Feed The Future India Triangular Training (FTF ITT) Program
On

RECENT TRENDS IN HARVEST AND POST-HARVEST TECHNOLOGIES IN FISHERIES

Date: 12 – 26 September, 2017
Venue: ICAR- Central Institute of Fisheries Technology, Kochi, India

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Published by: Director, CIFT, Cochin-29

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For citing entire book:

Ravishankar, C.N., Prasad, M.M., Mohanty, A.K., Murugadas, V., ManjuLekshmi, N., Anandan, R., Sajeev, M.V., Mohan, C.O., Rejula, K., &Aniesrani Delfiya, D.S. (eds.) (2017) *Recent trends in harvest and post-harvest technologies in fisheries*, Central Institute of Fisheries Technology, Kochi, India.

Example for citing a chapter in the book:

Ravishankar, C.N (2017) Indian fisheries: Harvest and Post-Harvest Scenario. *In*: Ravishankar, C.N., Prasad, M.M., Mohanty, A.K., Murugadas, V., ManjuLekshmi, N., Anandan, R., Sajeev, M.V., Mohan, C.O., Rejula, K., & Aniesrani Delfiya, D.S. (eds.) *Recent trends in harvest and post-harvest technologies in fisheries*. Kochi, India, Central Institute of Fisheries Technology, pp. 1-22.

Design and Cover page: Sh. ArunJyothi P.V

Printed at: Krishna Copy Center, Kaloor, Ernakulam-17

Foreword

ICAR-Central Institute of Fisheries Technology was established as Central Fisheries Technological Research Station CFTRS on 29th April 1957 and recently completed 70 years of existence with thundering Diamond Jubilee Celebrations. Building a scientific institution requires decades of dedication of not by one individual but of a strong team with indomitable altruistic spirit that is basis for strong foundations. In CIFT there is no dearth for that team spirit as evidenced by all walks of scientific progress from harvest to post harvest fisheries in terms of outstanding research, disseminating in different fora at national and international level. Knowledge gaining requires extremes of endeavours but more important is spreading the same to different levels to pragmatise makes it more fruitful. In this regard the present international training programme under Feed The Future India Triangular Training (FTF ITT) Program on '**Recent trends in Harvest and Post-Harvest Technologies in Fisheries**' being held from 12-26 September,2017 one more test to see how far the team spirit of CIFT can stretch to meet demands at global level. This programme is being organised as a result of new agriculture partnership between US and India to address Global Food Security as a part of FTF-ITT under the joint initiative of Indo-US collaboration funded by USAID, India and coordinated by MANAGE, Hyderabad is great opportunity for the CIFT team. I am sure they come out with flying colours. The manual contain more than 40 chapters covering all aspects of harvest and post-harvest fisheries by experts in the field with decades of pragmatic experience. On behalf of CIFT I welcome our international executive guests from Afghanistan, Afghanistan, Ghana, Kenya, Liberia, Malawi, Mongolia, Sudan and Uganda to the program with a wish they become brand ambassadors in taking forward the knowledge gained to respective countries to fill the much needed gap of food, nutritional security and socioeconomic essentials of millions through harvest and post-harvest fisheries.

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Content

Chapter 1

Indian fisheries: Harvest and Post-Harvest Scenario

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Fish as a cheap source of protein, bioavailable minerals, vitamins and essential fatty acids, ensures global nutritional security. India witnessed around 14-fold increment in fish production from 0.7 million tonnes in 1950's to 10.43 million tonnes in 2014-15. With a contribution of 5.05% to world's capture production and 6.6% of total aquaculture fish production, India emerged as one among the most progressive fish producing countries in the world. Fisheries as a major agricultural sector, constitutes 0.92% of total GDP and 5.58% of total agricultural GDP of India. With the global fish export value of 148,147 million USD, India ranked seventh position among the top fish exporters of the world. The sector is crucial in securing food supply, job opportunities, nutritional needs and earning foreign exchange for the country, cataloguing it as a sunrise sector of Indian economy.

Technological developments in harvest sector

Introduction of new materials for fishing gears, mechanization of fishing crafts and modern electronic technologies for navigation and fish location, paved way for the significant increase in fish production in India over the years. ICAR-CIFT has been involved in the design and optimization of a range of crafts and gears since its inception, which gave a major fillip to the harvest sector of Indian fisheries. Considering the plateauing /decline in catches perceptible since last two decades, ICAR-CIFT has shifted its focus from increasing production to responsible harvest of resources. As a result a large number of technologies for sustainable harvest and green technologies with reduced emissions were developed.

Environmental protection and eco-friendly technologies for harvest sector

The Institute has successfully constructed few rubber wood canoes treated with a dual preservatives and combination treatment technology developed at the Institute for marine and backwater fishing. The cost of the canoe is 35-40% less than a canoe of same size built of 'Anjili' (*Artocarpus hirsuta*), the usually used wood. This saves the depleting forest wealth, helps the rubber farmer to get a better prize for the under-utilized wood and gives a durable, maintenance-free boat at affordable cost to the poor (Fig.1).

Six new designs of eco-friendly and resource specific demersal trawls were developed. Trials carried out have shown that with proper rigging, none of the designs dragged bottom debris and benthos, preserving the bottom ecology of the trawling grounds.

V-form otter boards designed and popularized by the Institute have also helped in eco-friendly trawling which has become popular along Gujarat, Andhra Pradesh and Kerala coasts.

Harvest technologies for responsible fishing

Square mesh codends and V form otter boards were popularized as eco-friendly and conservational fishing methods. Square mesh cod ends were seen to function better than diamond mesh in conservation by ensuring escapement juveniles.

Use of optimum mesh size for target species and size class is imperative in order to prevent capture of non-target species, sub-adults and juveniles. With this in mind, a simple device for easy measurement of mesh size was developed. Selection of right size of mesh will help in popularizing responsible fishing.

Turtle Excluder device (TED) developed at the Institute was tested at Cochin, Visakhapatnam and Paradeep and found to be working satisfactorily. Turtle escape was 100% with minimum loss of valuable catch. The device is being popularized in maritime states where fishing induced turtle mortality is reported to be high.

The purse fishery of Kerala was facing hard times and as the number of vessels was reduced to 17 from 100 when ICAR-CIFT came up with suggestions for change in the mesh size. The purse seine nets and ring seines of Kerala are criticized for its very small mesh size (10-18 mm) destroying the fish wealth, as very small fish and juveniles cannot escape the net. The newly introduced purse-seine net has 45 mm mesh which has improved the catches. With increased mesh size, the target species were large sized mackerels, skipjack tunas, pomfrets, large sized carangid species etc. This net has found wide acceptance among fisherman. The new version of purse seine is a step towards conservation of fishery resources and at the same time assures good income to the fishermen, as the catches are of good marketable size.

