Chapter 3

Technological developments in fish processing technology

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Fish is a highly nutritious, protein rich food. In the last 50 years, the fish eaters of the world have doubled. Health benefits associated with fish consumption have resulted in consumers favoring fish products. The seafood industry has changed beyond recognition. India's seafood industry is one of her biggest foreign exchange earners. The export of marine products has steadily grown over the years from a meagre ₹ 3.92 crore in 1961-62 to ₹ 12901.47 crore in 2010-11. Export of fish products increased from 15732 tons (₹ 3.92 Crore) in 1961-62 to 813091 tons (₹ 12901.47 crores) in 2010-11. Average unit value realization increased from 1.29 US $ per kg in 1970s to 3.51 US $ per kg in 2010-11.

Off late, the annual growth of the Indian marine products industry is showing a downward trend. Quantity wise, the growth rate is encouraging but value wise it is poor. This is due to the failure of the industry to diversify its products and markets in tune with the changing market trends. The industry still remains mainly shrimp oriented, because it is more lucrative. Even though export of fish is high; the value realization is less compared to shrimp. India exports mainly whole fish and shellfish, which is processed into several high value products in the importing countries and are again exported at a very high rate. This has resulted in tremendous loss to our seafood industry. As the catches from the capture fisheries are declining, it is very important to utilize the harvested catch judiciously. The industry is also facing a crisis due to the disappearance of operating margins and the sector needs an urgent infusion of funds to avoid closures and lay-off.

Value addition and introduction of new types of products from low cost fishes is the only solution to the problem. Present market trends reflect a rapidly growing demand for ready to cook and ready to serve convenience products. Value addition is the most talked about word in the fish processing industry these days, because of the increased realization of foreign exchange and high unit value for such products. This has resulted in adoption of modern technologies in processing of value added products from fish and shellfish.

Technology upgradation and value addition have become necessity in processing several such products from shellfish and low value fish and successfully marketing them in overseas countries and in the urban domestic markets. The increased demand for fish has prompted the development of many new preservation techniques which can be adopted by the fish processing industry without sacrificing safety, quality, shelf life and satisfying the consumer demand.

Food processing occupies a position of major importance in the world food trade. In the past, studies on food preservation have been concentrated on developing new or improved products. At present and in future, studies on food preservation are of more critical nature such as reducing post harvest losses and developing new processes that optimize cost, nutritional quality, environmental impact and utilization of resources and energy. The spoilage rate of fish is very high compared to most other meat products. Hence there exists a great need for more effective and more widely used methods for fish preservation so as to reduce the staggering amount of fish that is unnecessarily wasted. The aim of fish processing is to develop novel preservation methods to prevent undesirable changes in the nutritive value and sensory quality of the products. This is achieved by developing cost effective methods of preservation which controls the growth of microorganisms, reduce undesirable changes in physical, chemical and sensory parameters and prevent contamination. The present status of Indian seafood industry with emphasis on need for special processing technologies like modified atmosphere packaging, active food packaging, high pressure processing, high pressure assisted freezing, pulse light preservation, radio frequency thawing, pulse electric field, ultra sound and super critical fluid extraction techniques have been discussed in this article.

Modified atmospheric packaging is a process by which the shelf life of fish is increased by enclosing it in an atmosphere so modified 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 has an extended shelf life of 10 days or more depending on the species. Different combinations of gases have been studied for extension of shelf life of fish in a modified atmosphere. Elevated carbon dioxide levels in MAP have been shown to inhibit the normal spoilage flora of seafood and double or triple shelf life. Studies conducted at CIFT, Cochin proved that a mixture of 80% carbon dioxide and 20% oxygen was more beneficial in extending the shelf life of *Catla catla* fillets when stored at 0-4°C. The shelf life was limited to 28 days using 80% carbon dioxide and 20% oxygen, and 20 days in gas mixtures of 50% carbon dioxide and 50% oxygen compared to 12 days in air. Gas composition of 40% carbon dioxide, 30% oxygen and 30% nitrogen was found to extend the shelf life of whole pearl spot by seven days. Using this gas composition the whole fish can be stored for a period of 18 days whereas air packed samples gave a shelf life of only 11 days. Dressed and gutted pearlspot packed in 60% carbon dioxide and 40% oxygen had a shelf life of 11 days in air compared to 22 days in modified atmosphere packaging. Seer fish steaks packed in 70% carbon dioxide and 30% oxygen had a shelf life of 12 days in air compared to 24 days in MAP. Seer fish steaks dipped in 1% sodium acetate or 2% potassium sorbate extended the shelf life up to 30 days. MAP can be effective if used in conjunction with packaging materials of correct O_2/CO_2 permeability characteristics. Properties required may not be found in one polymer, hence laminated films are used.

