

Advances in Fish Processing Technology

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Introduction

The demand for supply of healthy and safe food products is ever increasing and several new products are flooding the markets. Health, nutrition and convenience are the major factors driving the global food industry in this era. Fish products have attracted considerable attention as a source of high-quality protein, essential vitamins, minerals and healthful polyunsaturated fatty acids to the human diet. As a result of this fresh fish and seafood's rank third among the food categories with the fastest overall growth worldwide, next to drinkable yogurt (18%) and fresh soup (18%). Consumption of both freshwater and marine fish is expected to increase in the future. As fish is highly nutritious, it is also highly susceptible to spoilage, due to intrinsic and extrinsic factors. Proper processing and packaging helps in maintaining the eating quality of fish for extended periods. Processing and packaging technologies ranges from chilling or ice storage, salted and drying to most recent and advanced high pressure and electromagnetic field applications, which attracts opportunities from both small scale and industrial level entrepreneurs. Fish products in live, fresh chilled, whole cleaned, fillets steaks, battered and breaded products, variety of dried products, smoked fish, fish sausage and traditional products are the range of low cost processing methods which can be readily adopted by small-scale fishers. The processing methods like canning or heat processing, freezing, vacuum and modified atmosphere packaging, analogue products, high pressure processing, pulsed light processing, irradiation, electromagnetic field etc. are the processing methods which requires higher investments and can be adopted by large scale entrepreneurs, apart from the above mentioned processing methods.

Benefits of Processing

- Converts raw food into edible, usable and palatable form
- Helps in preservation and storage of perishable and semi-perishable commodities
- Helps in avoiding glut in the market and reduces post-harvest losses.
- Makes the produce available during off-season
- Development of ready-to-consume convenient products which saves time.
- Helps in improving palatability and organoleptic quality of the produce by value addition and helps in inhibiting anti-nutritional factors
- Helps in easing marketing and distribution tasks
- Enables transportation of delicate perishable foods across long distances

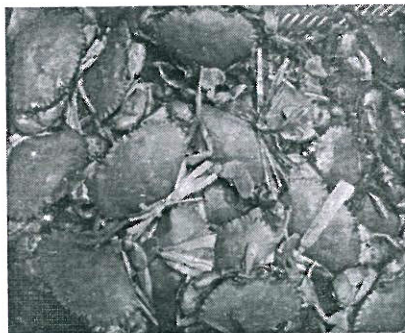
- Makes foods safe for consumption by controlling pathogenic microorganisms
- Modern food processing also improves the quality of living by way of healthy foods developed for special people who are allergic to certain ingredients, diabetic etc.
- Food processing also brings nutritional and food security
- Generates employment.
- Provides potential for export to fetch foreign exchange

Based on the perishability and the extent of preservation required, foods may be classified as:

1. **Perishable foods:** Those that deteriorate readily (Seafood, meat, fruits and vegetables) unless special methods of preservation are employed.
2. **Semi-perishable foods:** Those that contain natural inhibitors of spoilage (root vegetables) or those that have received some type of mild treatment which creates greater tolerance to the environmental conditions and abuses during distribution and handling (such as pickled meat and vegetables).
3. **Non-perishable foods (shelf-stable):** Those that are non-perishable at room temperature (cereal grains, sugar, nuts). Some have been made shelf stable by suitable means (canning) or processed to reduce their moisture content (dried fish and shellfishes, raisins). Food preservation in the broad sense, refers to all the measures taken against any kind of spoilage in food.

Live Fishery Products

There is a great demand for live fish and shellfishes, the world over. These products fetches maximum price compared to all the other forms of value added products as it maintains the freshness. The candidate species for live transportation include high value species, cultured grouper, red snapper, seabreams, seabass, red tilapia, reef fish, air breathing fishes, shrimp, crabs, lobster, clams, oyster and mussels. These are normally transported in air cargo maintained at low temperature in order to lessen the metabolic activities of the animals.