CIFT SPTS-1 was developed as an alternative to shrimp trawling in the small-scale mechanized trawler sector, after extensive field –testing .It is capable of attaining catch rates beyond 200kg.h^{-1} in moderately productive grounds and selectively harvest fast swimming demersal and semi–pelagic finfishes and cephalopods, which are generally beyond the reach of conventional bottom trawls, currently used in commercial trawl fisheries in India.

Harvest technologies for the traditional sector

An improved design of FRP boat for backwater fishing was developed and canoes constructed for use in place of wooden canoes, which are very costly. Light weight, strength and durability are the main advantage of this material. They also have longer life when compared to traditional wooden canoes, which is a boon to the poor fisherman. The boat can be used for coastal fishing also.

Fiberglass reinforced plastic (FRP) sheathed, untreated rubber wood canoes were constructed and given for experimental fishing to artisanal fishermen. Both, the preservative treated rubber wood canoe and FRP sheathed untreated rubber wood canoe, were found to be in sound condition even after 26 and 16 month field operation respectively. Fishermen have shown interest in the new technologies.

High tenacity nylon monofilament of mesh size 30 mm bar were found to be superior to nets with other mesh sizes and was found best for fabrication of gillnets for obtaining good catches.

Design of twin hulled 3.6 m solar-powered boat for use in aquaculture farms, gillnetting, line fishing, transportation and aqua tourism (Fig.2). The boat with length of 3.6 m is twin hulled and is solely propelled by solar power. It can be put to use in aqua farms for aquacultural purposes and for gillnetting, line fishing, transportation and aqua tourism. Its main advantages are that it does not burn fuel, there is no atmospheric or sound pollution, has more deck space with clean FRP surface for fish handling and is suitable for shallow waters.

Harvest technologies for the mechanized sector

A prototype of a 5.22m L_{OA} aluminum alloy boat was designed and constructed for fishing and related activates in reservoirs and rivers. This is the latest in a series of materials being evaluated by the Institute for construction of fishing vessels for the artisanal as well as mechanized sectors. Light weight, corrosion resistance, toughness and resilience make aluminum alloy a good material for construction of marine craft. This new material avoids expenditure on paints etc. and gives good re-sale value.

A sail system for use on-board medium class fishing vessels was developed for reducing fuel consumption during free running mode.

Experimental fishing carried out with nylon gillnets and hand lines at Agatti islands, Lakshadweep have revealed the scope for use of these gears on the island. The islanders are now taking to such fishing methods in addition to the traditional pole and line fishing for tuna.

Standardized the parameters to exploit semi-pelagic fishery resources.

Separator trawl studies confirmed the differential behavior and sorting of catch to the lower and upper cod ends. The Internationally recognized Juvenile Fish Excluder cum Shrimp Sorting Device (JFE-SSD) was the resulting invention.

Design and construction of an energy efficient, green combination fishing vessel named, 'Sagar Haritha'. The 19.75 m multi-purpose fishing vessel, FV Sagar Harita, built under the project "Green Fishing Systems for the Tropical Seas" funded by National Agricultural Science Fund is a fuel efficient combination fishing vessel combines deep sea fishing methods like long-lining, gill netting and trawling (Fig.3). This development has turned out to be a land mark in the deep sea fishing industry of the country as no standard design of combination fishing vessel incorporating fuel efficiency features, to reduce carbon foot print is available for mechanized fishing sector of Kerala. Modifications in the hull design and changes in the operation parameters of this fishing vessel significantly reduce fuel consumption and emission of green house gases. The hull of the vessel is made of marine grade steel and the cabin and wheel house is made of FRP to reduce weight and to improve the carrying capacity and speed. The main engine power is 400 hp which is 20% lower than comparable size vessel. The fishing gear handling equipment such as split trawl winch, long line hauler, setter and gillnet hauler designed at ICAR-CIFT with hydraulic power are installed onboard. A 600 watt solar power panel is designed and installed for emergency lighting and navigational aids to promote the utilization of renewable energy resource in the sector. Acoustic trawl telemetry system with under water sensors is also installed onboard.

Harvest technologies for the inland fisheries sector

- Monoline fishing (long lining) was introduced for the first time in the reservoirs (Hirakud reservoir).
- Trammel nets of 70mm bar mesh size were found superior to other mesh sizes tried in the reservoir, contributing to 76% of the total catches
- Potential fishing zones of Thangu reservoir on Hariharjore, a tributary of Mahanadi, were demarcated based on optimum water quality parameters and depth. Survey was undertaken of some of the rivers of North Kerala with particular reference to use of bamboo in fishing. Bamboo is currently used in fabrication of traps, barriers and as gear and aquaculture accessories.
- ICAR-CIFT has designed and fabricated new collapsible fish trap and crab trap for the helping the poor fishermen operating fish

traps. Crab traps were operated in Cochin backwater with fish and chicken waste as bait. The design of the collapsible trap is simple and cost-effective and any fisherman can adopt the technology. Since it is made of synthetic netting, it is light in weight. A fisherman can transport and easily operate 10-15 traps using a canoe unlike the traditional traps.

Technological developments in post harvest sector

Preservation and processing aids

Chilling is the most common and traditional method of keeping fish in fresh condition. The simplest way for chilling is icing, by which fish can be kept for 12-15 days without spoilage. However, fatty fishes like oil sardine and mackerel show visible signs of spoilage even before 10 days of storage in ice. Freezing is the major processing technique applied for long term storage of fishes for human consumption. About 12% of the fish catch is frozen for further marketing or utilization against 26% in world scenario. Fisherfolk with no/little access to modern facilities rely on the traditional methods for the preservation of fish. This includes drying, salting, pickling and smoking. All these techniques are still in practice and are preferred over a wide range of population, even though chilling and freezing gets a preference. Drying and curing also remains as of considerable importance for the utilization of seasonal bulk landings. The conventional method of curing follows sun drying the whole/gutted fish with or without prior salting. Cured fish products have good economic potential and fetch attractive prices in global market.

ICAR-CIFT has introduced a hybrid solar dryer with an alternate electrical back up heating system. Effective harnessing of solar energy using specially designed solar air heating panels and proper circulation of this hot air across the SS trays loaded with fish with the help of blowers makes the drying process faster (Fig.4). The chance of contamination and spoilage due to sand, dust, flies, insects, birds, animals and rain is completely eliminated as drying takes place inside closed chamber. The spreading of fish in S.S. perforated trays and stacking of the trays inside the drying chamber helps in reducing the space requirement of the drying process. The alternate electrical back-up heating system under controlled temperature conditions enables drying to continue even under unfavourable weather conditions like rain, cloud, non-sunny days and even in night hours, so that the bacterial spoilage due to partial drying will not occur. The eco-friendly solar drying system reduces fuel consumption and ensures significant impact in energy conservation. In India, on an average, 5% of the total fish catch is converted to cured products against 12% of the cured product proportion in world fish production.

