whole, headless, peeled gutted, headless gutted fish, fillets, steaks, loins, cubes can be preserved by chilling. Shelf life of 12-15 days has been achieved for seerfish and black-pomfret. Indian Mackerel and Indian oil sardine had very short shelf life in ice (3-7 days), due to rancidity and belly bursting. Tilapia from freshwater and brackish water showed significant difference in shelf life when stored in ice. The former kept longer (14-15 days) than latter (8-10 days). In general, shrimps had a shelf life of 8 days, compared to 7-10 days for crabs and 8-9 days for cephalopods. Whole fish retains better quality in chilled storage compared to whole cleaned fish. Among the different types of ice, tube ice and slurry ice performed better in maintaining quality. As consumers prefer fresh fish products without chemical preservatives, use of alternative natural preservatives enhances the quality of fish. The chitosan treatment further extended the eating quality of skinless leather jacket steaks up to 16-19 days, compared to 11 days for control samples. Chitosan treatment for double filleted Indian oil sardine and ribbonfish enhanced the shelf life considerably. Treatment with plant extracts like rosemary (*Rosmarinus officinalis*) essential oil, curry leaf (*Murraya koenigii*) essential oil, ginger (*Zingiber officinale*) essential oil, oregano (*Origanum vulgare*) essential oil, essential oil from fresh lemon grass leaves (*Cymbopogon citratus*) and lemon grass extract, extracts of sea grape (*Caulerpa lentillifera*), moringa gum (*Moringa oleifera*), gum ghatti or Indian gum obtained from the species *Anogeissus latifolia*, tragacanth gum (*Astragalus* spp.), guar gum from guar beans (*Cyamopsis tetragonoloba*), mint (*Mentha arvensis*) leaves, citrus (*Citrus aurantium*) peels, pomegranate

(*Punica granatum*) peel and seed extract and grape seed extract alone or in different combinations improved the quality and shelf life of chilled fish products as they exhibit antimicrobial and antioxidant properties. These can be used by the industry as natural preservatives instead of chemical preservatives which may be harmful to human health in long term.

Advanced Packaging Methods for Chilled Fishes

Though chilled fish products are highly appreciated by the consumers, their limited shelf life pose threat to long term preservation. To overcome this, various packaging materials including laminated packaging materials can be used. The normal poly bag used in the industry is LDPE with very high permeability for water and gases which limits the shelf life of fish products. Use of packaging materials by laminating two or three packaging materials will improve the properties leading to improved shelf life. One such packaging material identified is polyester laminated with low density polyethylene for chilled fishes, which has given considerable improvement in the quality and shelf life of fish products. Apart from interventions in packaging material, advanced technologies like vacuum packaging, modified atmosphere and active packaging technologies have been developed by the Division, for a number of fishes.

Frozen Fishery Products

Most of the international trade in fishery products is done by freezing preservation. Freezing involves the conversion of nearly 80 % water present in fishery products to ice i.e., a phase change from liquid to solid phase takes place in freezing. During this process the microbial and enzymatic changes are minimal due to the less water available for their action. Slow freezing affects the quality, whereas quick freezing preserves the quality. Quick freezing is normally accomplished by using any of the following four methods: air blast freezing, indirect contact freezing (plate freezing), immersion freezing and cryogenic freezing. Normally products are frozen till it attains a core temperature of -18 ºC or lower and are stored in cold storage maintained at this temperature. The freezing and frozen storage of fish have been largely used to retain their sensory and nutritional properties. Frozen products form one of the largest portions of fishery products traded all over the world. Freezing time for different freezing methods, subsequent storage conditions, treatments to overcome problems during storage, packaging methods etc. requires optimization. Wrapping with polyethylene increases the storage life of fishery products. Frozen storage characteristics of body and claw meat of crab are significantly different and claw meat results in longer shelf life. Frozen storage of mussel meat indicates that cooked frozen meat kept for longer periods in better condition than the fresh meat. The shelf life of fishes differed depending on the fat content and period of ice storage before freezing. Effect of different freezing methods like plate freezing, air blast freezing and brine freezing methods on quality of tiger shrimp (*Peneaus monodon*) and Pacific white shrimp (*Litopenaeus vannamei*) indicated better textural and biochemical quality for brine frozen samples whereas salt content (NaCl) was slightly higher compared to plate and air blast frozen samples. Various chemical agents and natural ingredients results in reduced

thaw drip. Rohu fillets treated with 1% chitosan and gelatin and packed in polyester laminated with LDPE and frozen in air blast freezer prevented thaw drip formation considerably. Blanching and cooking followed by freezing is commonly used for shrimps and cephalopods in seafood industry.