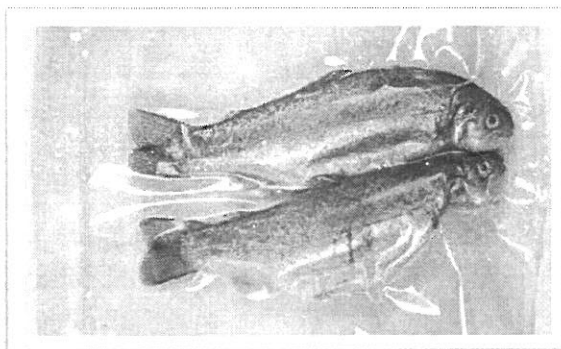
Live transportation of crabs

Chilled Fishery Products

Chilling is an effective method of maintaining the freshness of fish products. This normally involves keeping fishes in melting ice or slurry ice to maintain the fish temperature around 1- 4 °C, which delays the enzymatic action and microbial activity, thereby extending the shelf life of the products. Traditionally, chilling is carried out using melting ice, either flake ice or crushed block ice. Of late, slurry ice has been introduced for chilling. 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 fishes from different environment has been studied by the Division extensively. 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).

Vacuum packaging:

Vacuum packaging involves the removal of air from the package and the application of a hermetic seal. The air removal creates a vacuum inside the packs and lack of O₂ in packages may minimize the oxidative deteriorative reactions and aerobic bacterial growth. Vacuum packaging can considerably extend the viable shelf life of many cooked foods. The use of vacuum packaging, in gas impermeable and heat stable materials, has many advantages, which include; no or low risks of post pasteurisation contamination, ease of handling, Inhibition of growth of aerobic spoilage organisms and inhibition or slowing of deleterious oxidative reactions in the food during storage due to oxygen barrier properties of the packaging material.



Vacuum packaging machine and Vacuum packed fish

There are number of criteria required for the films used for vacuum packaging in large scale production methods. These requirements include: high durability, ie. ability to withstand considerable mechanical stresses during packaging, handling and transport, retention of flexibility even at low temperatures (-2 to 4°C) to enable satisfactory handling in the packaging

and refrigeration rooms, ability to withstand heating to at least 150°C without structural damage, leaching of potentially toxic plastics or plasticisers, impermeability to liquids, including oils and fats and macromolecules, impermeability to gases, in particular oxygen, so that oxidative deterioration of the packaged food stuffs is limited or inhibited, manufactured from non-toxic, food acceptable, odourless materials and must be able to create airtight durable heat seals to close packs. Many of these criteria have been met by a range of materials mostly multi layered or laminated plastics. Vacuum packed foods maintain their freshness and flavor 3-5 times longer than with conventional storage methods, because they don't come in contact with oxygen. Foods maintain their texture and appearance, because microorganisms such as bacteria mold and yeast cannot grow in a vacuum. Freezer burn is eliminated, because foods no longer become dehydrated from contact with cold, dry air. Moist foods won't dry out, because there's no air to absorb the moisture from the food. Dry, solid foods, won't become hard, because they don't come in contact with air and, therefore, can't absorb moisture from the air. Foods that are high in fats and oils won't become rancid, because there's no oxygen coming in contact with the fats, which causes the rancid taste and smell.

Modified Atmospheric packaging:

Fresh fish is highly susceptible to spoilage from post mortem autolysis and microbial growth. The high ambient temperature of our country favours rapid growth of microorganisms. Presently ice and mechanical refrigeration are the most common means of retarding microbial and biochemical spoilage in freshly caught seafood during distribution and marketing. However, as ice melts it tends to contaminate fish accelerating spoilage and reduces shelf life. Modified atmosphere packaging, a technologically viable method has been developed as a supplement to ice or mechanical refrigeration to reduce the losses and extend the storage life of fresh seafood products. In modified atmosphere packaging air is replaced with different gas mixtures to regulate microbial activity and /or retard discolouration of the products. The proportion of each component gas is fixed when the mixture is introduced into the package; however, no control is exercised during storage. The composition of the gas mixture changes from its initial composition as a result of chemical, enzymatic and microbial activity of the product during storage. It is primarily the enrichment of Carbon dioxide in the storage atmosphere as a means of controlling microbial growth, which results in the extension of shelf life of products. Carbon dioxide lowers the intra and extracellular pH of tissues and possibly that of microorganisms. Further it may affect the membrane potential of microorganisms and influence on the equilibrium of decarboxylating enzymes of microorganisms. The gases normally employed are carbon dioxide, mixtures of carbon dioxide and nitrogen, carbon dioxide and oxygen and carbon dioxide, oxygen & nitrogen with the sole objective to extend the shelf life of the product beyond that obtained in conventional refrigerated storages. Inhibition by Carbon dioxide manifests in an increased lag phase and a slower rate of growth of microorganisms during logarithmic phase. Inhibition by Carbon dioxide was found to be more effective when the product was stored at the lowest range of refrigerated temperatures. Packaging materials generally employed for this purpose are flexible films of nylon/surylyn

laminates, PVC moulded trays laminated with polythene, polyester/low density polythene film etc. The use of high barrier film along with MAP that contains CO₂ effectively inhibits bacterial growth during refrigerated storage of packaged fresh fishery products.



Modified Atmosphere packaging equipment

Gas composition analyzer

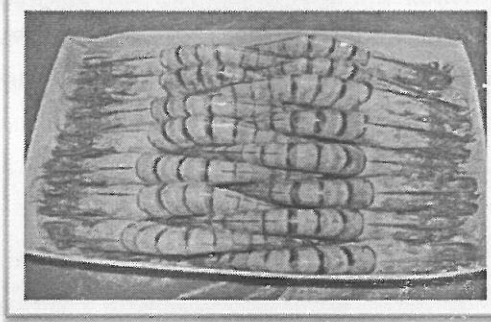
The composition of the gas mixtures used for MAP of fresh fish varies, depending upon whether the fish in the package is lean or oily fish. For lean fish, a ratio of 30 % Oxygen, 40% Carbon dioxide, 30% Nitrogen is recommended. Higher values of Carbon dioxide are used for fatty and oily fish with a comparable reduction in level of Oxygen in the mixture leading to 40-60% Nitrogen. By excluding oxygen, the development of oxidative rancidity in fatty fish is slowed. On the other hand, oxygen can inhibit the growth of strictly anaerobic bacteria like *Clostridium botulinum* although there is a very wide variation in the sensitivity of anaerobes to Oxygen. It is also seen that inclusion of only some Oxygen with Nitrogen or Carbon dioxide will not prevent botulism with absolute certainty.

Frozen Fishery Products

Freezing is an age old practice to retain the quality and freshness of fishery products for a long time. This involves the conversion of water present in fishery products to ice i.e., a phase change from liquid to solid phase takes place in freezing. This retards the microbial and enzymatic action by reducing the water available for their action. This involves exposing fish products to very low temperature ($<-35^{\circ}\text{C}$) to enable freezing of free water and maintained at -18°C till it is consumed. Plate freezing, air blast freezing, cryogenic freezing and individual quick freezing are the methods adopted by the industry to preserve food products.