Smoking or smoke curing is an ancient method of preservation of fish. Smoking also imparts a unique taste and flavour to the fish. It is an age old practice of preserving certain varieties of fish like tuna and little tunnies. The practice of smoke curing of fish by heating fish in an earthen pot with firewood is popular in NEH states of India, Lakshadweep islands, and remote deltas like Godavari and Krishna deltas in Andhra Pradesh. Masmin, Ngari and Colombo cured fatty fishes are some traditional cured fish products commonly prepared in these regions. However, the practice is being discouraged by many on health grounds, as wood smoke quite often contains a carcinogen, benzopyrene. Also, long term and frequent exposure to wood smoke creates respiratory and eye ailments. ICAR-CIFT has developed an eco-friendly model of a community smoking kiln (Green kiln) popularly known as COFISKI, which ensures more shelf life of over six months to the smoked fish. The smoke cured fish products of COFISKI were free from human pathogenic bacteria such as *Salmonella*, *Shigella* and *E. coli* and harbored very few number of hygiene indicator bacteria viz., fecal Coliforms, fecal *Streptococci*, Coagulase positive *Staphylococci* making it safe and fit human consumption. In traditional fish smoking kilns curing of fish are confined to individual family, whereas, COFISKI inculcated community feeling among the fisherwomen in all the villages under adoption. Thus removing socio-economic barriers and tackling the problem as one group instead of solving alone.

Smart processing and packaging technologies - A leap towards energy efficiency

Seafoods are highly perishable and usually spoil faster than other muscle foods. They are more vulnerable to post-mortem texture deterioration than other meats. Freshly caught fish undergoes quality changes as a result of autolysis and bacterial activity. Extent of these changes with time determines shelf life of the product. The novel non thermal technologies like high pressure processing, pulsed light, ultrasound, irradiation etc. find application in preservation of food and are in the line of commercialization. Microwave processing is a thermal processing aid, which has gained wide popularity owing to the rapidity of the process and applicability to a large category of products. Recent trend is to employ these techniques in newer combinations that can deliver effective preservation, without the extreme use of any single technique. These techniques aim at inactivation of microorganism rather than inhibiting them. Another interesting application in the development of ingredients and finished products is the functional modification of the food macromolecules that help the processor to have outstanding quality, with reduced cost, time and energy. The new technologies now introduce more possibilities in non-thermal or mild heat alternatives to the conventional heat processing.

High pressure processing:

High pressure processing (HPP) is a non-thermal processing technique, which uses very high pressures of more than 100Mpa to preserve food by inactivating microorganisms, spoilage enzymes and alter the food attributes, in order to achieve consumer-desired qualities. HPP was initially adopted for processing beverages and semi-liquid food items, but now this has been one of the most explored technologies and today it is a commercial reality (Fig.5). Usually the product is packed in flexible packages before processing and preferably kept in refrigeration after processing. The major attraction is that the nutritional or sensory qualities of the product are retained and thermal ill effects are avoided. This technology is used in the area of seafood safety that led seafood processors to explore high pressure technology in product development and extension of shelf life. Oysters, clams, mussels, lobsters, crabs, shrimp, cod, hake, ready to eat (RTE) seafood meals, are some examples of products that are currently being processed with HPP. A potential application of HPP is for shucking bivalves (complete separation of meat from the shell) providing high yield of product without any mechanical damage. This technology could open up the new areas of product development and product improvements in all segments of meat and fish industry. Another approach in food industry is pressure assisted freezing and thawing, which finds its unique application in product development and product quality improvement. Since HPP has minimal detrimental impact on thermally labile bioactive compounds the technology is becoming a topic of major interest for cosmetic, nutraceutical and pharmaceutical industry. Salient findings of HPP in work done at ICAR-CIFT areas follows: Indian white prawns were subjected to pressure levels of 150, 200, 250 and 300MPa with holding time at 5 min at 25 °C and subsequent stored in iced condition for shelf life evaluation. 250 MPa had a shelf life of 30 days with respect to physical and biochemical parameters. Yellow fin tuna chunks were subjected to 150, 200 and 250MPa with holding time at 5 min at 25°C and subsequent stored in iced condition for shelf life evaluation. 200 MPa had a shelf life of 30 days. Evaluation of gel strength of fish mince (unwashed) and surimi (single washed) by high pressure treatment were carried out and HPP treated had positive effect on the gelling property of sausage.

Pulse light technology:

This non thermal preservation technique uses very high-power and very short-duration pulses of light emitted by inert gas flash lamps to decontaminate and sterilize foods (Fig.6). A spectrum of white light from UV wavelength of 200nm to infrared wavelength of 1100nm is used. Exposure to PL is in the form of high intensity UV light pulses resulted in microbial inactivation through a photochemical, photothermal, and photophysical route. Hence an effective microbial inactivation is achieved, without any adverse effect on the product properties. The application of pulse light has been conducted in various foods but only few studies have been reported in fish and fishery products. The use of pulse light for the sterilization of packaging material is a growing area of food research.

Pulse electric field technology:

PEF uses high voltage short pulses to preserve the food, so as to inactivate microbes with minimal effect on quality attributes of the product. It is one of the most appealing technology due to short treatment time (typically below 1 second); hence, foods treated this way retain their fresh aroma, taste, and appearance. It is suitable for preserving liquid and semi-liquid foods. 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 that cannot be pumped.

Irradiation:

Irradiation (gamma rays, X rays, and electron beams) process exposes the food to controlled levels of ionizing radiations which is detrimental to harmful bacteria, pests or parasites. The food packed is passed through the radiation chamber on a conveyor belt and exposed to radiations, without direct contact with radioactive material. Effect of irradiation on nutritional quality depends on the type of food and the dosage of radiation used. It can be used to prolong the shelf life of fruits and vegetables by inhibiting sprouting and delays ripening. Irradiation produces some chemical changes, which, although lethal to food-borne bacteria, do not affect the nutritional and sensory quality of the food but lead to the production of small amounts of radiolytic products.