Dried and Salted Fishery Products

Drying is perhaps one of the oldest methods of food preservation known to mankind. Drying or dehydration is mainly by application of heat to remove the water content and to concentrate the solid content, which in turn reduces the water activity of the product, thereby assuring microbial stability and extended shelf-life of the product. In some cases, salt is also used along with drying to prolong the shelf life of fish. Salt absorbs much of the water in the food and makes it difficult for micro-organisms to survive. Generally, small sized fishes such as anchovies, Bombay duck, lizardfish shark, ribbonfish, threadfin bream and lesser sardines; small freshwater fishes; medium and small sized shrimps are dried whole after proper washing, whereas some large species of fishes such as sharks and catfishes are washed, degutted and spread open to dry for human consumption. Some fish species are also dried for use as poultry feed. These are dried without any pre-treatment. In majority of the countries, sun drying has been the method predominantly used for drying. Due to poor quality, these products generally fetch low prices in the local as well as international markets. However, with the introduction of modern automatic hygienic drying techniques and attractive packaging, it has been possible to fetch better prices for dried fish products. Drying time varied from 10-11 h for solar drying and 20-22 h for sun dried shrimps. For fishes like ribbonfish, jewfish and lizardfish, drying time was 15-18 h in solar dryer compared to 28-32 h for sun drying. Solar dried samples had good sensory attributes and better acceptability. Treating with calcium propionate at appropriate level reduces fungal problems and the dried fish after treatment can be kept for 8-10 months, compared to only two months in the case of untreated samples. Laminated Bombay duck, a unique process, results in shelf life of at least one year. Dried jellyfish and *Beche-de-mer* from cured Holothurians commonly known as sea cucumbers are other seafood products preserved in dried form.

Smoked Fishery Products

Smoking is one of the most widely used traditional fish processing methods employed in many countries to preserve fish. The preservation effect of the smoke product is due to the absorption of smoke particle into the flesh and well as the drying due to the heat generated during the smoking process. The smoke particles, mainly phenolic compounds, carbonyl and organic acids, being absorbed by the product, inhibit bacterial growth on the surface of the product. The smoke particles also have a positive effect on the taste and colour of the product and in many instances, smoking is normally practiced to improve these sensory characteristics. Smoked fish product results in better sensory attributes and improves the shelf life. *Masmin*, a traditional product of Lakshadweep Island is smoked and dried ethnic product. Due to health risks involved in hot smoked product, liquid smoking is being practiced in some countries.

Sous-vide products

'Sous-vide' is a French word meaning cooking under vacuum. In this, the product is packed in suitable high barrier packaging material, vacuum packed and exposed to slow heating for cooking and then cooled immediately and stored under chilled storage or refrigerated condition. Processing conditions for cook chilled and vacuum cooking, commonly known as *sous-vide*, products has been optimized. Cook chilling at desired temperature improves the shelf life of cobia (*Rachycentron canadum*) considerably, compared to control samples. Shelf life studies of *sous-vide* packed cobia was 25 days, compared to only 12 days for vacuum packs. Condiment incorporated Indian white shrimp had a shelf life of 28 days, compared to eight and 15 days for air and vacuum packed samples in chilled condition.

Thermal Processed Fishery Products

Thermal sterilization is one of the most efficient methods of food preservation widely practiced world-wide. The main objective of the thermal processing is to achieve long term shelf stability. Thermal processing generally involves heating the food products packaged in hermetically sealed containers for a pre-determined time at a pre-selected temperature to eliminate the pathogens of public health significance as well as those microorganisms and enzymes that deteriorate the food during storage. Ready to eat fish in conventional form like natural pack, oil, brine and sauce, to ethnic varieties like curries of regional importance are available in the market. Canning of smoked sardines, canning of fish in brine and tomato sauce; canning of crab meat; squid masala; sardine curry; mackerel curry; seer fish moilee; tuna curry; mussel and clam in masala, curry and oil medium and region-specific curries, fish and rice combination, fish biryani are some of the notable products available in the market.