Active packaging is defined as a system of packaging that changes the condition of the package to extend the shelf life or to improve the safety or sensory properties while maintaining quality of foods. The condition of food determined by various aspects such as physiological, chemical, physical, microbiological and infestation can be regulated in numerous manners through the application of appropriate active packaging systems. These systems can be classified into active scavenging systems (absorbers) and active releasing systems (emitters). Scavenging systems remove undesirable compounds such as oxygen, excessive water, ethylene, carbon dioxide, taints and other specific food compounds. Releasing systems actively add compounds to the packaged food such as carbon dioxide, water, antioxidants or preservatives. Both absorbing and releasing systems aim at extending shelf life and/or improving food quality. Most important active packaging concepts include: O_2 and ethylene scavenging, CO_2- scavengers and emitters, moisture regulators, anti-microbial packaging, antioxidant release, release or adsorption of flavours and odours.

The commercial use of atmosphere modifiers and oxygen scavengers in particular, with fish products has been mostly limited to the Japanese market and to dried (seaweed, salmon jerkey, sardines, shark's fin, rose mackerel, cod, squid) or smoked (salmon) products. These ambient stored products have low water activity (less than 0.85), so the microbial deterioration is not shelf life limiting, therefore the effect of the oxygen scavengers is to prevent oxidative reactions, discolouration and mould growth. Other commercial products are fresh yellow-tail, salmon roe, and sea urchin, all stored at super-chilling conditions packaged with oxygen scavenger primarily to prevent oxidation and discolouration, and also to inhibit bacterial growth to a lesser degree. Different oxygen scavengers are chosen depending on the amount of oxygen required to scavenge (pack size and material) and product water activity. Oxygen scavengers for high water activity foods react faster compared to scavengers for dry foods but in general the absorption is slow and exothermic.

In some cases, like meat and fish products, high CO_2 levels (10-80%) are desirable to extend the shelf-life. CO_2 has a prevailing inhibitory effect on bacterial growth. It is particularly effective against gram-negative, aerobic and psychrotrophic spoilage bacteria, such as *Pseudomonas* sp. In MAP, partial vacuum is created in the package as a result of dissolution of CO_2 into the product and removal of O_2 using O_2 scavengers. In such cases, simultaneous release of CO_2 from inserted sachets is desirable. Such systems are based on either ferrous carbonate or a mixture of ascorbic acid and sodium bicarbonate. The commercial CO_2–emitters usually contain ferrous carbonate and a metal halide catalyst although non-ferrous variants are available, absorbing the oxygen and producing equal volumes of carbon dioxide. Carbon dioxide could also be produced inside the packages after packaging by allowing the exudates from the product to react with a mixture of sodium carbonate and citric acid inside the drip pad, an approach used successfully for cod fillets. Studies conducted using salmon fillets with soluble gas stabilization technique with combined oxygen absorber and carbon dioxide emitter (Ageless G-100) indicates fast microbial growth when stored in air without absorbers and slower growth rate using absorbers and emitter. Work carried out at CIFT indicates that catfish (*Pangasius sutchi*) steaks in air pack with O_2 scavenger had a shelf life of 20 days, whereas air packed samples had a shelf of 10 days at 0-2°C using EVOH pouches. Seer fish (*Scomberomorus commersoni*) steaks in indigenous HDPP trays with false bottom had a shelf life of 12 days, 25 days in CO_2 emitter without treatment and 30 days in CO_2 emitter with 1% sodium acetate treatment. Oil Sardine (*Sardinella longiceps*) beheaded, descaled and gutted had a shelf life of eight days in air, 16 days in CO_2 emitter and 26 days in CO_2 emitter with O_2 scavenger.

High Pressure Processing (HPP)