Ultrasound Processing:

The application of ultrasound in food processing is another area in non thermal approaches, which exploits the preservative effect of the high intensity sound waves. The treatment enhances shelf life of product with greater homogeneity and energy savings. The preservative effect is by the inactivation of microbes and spoilage enzyme by mechanical actions. Ultrasonication (application of ultrasound at low temperatures), thermosonication (application of ultrasound at high temperatures), manosonication (application of ultrasound and pressure together) and manothermosonication (combined application of ultrasound, pressure and heat) are the various categories of ultrasound processing techniques. The technology finds its application in the field of extraction of proteins, lipids and their functional modifications, emulsification, viscosity improvement, homogenization and improvement of dispersion stability in liquid foods. Ultrasonics has been successfully used to inactivate *Salmonella* spp., *Escherichia coli*, *Listeria monocytogenes*, *Staphylcoccus aureus* and other pathogens. Ultrasound technology can be effectively used for freeze thawingof foods without generation of excessive heat.

Microwave processing:

Unlike non-thermal processing techniques, microwave processing involves generation of heat. Still it is attractive due to its instantaneous and rapid increase in temperature, controllable heat transmission, and easy clean-up opportunities. It is currently being used to replace or complement conventional processing technology for pasteurising or sterilising food products as well as to meet the demands of on-the-go consumers who want quick food preparation and superior taste and texture. The largest use of industrial microwave processing of food has been for tempering of meat for further processing. Conventional tempering techniques take a lot of time with considerable drip loss resulting in loss of protein and quality and economic loss. The microwave tempering can be performed in few minutes for a large amount of frozen products (5–10 min for 20–40 kg). Currently, most food industries use microwave at 915 MHz for tempering purposes. Applications of microwave drying include microwave assisted hot air drying, microwave vacuum drying and microwave freeze drying. Microwave heating is found to be an ideal system for cooking bacon and sausages, a sit greatly reduces loss of moisture through drip, fat, nutrients, and flavour. Microwaveable foods in suitable packaging materials are being developed by food processers to meet the growing demand. These convenience foods are microwaveable for use at home and away. High-density polypropylene (HDPP) is a suitable for microwave process over other materials since it can withstand the high temperature.

Modified Atmosphere Packaging:

Modified atmosphere packaging is a technologically viable method to 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 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. 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 CO_2 effectively inhibits bacterial growth during refrigerated storage of packaged fresh fishery products. 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.

Active packaging system:

The concept of active packaging started with a shift in the protection function of packaging from passive to active. It is an innovative concept that can be defined as 'a type of packaging that changes the condition of the packaging and maintains these conditions throughout the storage period to extend shelf-life or to improve safety or sensory properties while maintaining the quality of packaged food'. They can be divided into three categories of absorber (e.g., O_2, CO_2, odour, ethylene), releasing system (e.g., N_2, CO_2, ethanol, antimicrobials, antioxidants), and other system. Other active packaging system may include the tasks of self-heating, self-cooling, microwave susceptor, anti-fogging and selective permeable film. The most important active packaging concepts forfishery products include O_2 scavenging, CO_2emitters, moisture regulators, antimicrobialpackaging, antioxidant release, release or absorption of flavours and odours. Active packaging systems with dual functionality (combination of oxygen scavengers with carbon dioxide and/or antimicrobial /antioxidant substances) is also available nowadays.

Intelligent packaging systems:

Intelligent packaging systems provide the user with information on the conditions of the food or its environment. It is a packaging system that is capable of carrying out intelligent functions (such as detecting, sensing, recording, tracing, communicating, and applying scientific logic) to facilitate decision making in order to extend shelf life, enhance safety, improve quality, provide information, and warn about possible problems. The intelligent devices such as sensors, small inexpensive labels or tags that are attached onto primary packaging (e.g., pouches, trays, and bottles), or more often onto secondary packaging (e.g., shipping containers) etc. are the integral part of intelligent packaging system, which facilitate communication throughout the supply chain so that appropriate actions may be taken to achieve desired benefits in food quality and safety enhancement. In contrary to active components, intelligent components do not have the intention to release their constituents into the food.

Smart packaging system:

Smart packaging is a broad terminology encompassing both active packing and intelligent packing concepts. Smart packaging offers a number of additional functionalities depending on the type of product, in addition to performing the four basic functions of packaging such as protection, communication, convenience and containment. They help extend shelf life, monitor freshness, display information on quality, improve safety, and improve convenience. The term smart packaging is substituted at times as diagnostic packaging, communicative packaging, functional packaging, enhancement packaging, etc.

Value addition – processor's opportunity:

Value added products are the need of the hour, since the consumers find little time for spending in preparing such products. The present day consumers, particularly urban consumers are showing more and more interest in food products which are available as ready to eat or ready to cook. The high level of expendable income and the usage of microwave ovens in households made the value added products an inevitable commodity in the super markets of the urban and even rural area. Obviously, the processors are at a side of great opportunity, as the global demand for convenient products such as marinated fillets, steaks, mince based products, extruded products etc is increasing rapidly. The major opportunities in value addition lie in the following areas:

Fish mince and mince-based products:

Fish mince separated from skin, bone and fins are used for preparation of a variety of ready to eat/fry products. Battered and breaded products commonly known as 'coated products' like fish fingers, fish balls, cutlet, patties etc. are the most popular among them. Battering and breading techniques have contributed significantly to value addition of fish and fishery products. These products fetch good demand in domestic as well as export markets as theyrequire minimum financial requirement and are affordable to low time traders.

Surimi and surimi-based products:

Surimi, washed mince added with cryoprotectants, also act as an intermediary in development of various products. World-wide, there is a continuous search of raw material which is suitable for surimi production. Low cost white fleshed fishes such as pink perch, croaker and perches can be conveniently used for the preparation of surimi. Even though, surimi and surimi-based products such as sausages are less popular in India, it is a much sought-after item in western markets. Moreover, shell fish analogue products from surimi fetches good demand in domestic and export markets. The Indian company 'Gadre Marine' is a leading manufacturer of surimi, exporting to 24 countries over the world.

Thermal processing and ready to serve products:

Long storage life at ambient temperature without any compromise for the nutritional quality made the ready to serve thermally processed products to emerge as a highly demanded commodity. Thermal processing, which is commonly referred as heat processing or canning is a means of achieving long-term microbiological stability for non-dried foods without the use of refrigeration, by prolonged heating in hermetically sealed containers, such as cans or retortable pouches, to render the contents of the container sterile. ICAR-CIFT has standardized the processing conditions for more than 25 product styles, including the ethnic varieties such as Hyderabadi prawn biriyani, Goan mackerel curry, Malabar seer fish curry (Fig.7), Tapioka and fish curry, Seerfish Moli, mussel/oyster masala etc. This technology has a long term impact as evidenced by the adoption of fish products in retort pouch by more than a dozen companies in India. Different types of packaging materials like cans, retort pouches with different layer configurations, semi rigid containers are used for the development of these products.