Specialty Fishery Products

A variety of value added products from low value fishes and specialty products can be prepared from fish and shellfishes. These include fish mince, *surimi*, balls, cutlets, fingers, patties, burger, coated products and many imitation products, specialty shrimp based products like whole shrimp, peeled shrimp, peeled and deveined (PD), peeled and un-deveined (PUD), cooked shrimp, stretched shrimp (Nobashi), cooked butterfly shrimp, skewered shrimp, shrimp head-on and centre peeled, shrimp head-on centre peeled and cooked, coated shrimps in different forms, coated squid rings, coated squid tube, coated fish fillets, coated oyster and mussels, wafers, fish with mixed vegetable products, fish soup powder, fish and prawn flakes, fish hydrolysates. Fish mince acts as base material for majority of these value added products. Fish fingers are regular rectangular sized fish portions made from either frozen fish fillet or fish mince. Skinless and boneless fillet are partially frozen before coating with batter and bread crumbs to get the correct shape of the finger.

Surimi

Surimi is a myofibrillar protein concentrate obtained from mechanical deboning of fish flesh which is washed with chilled water and with added cryoprotectants. Fishes from all the different habitats viz., marine, freshwater and brackishwater can be used for *surimi*

preparation. The *surimi* can be used as base material for the preparation of textured imitation products like lobster tail, crab legs, shrimp, scallop and crab stick.

Fish sausage

Sausages are usually prepared from minced meat mixed with ingredients like fat, binders, fillers, spices and salt, according to the consumer preference. The mixed and comminuted meat is stuffed into cylindrical casings, either natural or synthetic, of desired size and marketed either as fresh, cooked, frozen, fermented, smoked or dried.

Dry Ice for transporting High Value Products

Transportation of fishery products to distant places is normally done using refrigerated systems maintaining the cold chain throughout the transportation. High value products like frozen crab sticks or value added products can be done using dry ice (solid CO_2; -78 ºC). In this, 1:1 (product to dry ice) ratio in thermocol boxes can be maintained and this can maintain the internal product temperature of -20 ºC for more than 5 days. High value products can be transported to distant markets maintaining the desired product temperature using dry ice.

Advanced Processing Technologies

High Pressure Processing

High Pressure Processing (HPP) also known as high hydrostatic pressure processing or ultra-high-pressure processing is a novel food processing method where food is subjected to high pressures (up to 87,000 pounds psi or 600 Megapascals or 6,000 atmospheres) to achieve microbial inactivation or to alter the food sensory attributes so as to achieve desired qualities. The processing is undertaken with or without application of heat to the product. The technology is environment friendly since it requires only electrical energy and there is minimum waste of products. In HPP process, the product is generally packaged in a flexible or semi flexible container and loaded into a chamber filled with a pressure-transmitting fluid. The hydraulic fluid, which is normally water, is pressurized with a pump, and this pressure is transmitted through the package into the food. High pressure processing is independent of size and geometry of the food and acts instantaneously, thereby reducing the total processing time. The process is most suitable for liquid foods and solids which contain a certain amount of moisture. Since the pressure is transmitted uniformly and simultaneously in all directions, food retains its shape even at extreme pressures.

HPP can be applied in a wide range of processing areas. HPP can be used to extend the shelf life of products and to eliminate the risk of various food-borne pathogens such as Escherichia coli, Salmonella and Listeria and other spoilage bacteria without greatly affecting the color and flavor of the product. HPP can be used to develop new gel based products with desired sensory attributes and mouth feel. HPP is commonly used worldwide in shell fish processing for 100 % removal of meat from the shells and for reducing the microbial risks during raw seafood consumption. Applications for marination and impregnation of desired flavors and colours can also be effectively undertaken. Pressure assisted thermal processing for

development of shelf stable ready to eat products is another promising area of research. Pressure assisted freezing and pressure assisted thawing so as to retain the microstructure and reduce drip loss of fish products can also effectively carried out. HPP fish processed products are always stored at chilled temperatures and only high acid fruit products can be stored at ambient temperatures.

HPP is being used in the United States, Europe, and Japan on a select variety of high-value food products to extend shelf life or to improve food safety. Some products that are commercially produced using HPP are cooked ready-to-eat meats, avocado products (guacamole), tomato salsa, applesauce, orange juice and oysters. High-pressure processing provides a unique opportunity for food processors to develop a new generation of value-added food products having superior quality to those produced conventionally.

Conclusion

All the above technologies have the potential to inactivate the pathogenic and spoilage causing organism and helps in offering quality products to consumers. There is a need for optimizing the critical process factors to achieve the target inactivation level for specific food applications without affecting quality. In addition to this, the applicability of emerging technologies on an industrial scale needs to be compared with other technologies. Systematic work is also necessary to investigate the impact on the nutritional and sensory properties of the treated foods. Almost all the advanced novel technology equipment's are expensive but research is essential to evaluate the complete functionality of this equipment with special emphasis on product quality and safety. Industrial adoption of these advanced post-harvest technologies ensures quality products to consumers in a sustainable manner.