Hydrostatic pressure technology is a novel non-thermal food processing technology in which foods are subjected to high hydrostatic pressure in the range of 1000-8000 atm (100-800MPa), at or around room temperature. It inactivates vegetative microorganisms, spores, enzymes and increases shelf life of foods. It can also be used for texturization of food products as it denatures protein and poly saccharides. Thus it opens up unique opportunities to the food industry for the development of novel foods of superior nutritional and sensory quality, novel texture, more convenient, higher safety and increased chilled or ambient shelf life. The main benefits of HPP in fisheries include inactivation of contaminant microorganisms, texturization of proteins, shucking of oysters and improved freezing and thawing operations. It is widely accepted that conformational changes of protein by high pressure takes place which may be the reason for the extension of shelf life. In many surimi based fish products gelling is an important function and fish muscle protein paste forms a gel upon application of high hydrostatic pressure. So the application of high pressure helps to formulate a number of products with good functional properties. Studies conducted at CIFT on Indian white prawns indicate that HP treatment can improve shelf life of prawn during chill storage. However samples treated with 100 MPa are found to have marginal difference against control during storage period. Pressure treatments of 270, 435 and 600 MPa gave an extended shelf life by reducing total viable count, total Enterobacteriaceae count and inhibiting enzymes responsible for nucleotide degradation. Based on sensory attributes, 270 MPa treated sample has shown better acceptance even though it reached microbiological limit. In case of Yellow fin tuna chunks packed in EVOH pouches, control samples had a shelf life of 20 days, 100 MPa had a shelf life of 25 days and 200 MPa had a shelf life of 30 days during chill storage.

Compared to 300 MPa treated samples, tuna chunks treated with 200 MPa were superior to 300 MPa in all aspects.

High Pressure Assisted Freezing

At high pressure up to 210 MPa, water can remain in liquid state down to about -22° C. This allows rapid freezing and thawing. During freezing, use of high pressure helps in supercooling and promotes uniform and rapid ice nucleation throughout the sample on pressure release, producing small ice crystals which preserves the natural texture.

In high pressure assisted freezing, samples are cooled under 200 MPa to -20°C without ice formation. As the pressure is released, small ice crystals are formed which prevents cellular damage compared to conventional freezing. In this, phase transition occurs under constant pressure which is higher than atmospheric pressure leading to the formation of ice crystals. Conventional freezing techniques are known to have detrimental effects on the food depending upon the methods. Slow freezing of food results in larger ice crystal formation, which may cause extensive mechanical damage, accelerated enzyme and microbiological activities, as well as potentially increased oxidation rates, resulting from the increasing substrate concentration and the insolubility of oxygen in ice. The major advantages are pressure assisted freezing (pressure-shift freezing), pressure shift thawing and possibility for storage of food under non-frozen conditions at sub-zero temperature under pressure.

Pulse Light Preservation

Pulse light technology is an emerging non-thermal processing method and involves exposure of foods to short duration pulses of intense broad spectrum light. Involves the use of intense and short duration pulses of broad spectrum "white light", where each pulse, or flash, of light lasts a fraction of a second and the intensity of each flash is approximately 20,000 times the intensity of sunlight at sea level. The spectrum of light includes wavelengths in the ultraviolet to the near infrared region. Usually a wavelength distribution having 70% of the electromagnetic energy within the range of 170-2600 nm is used. These high intensity flashes of light pulsed several times in a second can inactivate microorganisms on food surfaces with remarkable rapidity and effectiveness. The technology can also be used to sterilize packaging material too. The material to be treated is exposed to at least one pulse light having an energy density in the range of 0.01-50 J/cm^3 at the surface. The effectiveness of light pulse treatment depends on several factors such as intensity, treatment time, food temperature and type of microorganisms. Light pulses have the ability to inactivate enzymes in food as well. However at present, industrial implementation of light pulse technology for food has been rather slow, despite its potential to produce safe, nutritious and high quality foods. Studies conducted at McGill university, Canada show promise for pulsed light treatment for cold smoked vacuum packaged salmon to control *Listeria monocytogenes* and *C. botulinum*. Work carried out at CIFT indicates that when Pearl spot fillets were packed in polyester polythene laminate and subjected to pulse light treatment for 12 sec using Xenon pulse light equipment with a total energy of 25 J/cm^2, the samples were acceptable up to 18 days compared to 12 days in control. The chemical parameters indicated that the pulse treated sample were superior to control samples.

Pulsed Electric Field (PEF) Processing

PEF processing involves treating foods placed between electrodes by high voltage pulses in the order of 20–80 kV for a short duration (usually 10 nano second to 20 micro second). The applied high voltage results in an electric field that causes microbial inactivation. The electric field may be applied in the form of exponentially decaying, square wave, bipolar, or oscillatory pulses and at ambient, sub-ambient, or slightly above-ambient temperature. After the treatment, the food is packaged aseptically and stored under refrigeration. The pulses are so short and frequent that all of the liquid in a pipe can be treated as it flows through the treatment chamber. By using multiple treatment chambers to apply pulses to a stream of fluid, kill ratios of 5-9 log have been achieved, similar to pasteurization without any adverse impact on the taste or nutritional value of the food. PEF can be used for processing liquid and semi liquid foods and holds potential as a type of low temperature alternative pasteurization process for sterilizing food products. PEF processing offers high quality fresh-like liquid foods with excellent flavor, nutritional value, and shelf life. Since it preserves foods without using heat, foods treated this way retain their fresh aroma, taste, and appearance. Application of PEF technology has been successfully demonstrated for the pasteurization of foods, fish soups, tomato juice and liquid eggs. Application of PEF processing is restricted to food products with no air bubbles and with low electrical conductivity. PEF is a continuous processing method, which is not suitable for solid food products which are not pumpable.