Extruded snack products:

Extrusion helps to improve the versatility for the development of high-nutritive, low cost and convenient food products. It is a thermodynamically efficient process and ensures the destruction of bacteria and anti-nutritional factors during extrusion process. Flavour, texture and taste are the major characteristics affecting the acceptability of these products. Usually, extruded products are prepared using cereal flour, which have less protein content and are limited in some essential amino acids. By incorporating protein-rich fish mince instead of cereal, the product is protein enriched snack food. 'Fish cure' is such a product developed by ICAR-CIFT with fish mince as base material. The flavour and taste of these products may be altered by coating with suitable spice/flavour mix. The production process involves mixing of fish mince with cereal flours, spices and salt and extrusion using a twin screw extruder (Fig.8). The dried and coated products are then packed in metalized polyester polyethylene pouches using nitrogen gas filling. The product is acceptable up to 3 months at ambient temperature.

Seaweed incorporated products:

A more recent addition to the food industry from marine sector is 'processed seaweeds and seaweed extracts'. The South-East and North - West coasts of India and the Andaman- Nicobar and Laccadive archipelagoes harbour a variety of seaweeds with rich biomass and species diversity. The seaweed industry is certainly on its way marching towards socio economic development of our nation. Apart from bringing umami taste to foods, seaweeds serve as a major storehouse of polyunsaturated fatty acids, dietary fibres, minerals, vitamins and sulphated polysaccharides in good amounts, which could be used to fortify beverages and health drinks. Dietary fibre extract from seaweeds, 'Nutridrink' (grape juice fortified with seaweed extract), fish soup fortified with seaweed bioactive compound, seaweed incorporated semi-seaweed biscuits (Fig.9) and noodles are a few novel products developed in this line by ICAR-CIFT.

Fish nutritional bars:

The new life styles of consumers add to the requirement of new health foods and nutritional energy supplements, in pleasing and portable way. Modern market, have gained a more attraction towards the convenient type nutritional bars/ energy bars/ protein bars in various forms and wide varieties can be made on the basis of different consumer requirement of health food, diet replacer, work out food, energy supplement, geriatric food, sugar free product and nutrient requirement for children. Globally, this trend is being driven by growing consumer awareness about better nutrition in physical performance and personal appearance. ICAR-CIFT has standardized some formulations for nutritional bars added with the best quality supplements from fish source. The protein from fish has been regarded as the high quality with well-balanced amino acid profile, that is easily digestible than any mammalian counter parts. ICAR-CIFT has developed a nutrient formulation with cereal mixes, dried fruits fortified with different biomolecules like high profile fish protein/ collagen peptide/ omega-3 oil in crunchy type granola bars with good shelf stability. Fortification of 10-15% fish protein alone and provide an average energy of 400 Kcal/100g was achieved (Fig.10).

Processed fish roe and caviar substitutes:

Fish roes, which form a major component of process discards, are nutritionally valuable sources of omega-3 fatty acids and essential amino acids. Generally, the roe obtained during dressing of fish is either discarded or sold at very low price as it forms a jelly mass during cooking. However, the roe mass may be spray dried using a suitable stabiliser like gum Arabic and the powder can be added to a wide range of foods without affecting the sensory characteristics of the products. Besides the commercially available roe from sturgeon, salmon and cod, fish caviar substitute from fresh water carp roe reconstituted with suitable gelling agents such as sodium alginate will have a greater potential as fish caviar substitutes.

Miscellaneous products:

A variety of products like fish sauce, fish salad, fish pickles, frozen whelk, squid fillet, shrimp skewer, stuffed squid with shrimp etc. have fairly good movement in domestic and foreign market. Canned crab, chilled pasteurised crab, crab cut, frozen 'snap and eat' legs are some of the crab based products available in the market. Identifying live crab exports as a money spinner, the Indian seafood industry is all set to rear mangrove crabs, so as to scale up the export of the crustacean that commands high price in the global market.

High value byproducts - Wealth from waste

Nearly 70-80% of the total weight of fish catch is generally discarded as bycatchor processing waste. Global fish waste generation is estimated to be in excess of 75 MMT and in the Indian scenario it is >4 MMT. It is estimated that fish processing waste after filleting accounts for approximately 75% of the total fish weight. About 30% of the total fish weight remains as waste in the form of skins and bones during preparation of fish fillets. Bio-conversion of these wastes is an environmental friendly and profitable option for the utilisation of fish waste. Some viable options for generating wealth from waste are detailed below.

Fish meal:

Fish meal is highly concentrated nutritious feed supplement consisting of high quality protein, minerals, vitamins of B group and other vitamins and other unknown growth factors. Fish meal is rich in essential amino acids. It is produced by cooking, pressing, drying and grinding the fish, bycatch fish, and miscellaneous fish, filleting waste, waste from canneries and waste from various other processing operations. The composition of fish meal differs considerably due to the variations in the raw material used and the processing methods and conditions. Better quality fish meal has been a prominent item of export from the very beginning of this industry. BIS has brought out the specification for fish meal as livestock feed for facilitating proper quality control. The proximate composition of fish meal, in general, is protein, 50-60%; fat,5-10%; ash, 12-35% and moisture, 6-10% employed. Around 15% of the global fish meal demand is met from fisheries resources alone. The projected (2030) annual growth rate in fishmeal use in aquaculture is 1.7%, where the current usage is at a tune of 3.9%. The recent development in captive breeding and rearing high value species such as cobia, grouper, pompano, Nile tilapia, lobster, Asian seabass etc. implies that there is a good scope for flourishing finfish and shellfish production through aquaculture in near future. This in turn highlights the bright future of fish meal industry in coming years, as most of these species demand high protein feeds for their optimum growth.

Fish protein hydrolysate:

Hydrolysates find application as milk replace and food flavouring. Enzymes like papain, ficin, trypsin, bromelein and pancreatin are used for hydrolysis. The process consists of chopping, mincing, cooking and cooling to the desired temperature, hydrolysis, sieving, pasteurizing the liquid, concentrating and drying (by vacuum or spray drying). The fish protein hydrolysate have desirable functional properties with potential applications as emulsifiers and binder agents; and can used in place of diary based and plant based protein hydrolysates as well as protein powders currently available in market place. The peptides formed by the hydrolysis of fish proteins are proven to have bioactive properties like antihypertensive, antithrombotic, immune modulatory and antioxidative properties. Also, they are good source of nutritional and functional properties. A variety of nutraceuticals from FPH are commercially produced and are available in international markets. Oyster peptide extract developed by ICAR-CIFT possessed antioxidant and anti-inflammatory activities. Similarly, hydrolysate made from squilla meat effectively reduced oil absorption in breaded and battered products, when incorporated in the batter mix.