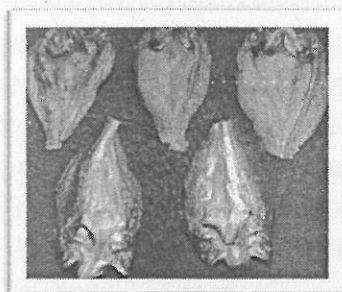
Block Frozen Prawns



Individually frozen Prawns

Dried and Salted Fishery Products

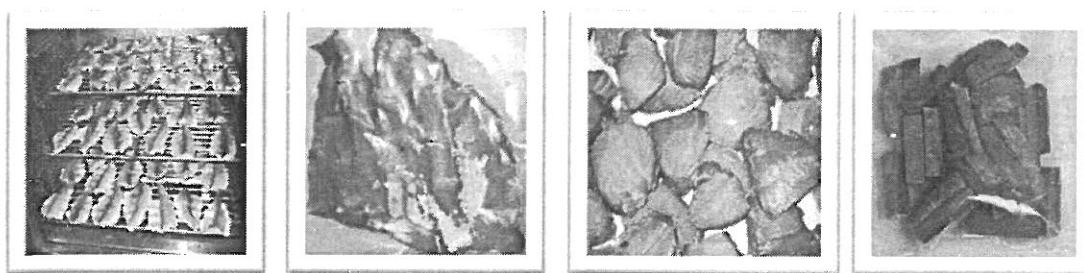
Drying is probably one of the oldest methods of food preservation. It consists of removal of water to a final desired concentration, which in turn reduces the water activity of the product, thereby assuring microbial stability and extended shelf-life of the product. In some cases, common table salt is also used 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.



Dried fish and shellfish products prepared hygienically

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 is a result of drying of the product during the smoking as well as due to smoke particle absorption into the flesh. 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.



Hot and liquid smoked fish chunks and masmin chunks

Retort pouch processing:

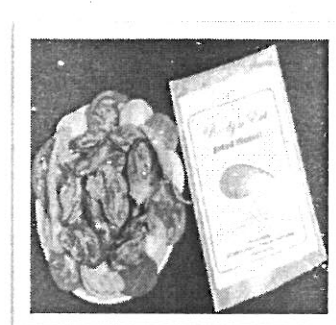
As in canning, retort pouch food is sterilized after packing, but the sterilizing procedure differs. The pouches are processed in an over pressure retort. The time and temperature will be standardized depending on the product. With the availability of retort pouches it can function as an excellent import substitute for metallic cans. Besides, cost reduction retort pouch packages have unique advantages like boil in bag facility, ease of opening, reduced weight and do not require refrigeration for storage. Processed food products can be kept for long periods at ambient temperature. The energy saving is more in processing in flexible pouches compared to cans. On a comparison of total costs, including energy, warehousing and shipping, the pouch looks even more favorable. There is 30 to 40% reduction in processing time compared to cans; solids fill is greater per unit, empty warehousing is 85% smaller and weight of the empty package is substantially smaller.



Retort Pouches



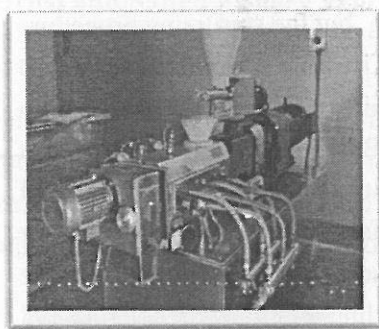
Retort pouch Products



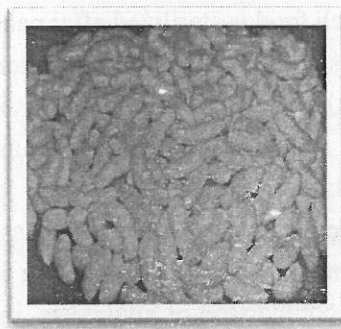
Extrusion

One such technology, which will be suitable for utilization of low value fish or by catch, is extrusion technology. Use of fish mince with cereals for extrusion process will enable production of shelf-stable products at ambient temperature. Extrusion cooking is used in the manufacture of food products such as ready-to-eat breakfast cereals, expanded snacks, pasta, fat-bread, soup and drink bases. The raw material in the form of powder at ambient temperature is fed into extruder at a known feeding rate. The material first gets compacted and then softens

and gelatinizes and/or melts to form a plasticized material, which flows downstream into extruder channel. Basically an extruder is a pump, heat exchanger and bio-reactor that simultaneously transfer, mixes, heats, shears, stretches, shapes and transforms chemically and physically at elevated pressure and temperature in a short time. At times, the extrusion cooking process is also referred as High Temperature Short Time process. In extrusion process gelatinization of starch and denaturation of protein ingredient is achieved by combined effect of temperature and mechanical shear. The conversion of raw starch to cooked and digestible materials by the application of heat and moisture is called gelatinization. During extrusion the conditions that prevail are high temperature, high shear rate and low moisture available for starch may lead to breakdown of starch molecules to dextrin.