Radio Frequency Thawing

Radio frequency thawing is similar to microwave ovens where fish products passing through the oven (heater), are subjected to a direct or volumetric heating process in the form of a radio frequency (RF) energy source. The RF heating process depends upon the ionic conductivity of the material being heated.

Radio frequency thawing systems are also available, where the frozen product is placed between two parallel electrodes and alternating radio frequency energy is applied to the electrodes. Temperature rise within the product is relatively uniform, the degree of uniformity being dependent on the size and composition of the product. It is suggested that 5 cm blocks of fish can be thawed rapidly. However, radio frequency treatments have more promising attributes for processing seafood. At the lower frequencies of RF, penetration of the RF energy into foods is much greater and enables the temperature of blocks to increase from –20°C to –2 or 0°C. Radio frequency systems are available in both batch and continuous methods. Batch RF systems operate from 40 to 350 kg/hour while continuous RF systems can operate from 900 to 3000 kg/hour.

Ultrasound Preservation

Ultrasound is probably the most simple and most versatile method for the disruption of cells and for the production of extracts. It is efficient safe and reliable. Ultrasound techniques are relatively low cost and robust process. Ultrasound cavitation creates shear forces that break cell walls mechanically and improves material transfer. This effect is being used in the extraction of liquid compounds from solid cells. The compound to be dissolved into a solvent is enclosed in an insoluble structure. In order to extract it, the cell membrane must be destructed. For the purpose, ultrasound is faster and more complete than maceration or stirring. The particle size reduction by the ultrasonic cavitation increases the surface area in contact between the solid and liquid phase, significantly. The mechanical activity of this technique enhances the diffusion of the solvent into the tissue; Ultrasound breaks the cell wall mechanically by the cavitation shear forces and it facilitate the transfer from the cell into the solvent. This technique has potential advantages over other techniques including freedom from radiation hazards, which may appear in some of the existing non-destructive methods. The presence of the small gas bubbles in the sample can greatly attenuate ultrasound making signal detection impossible. This can be solved by using reflection measurements rather than transmission measurement.

Supercritical Fluid Extraction

Supercritical carbon dioxide is a fluid state of carbon dioxide where it is held at or above its critical temperature and critical pressure. Carbon dioxide usually behaves as a gas in air at STP or as a solid called dry ice when frozen. If the temperature and pressure are both increased from STP to be at or above the critical point for carbon dioxide, it can adopt properties midway between a gas and a liquid. It behaves as a supercritical fluid above its critical temperature (31.1°C) and critical pressure (72.9 atm/7.39 MPa), expanding to fill its container like a gas but with a density like that of a liquid. Supercritical CO_2 is becoming an important commercial and industrial solvent due to its role in chemical extraction in addition to its low toxicity and environmental impact. The relatively low temperature of the process and the stability of CO_2 also allows most compounds to be extracted with little damage or denaturing. The use of supercritical fluids as an extraction media provides a powerful alternative to traditional chemical extraction methods. SFE is relatively cheap, non-toxic, and non-flammable with zero ozone-depletion potential. Well known processes such as the decaffeination of coffee, or the fractionation of hops for the flavoring of beer, have been abetted by more recent processes producing an array of food-related products. These products include spice and flavor extracts, defatted or reduced-cholesterol products, natural antioxidants, and specialized oil-derived products for the nutritional market. However, the research works done on the application of SFE in processing fish and fish products are relatively scanty. The future appears bright for further extension of the critical fluid technology platform towards the processing of fish and fishery products for health food, and nutraceutical markets. Some additional benefits can occur when using high pressure carbon dioxide or water for processing seafood products, such as the deactivation of harmful microbes or enzymes, allowing sterilization or stabilization of the resultant end products, without resorting to the extreme temperatures and pressures required in ultra-high pressure seafood processing. CIFT has developed chemical techniques for the production of nutraceuticals from seafoods. Chemical processes involved in preparation of fish products are highly expensive in terms of chemicals and man power. Hence, an alternative technique such as SFE may be effective in the preparation of these products. Investigations by CIFT in collaboration with the private industry indicate that supercritical extraction is an effective method for extraction of fish oil rich in EPA and DHA.