Fish collagen/gelatin/collagen peptides:

Collagen is the major structural protein in the connective tissue. Collagen extracted from fishes can be used in cosmetics, foods, biomedical applications etc. ICAR-CIFT has developed the method for the preparation of absorbable surgical sutures from fish gut. Gelatin is the hydrolysed form of collagen with applications in development of bio degradable packaging, food and pharmaceuticals. Both collagen and gelatin are high molecular weight proteins of approximately 300 kDa, hence a considerable proportion is unavailable to human body for biological functions. Consequently, in recent years, much attention has been paid to the development of small molecular weight peptides from the native collagen with improved biological activities. This can be achieved by the process of hydrolysis in which the native collagen/gelatin molecules are cleaved to small fragments of less than 5 kDa. Currently, collagen peptides are being incorporated in a wide array of food products including protein bars, cereal bars, protein drinks, smoothies, yogurts, cold desserts, soups, cured meats etc. Nowadays, collagen/gelatin peptides have gained increasing attention as these peptides exhibit various biological activities such as antioxidant, anti-hypertensive, anti-human immunodeficiency virus, anti-proliferative, anticoagulant, calcium-binding, anti-obesity, anti-diabetic activities and postponement of age-related diseases. ICAR-CIFT has standardised a protocol for the extraction of collagen peptide from fish scale and bone (Fig.11). Further a nutritional mix based on collagen peptides was developedwith a protein content of 78%. The product is mainly intended for middle aged and old people, ladies and sports-persons who needs a regular supply of collagen for healthy joints and bones. It may also be beneficial for patients suffering from osteoporosis and long-term- nursing home residents where there is a possibility of development of pressure ulcers.

Chitin:

The shrimp processing industry in India churns out more than 2 lakh tones of head and shell waste per annum, which can be economically converted to chitin and its derivatives. Chitin is the most abundant polymer next to cellulose. It is a linear polymer of N acetyl-D-glucosamine. Glucosamine hydrochloride can be produced from chitin by hydrolysis. Glucosamine hydrochloride and sulphate are at present marketed as food supplement for the treatment of osteoarthritis. It also possesses other beneficial actions in wound healing and skin moisturization. The deacetylated chitin is known as chitosan. Chitin and chitosan have various applications in agriculture such as in germination of seeds and enhanced protection against pathogenic organisms in plants and suppress them in soil to induce chitinase activity and protenase inhibition, antivirus activity, in micro encapsulationfertilizersandinsecticides. The delivery of drugs and the interactions with living tissues seem to be the major topics of current research on chitosan. Other areas of interest are the antimicrobial action, nerve regeneration, cartilage and bone regeneration, skin and bone substitutes, oral delivery for wound healing etc. Carboxy methylation of chitosan imparts water-solubility to chitosan. ICAR-CIFT has recently standardised the methodology for production of chitin, glucosamine hydrochloride, chitosan and carboxymethyl chitosan. Similarly, collagen-chitosan film from fish waste, developed by the Institute has wide applications in wound dressing and dental surgery.The antioxidant chitosan derivative developed was found to be useful in micro-encapsulating vitamins and ß carotene, so as to give a novel delivery system. Similarly, a biocompatible and biodegradable wound healing formulation, composed of microencapsulated curcumin and hydrogel composite (Succinyl chitosan-fish collagen-poly ethylene glycol) developed at ICAR-CIFT, showed significantly enhanced rate of collagen deposition and hydroxyproline content in wound tissue on 14th day of post wounding as compared to control and standard. Apart from that, free radical mediated grafting of gallic acid, ferulic acid, vanillic acid and coumaric acid onto chitosan were optimised. All the derivatives showed good antioxidant and antimicrobial activities.

Fish ensilage and foliar spray:

When the animal farms are very near to fish landing centres it is worthwhile to go for silage production. Fish silage is made from whole fish or parts of the fish to which no other material has been added other than an acid and in which liquefaction of the fish is brought about by enzymes already present in the fish. The product is a stable liquid with a malty odour which has very good storage characteristics and contains all the water present in the original material. It is a simple process and it requires little capital equipment particularly if non-oily fish are used. The use of oily fish usually requires oil separation. This involves expensive equipment and is suited to a fairly large-scale operation. The silage may be suitable converted to foliar spray, as foliar feeding is an effective method for correcting soil deficiencies and overcoming the soils inability to transfer nutrients to the plant. The experiments conducted at ICAR-CIFT have shown that foliar feeding can be 8 to 10 times more effective than soil feeding and up to 90 percent of foliar fed nutrients. The application of foliar spray has been advocated in spices like cardamom, black pepper, tea etc and encouraging results have been reported. The quick absorption of the nutrients and precise dosage of foliar sprays has resulted in the success of precision farming of costly vegetables and flowering plants. The controlled nutritional supply through praying is an effective method which gives predicted resulted in most of the cases. The optimized supply of required micro and macro nutrients results in the maximum productivity of the available space and minimizes the wastage of costly inputs.

Fish calcium:

In marine ecosystem, there is a large amount of calcium, mainly in the form of calcium carbonate and calcium phosphate, distributed as skeletal elements of teleosts, exoskeletal elements of molluscs or as coral deposits. Every year a considerable amount of total fish catch is discarded as processing left overs and these include trimmings, fins, frames, heads, skin and viscera The bone fraction, which comprises approximately 15-20% of the total body weight of fish has high calcium content. Calcium and phosphorus comprise about 2% (20 g/kg dry weight) of the whole fish. Generally, fatty fish have lower ash levels compared to lean species. The filleting wastes of tuna and other bigger fishes are very good sources for calcium when the quantity of calcium is concerned. Also, the bone structure differs between species since a large number of teleosts have acellular bone (bone without enclosed osteocytes). Cellular bones are confined to only a few fish groups, e.g. Salmonidae. The higher surface to volume ratio in acellular fish bone is likely to increase the calcium availability compared to cellular bone. The ash content is highest in lean fish species with acellular bones. Apart from that exoskeleton of mollusks and coral deposits are excellent source of calcium. However, the calcium form these deposits are mainly in the form of calcium carbonate. Central Institute of Fisheries Technology, Cochin has optimised the process to extract from fish bone which is mainly treated as processing discards during filleting operation of larger fishes, *viz* tuna, carps etc. The calcium powder was supplemented with vitamin D which is known to enhance absorption and bioavailability of calcium in the body. *In vivo* studies conducted at ICAR-CIFT in albino rats have shown that fish calcium powder supplemented with vitamin D has improved the absorption and bioavailability.

Chondroitin Sulphate:

Chondroitin sulphate obtained from shark cartilage is used for the treatment of arthritis. It is part of a large protein molecule (proteoglycan) that gives cartilage elasticity.