Twin screw extruder



Extruded snack food



Microwave processing

The applications of microwave heating on fish processing include drying, pasteurization, sterilization, thawing, tempering, baking etc. Microwaves are electromagnetic waves whose frequency varies within 300 MHz to 300 GHz. Microwave heating is caused by the ability of the materials to absorb microwave energy and convert it into heat. Microwave heating of food materials mainly occurs due to dipolar and ionic mechanisms. Water content in the food material causes dielectric heating due to the dipolar nature of water. When an oscillating electric field is incident on the water molecules, the permanently polarized dipolar molecules try to realign in the direction of the electric field. At high frequency electric field, this realignment occurs at a million times per second and causes internal friction of molecules resulting in the volumetric heating of the material. Microwave heating also occurs due to the oscillatory migration of ions in the food which generates heat in the presence of a high frequency oscillating electric field. Studies showed that chemical changes involved during different microwave cooking practices of skipjack tuna and will retain omega-3 fatty acids compared to frying/canning. Microwave blanching can be carried out for color retention and enzyme inactivation which is carried out by immersing food materials in hot water, steam or boiling solutions containing acids or salts. Microwave drying is used to remove moisture from fish and fishery products. Microwave drying has advantage of fast drying rates and improving the quality of product. In microwave drying, due to volumetric heating, the vapors are

generated inside and an internal pressure gradient is developed which forces the water outside. Thus shrinkage of food materials is prevented in microwave drying. One of the disadvantages of microwave drying is that excessive temperature along the corner or edges of food products results in scorching and production of off-flavors especially during final stages of drying. Microwave combined with other drying methods such as air drying or infrared or vacuum drying or freeze drying gave better drying characteristics compared to their respective drying methods or microwave drying alone.



Microwave dried shrimps

Ohmic heating:

Ohmic heating is an emerging technology with large number of actual and future applications. Ohmic heating technology is considered a major advance in the continuous processing of particulate food products. Ohmic heating is direct resistance heating by the flow of an electrical current through foods, so that heating is by internal heat generation. Ohmic heating is defined as a process wherein electric current is passed through materials with the primary purpose of heating the object. During ohmic heating, heating occurs in the form of internal energy transformation (from electric to thermal) within the material. Therefore it can be explained as an internal thermal energy generation technology and it enables the material to heat at extremely rapid rates from a few seconds to a few minutes. Ohmic heating have a large number of actual and potential future applications, including its use in blanching, evaporation, dehydration, fermentation, extraction, sterilization, pasteurization and heating of foods. The microbial inactivation due to ohmic heating can be explained by the presence of electric field. The additional effect of ohmic treatment may be its low frequency (usually 50e60 Hz), which allows cell walls to build up charges and form pores. As a main consequence of this effect, the D value observed for the microbial inactivation under ohmic heating is reduced when compared to traditional heating methods. More research is needed to completely understand all effects produced by ohmic heating to food products, effects of applied electric field, the applied electric frequency during ohmic heating over different microorganisms and foods, cold spot determination etc.

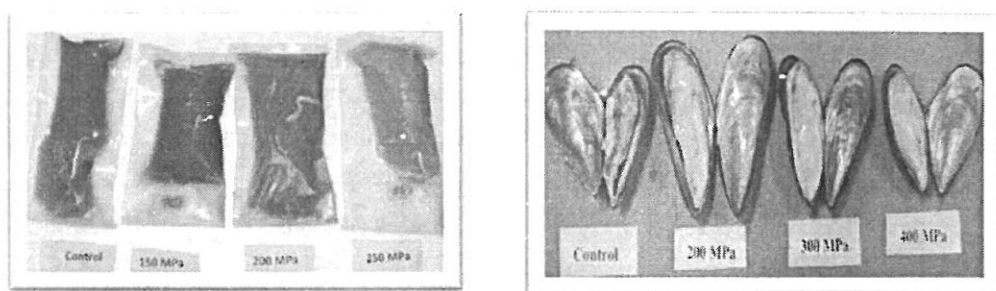
Infrared and Radiofrequency Processing Technologies:

Electromagnetic radiation is a form of energy that is transmitted through the space at an enormous velocity (speed of light). The heat generation in material exposed to EMR could be due to vibrational movement (as in case IR) or rotational movement (as in case of RF and MW) of molecules. Application of EMR heating is gaining popularity in food processing because of its definite advantages over the conventional processes. Faster and efficient heat transfer, low processing cost, uniform product heating and better organoleptic and nutritional value in the processed material are some of the important feature of EMR processing. In conventional heating system like hot air heating, the heat is applied at the surface which is carried inwards through conduction mode of heating. In case of EMR/dielectric heating, the waves can penetrate the material to be absorbed by inner layers. The quick energy absorption causes rapid heat and mass transfer leading to reduced processing time and better product quality.

The main advantage of electromagnetic heating over conventional electric and gas oven based heating is its high thermal efficiency in converting the electrical energy to heat in the food. In ordinary ovens, a major portion of the energy is lost in heating the air that surrounds the food, fairly a good amount escapes through the vent, besides being lost through the conduction to the outside air. In contrast, almost all the heat generated by electromagnetic radiations, which reaches the interior of the oven, is produced inside the food material itself. According to the reports the energy efficiency of EMR based systems is 40-70%, as compared to approximately 7-14% in case of conventional electric and gas ovens.

High pressure processing:

High pressure processing (HPP) is an emerging and innovative technology that has a great potential for extending the shelf-life with minimal or no heat treatment. It is also effective in preserving the organoleptic attributes of many foods. High pressure Processing is a non-thermal technology in which the food product to be treated is placed in a pressure vessel capable of sustaining the required pressure and the product is submerged in a liquid, which acts as the pressure transmitting medium. Water, castor oil, silicone oil, sodium benzoate, ethanol or glycol may be used as the pressure transmitting medium. The ability of the pressure transmitting fluid to protect the inner vessel surface from corrosion, the specific HP system being used, the process temperature range and the viscosity of the fluid under pressure are some of the factors involved in selecting the medium.



High pressure processed tuna and mussel

Ultrasound Processing:

Ultrasound refers to sound that is just above the range of human hearing, i.e. above frequency of 20 MHz. Ultrasound when propagated through a biological structure induces compressions and depressions of the medium particles imparting a high amount of energy to the material. The sound ranges for food applications employed can be divided into two, namely, low energy, high frequency diagnostic ultrasound and high energy low frequency power ultrasound. Low energy applications involve the use of ultrasound in the frequency range of 5-10 MHz at intensities below 1 W/cm². Ultrasonic waves at this range are capable of causing physical, mechanical, or chemical changes in the material leading to disrupting the physical integrity, acceleration of certain chemical reactions through generation of immense pressure, shear, and temperature gradient in the medium. Ultrasonics has been successfully used to inactivate *Salmonella* spp., *Escherichia coli*, *Listeria monocytogenes*, *Staphylococcus aureus* and other pathogens.

Application of enzymes:

Enzymes have been used for the production of various cured and fermented fish products from centuries. Because of their appreciable activity at moderate temperature, products and process have emerged that utilizes enzymes in a deliberate and controlled fashion in the field of food processing. Cold active enzymes including elastase, collagenase, chymotrypsin extracted from Atlantic cod were used in various food processing applications. The other applications of cold active enzymes include caviar production, extraction of carotenoprotein etc. Treatment with protease under mild treatment conditions extending for a few hours can result in the recovery of the proteins from fish frame or shrimp shell waste. The role of transglutaminase in surimi production is well established. The gel strength of surimi can be improved by the application of extracellular microbial transglutaminase. Lipase extracted from *Pseudomonas* spp. can be used to produce PUFA enriched cod liver oil. Enzymatic de-skinning of fish fillets was done by partial denaturation of skin collagen using a gentle heat treatment followed by immersion in enzyme solution for several hours at low temperature (0-10°C). De-skinning of tuna, Herrin, Squid were also carried out by using different enzyme technology.