Squalene:

Squalene is a highly unsaturated hydrocarbon present in the liver oil of certain species of deep sea sharks mainly *Centrophorus* and *Squalidae* spp. The liver oil of these species contain high percentage of squalene (90%) which can be isolated and purified and can be used as a dietary supplement. It belongs to a class of antioxidant molecules called isoprenoids. Squalene is found to be a proficient chemo preventive agent against lung metastasis in mice bearing lung carcinoma. Squalene revives damaged body cells and aids to revitalize cell generation. Its chief attribute is the protection of cells from oxidation reactions. Squalene assists to clean, purify, and detoxify the blood from toxins, facilitating systemic circulation. It purifies the gastrointestinal tract and kidneys, causes better bowel movement and urination. Squlalene helps in regulating the female menstrual cycle and also improves irregular and abnormal cycles. ICAR-CIFT has standardized the protocol for extracting squalene from shark liver oil.

Hydroxyapatite (HAp):

Hydroxyapatite is the major mineral component of bone tissue and teeth, with the chemical formula of $Ca_{10}(PO4)_6(OH)_2$. The composition Hap derives from biological sources differs from that of synthetic hydroxyapatite, due to the presence of several ionic substitutions in the lattice, such as CO_3, F, Mg^{2+} and Na^+. It is a member of the calcium phosphate group with 1.67 stoichiometric of Ca/P ratio. It is one of the few materials, classified as a bioactive biomaterial that supports bone in growth and osseointegration when used in orthopedic, dental and maxillofacial applications. Fish bone and scale is a rich source of hydroxyapatite. The hydroxyapatite content of fish skeleton may vary between 40-60%. Generally, very high heat treatment is used for extraction of HAp from bone and this temperature gives a higher strength to HAp structure. The high temperature also burns away any organic molecules such as collagen protein. Hydroxyapatite, found in fish is chemically similar to mineral components of bone and hard tissues in mammals. Approximately, 65-70% of the fish bone is composed of inorganic substances. Almost all these inorganic substances are hydroxyapatite composed of calcium, phosphorous, oxygen and hydrogen.

Pigments:

Astaxanthin, fucaxanthin, melanin etc. from different fish resources are found to have a variety of bioactive properties. The filleting discards of salmonids and the shell wastes of crustaceans contain significant amounts of carotenoid pigments such as astaxanthin and canthaxanthin. The protective role of carotenoids against the oxidative modification of LDL cholesterol could be explored by incorporating in health drinks. Carotenoids are also highly sought after as natural food colours. Cephalopod ink is another less tapped reservoir of a range of bioactives having therapeutic and curative values. It is an intermixture of black pigment melanin, glycosaminoglycans, proteins, lipids, and various minerals. Cephalopod ink has been reported to have anti-radiation activity, antitumor activity, immune-modulatory activity, procoagulant function and so on.The pigment melanin can be used both as a natural colorant as well as antioxidant, in addition to a number of other therapeutic and prophylactic properties including anticancer, antihypertensive, anti IDA etc.

ICAR-CIFT in quality assurance of post harvest fisheries sector of India

As fish is a food commodity that has been traded across the world, there is lot of research and development activities carried out by ICAR-CIFT on the quality and safety of fish and fishery products. For ensuring quality and safety of seafood, the Indian Council of Agricultural Research set up an independent division in 1996 for taking up research, consultancy, training and analytical services in seafood quality assurance. ICAR-CIFT has proved itsexpertise in areas such as seafood quality assurance, food safety, sanitation and hygiene in fish processing establishments, production and evaluation of process water and ice, modern quality management programmes such as HACCP, ISO 22000 and regulatory requirements *viz.*, EU regulations, Codex/IS/ISO standards etc. ICAR-CIFT is involved in the Assessment Panel of Experts (APE) and Supervisory Audit Team (SAT) for establishing quality regime in fish and fish based products. Also ICAR-CIFT humbly takes the credit of implementing HACCP in India for the first time in the early 1990s. Some of the salient research activates include microbiological interventions, development of methods for chemical contaminants, different package of practices based on HACCP, withdrawal period of antibiotics, challenge studies of different food borne pathogens, quality index schemes, different chemical hazards, antimicrobial property of phytochemicals etc. ICAR-CIFT is actively involved in developing and implementing an energy efficient effluent treatment plant for the fish processing units within the state and outside.The institute is also providing consultancy in the design, development and getting accreditation as per ISO/IEC 17025:2005. ICAR-CIFT has proudly contributed to the development of standards and the recent one is development of four standards for International Standards

Organizations (ISO) for the traceability of both wild and cultured Molluscs and Crustacean. CIFT has taken accreditation as per ISO/IEC 17025:2005 in 2005 and has been doing service to the industry and the needy. The institute has accredited for more than 120 parameters in chemical, microbiological and mechanical areas. The institute is also identified as the quarantine centre for fish and fishery products, for DADF, Ministry of Agriculture.

Conclusion

Fisheries is considered as a sunrise sector in India due to its recent renaissance and growth potential. The technological advancements in the harvest and post-harvestsector catalysed by the mechanization of fishing crafts and modern electronic technologies for navigation and fish location, along with energy efficient processing aids, offer good scope for the development of sector. Product diversification, promoting more public-private partnerships, creating more awareness on quality assurance throughout the value chain, taking initiatives for increased infrastructure facilities for market development, awareness creation on responsible and sustainable fishing practices etc. are crucial steps towards achieving 'blue revolution'.

Fig.1. Rubber wood canoe

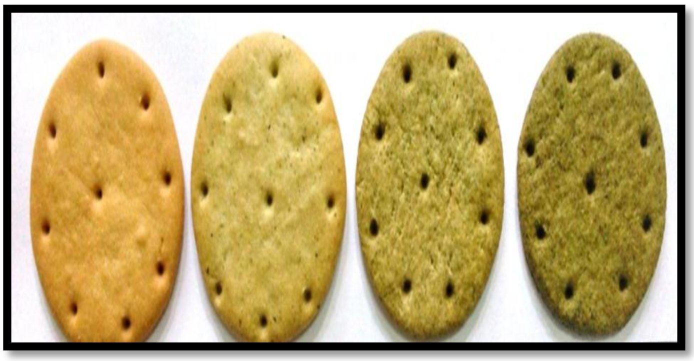
Fig.2. Solar-powered boat useful for aquaculture etc

Fig.3.Sagar Haritha': Energy efficient green fishing vessel

Fig.4. Solar dyer

Fig.5. High pressure processing unit   Fig.6. Pulse light processing unit

Fig.7. Fish curry in retortable pouches   Fig.8. Extruded fish snack



Seaweed enriched biscuits developed at ICAR-CIFT

Fig.11.Collagen peptide from fish scale and Nutritional mix formulated by CIFT

Chapter 2

Responsible fishing and its strategic implementation for sustainability

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Introduction

India is situated north of the equator between 8°4' and 37°6' north latitude and 68°7' and 97°25' east longitude, is the largest peninsular country in the world bordered by Arabian Sea in the west, Indian Ocean in the south and the Bay of Bengal in the east. India has a coastline of 8118 km and 0.5 million sq. km continental shelf endowed with 2.02 million sq. km of Exclusive Economic Zone (EEZ). It has a catchable annual fisheries potential yield of 4.41 million t occupying third rank in world marine fish production (Table 1). India's territorial waters extend into the sea to a distance of 12 nautical miles from the coast baseline. The vital details on marine capture fisheries of India are given in table 1.

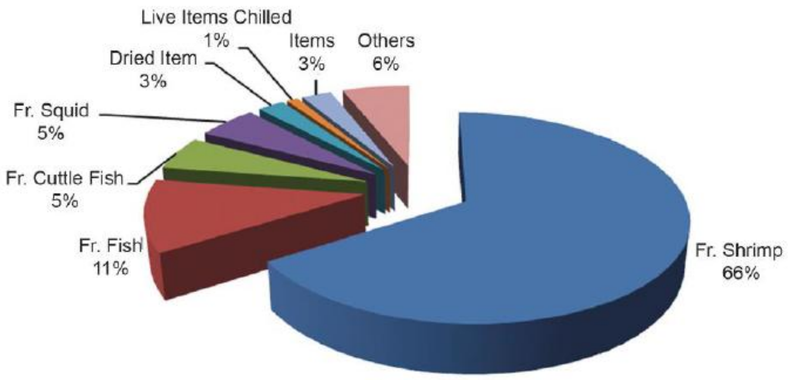
Table 1. Marine capture fisheries of India

	India
Lengthofcoastline(km) :	8,118
Continentalshelf(km^2) :	5,30,000
ExclusiveEconomicZone(km^2) :	20,20,00
AnnualpotentialyieldfromEEZ(metrict) :	4.41
Fishingvillages(No.) :	3,432
Fishlandingcentres(No.) :	1,535
Fishermenfamilies(No.) :	8,74,749
Fisherpopulation(No.) :	40,56,21
Marinefishingfleet(No.) :	1,99,141
Mechanisedfishingvessels(No.) :	72,749
Motorisedfishingvessels(No.) :	73,410
Non-motorisedfishingvessels(No.) :	52,982
Fishproduction(2016)(million t)	3.63

Source: GOI (2011a); DADF (2012); CMFRI (2012, 2013a, 2016)

The contribution to foreign exchange earnings by the fishery sector substantially increased from `46 crores in 1960 - 61 to 30,420.83 crores (US$ 4.7 Billion) in 2015-16. Seafood exports from India, during 2015-16, has been 1.05 million t (MPEDA, 2016). USA and South East Asia continued to be the major importers of Indian seafood as in the previous year. Frozen Shrimp was the major export item followed by frozen fish. (MPEDA, 2016).

Item wise exports 2015-2016 (Value in USD)



MPEDA (2016)

Fishery resource potential and production

Fish production in India has shown an increasing trend during the last six decades. Globally, India ranked second in world total fish production. The total fish production in the country increased twelve fold from 0.74 million t in 1950 to 10.07million t in 2014-2015 (FAO, 2016). India, with its highly productive fishing area has registered 3.63 million t marine fish production during 2015-16. Indian mackerel became the highest contributor with 2.49 lakh tonnes as the declining trend in Indian oil sardine landings continued.

The summary of the potential resources in the different realms and depth zones are given in Table 2 and 3

Table 2. Potential yield for different realms

Realm	**Potential**
Pelagic	2,128,424
Demersal	2,066,763
Oceanic	216,500
Total	**4,411,687**

Source: GOI (2011b)

Table 3. Potential yield for different depth zones

DepthZone	Potential
Upto100m	3,821,508
100-200m	259,039
200-500m	114,640
Oceanic	216,500
Total	**4,411,687**

Source: GOI (2011b)

Fish harvesting systems

Fishing gears and practices ranging from small-scale artisanal to large-scale industrial systems are used for fish capture in India. Most important among these are trawls, purse seines, lines, gillnets and trap systems. Some of the traditional gears have also evolved into large and more efficient versions.

The mechanisation of indigenous vessels enabled the fishermen to fish in distant off-shore waters, which were previously inaccessible to them (Chidambaram, 1956). Introduction of small mechanised vessels, motorisation of country vessels, introduction of resource specific vessels and introduction of fishing fleet with state of the art equipment for fish detection and capture were the four development phases (Edwin et al 2014). Synthetic materials have been the mainstay in the production of fisheries gear since the past half century, the main synthetic fibre being used for fishing are Polyamide (PA), Polyethylene (PE), polypropylene (PP) etc.

Now, the entire mechanised fisheries sector uses only synthetic fibers for net making. Twisted netting yarns and braided netting yarns of different sizes are available in the country. Polyamide (PA) monofilament is being extensively used as an import substitute for tuna and shark longlines. The development of combination wire rope for deep-sea fishing is a recent innovation which has now been commercialised. CIFT has standardised specifications for the use of PP multifilament netting yarn with lower specific gravity and better tenacity than nylon.

There are about 1, 99,141 fishing vessels in the sector, of which nearly 72,749 are mechanised vessels (36.5%), 73,410 are motorised (36.9%) and the rest 52,982 non-motorised (26.6%) (Table.4).

Table 4. Fishing vessels in India

State/Union Territory	MechanisedVessels	MotorisedVessels	Non MotorisedVessels	TotalMarine FishingVess
WestBengal	14,282	0	3,066	17,348
Odisha	2,248	3,922	4,656	10,826
Andhra Pradesh	3,167	10,737	17,837	31,741
TamilNadu	10,692	24,942	10,436	46,070
Puducherry	369	1,562	662	2,593
Kerala	4,722	11,175	5,884	21,781
Karnataka	3,643	7,518	2,862	14,023
Goa	1,142	1,297	227	2,666
Maharashtra	13,016	1,563	2,783	17,362
Gujarat	18,278	8,238	1,884	28,400
Daman&Diu	1,000	359	321	1,680
Andaman & Nicobar	61	1491	1637	3189
LakshadweepIslan	129	606	727	1462
Total	72749	73,410	52,982	1,99,141

Source: DADF (2012)

Advances in satellite-based technologies such as global positioning system (GPS) have positively influenced the precision in fishing, and Global Maritime Distress Safety System (GMDSS) based rescue system have facilitated safety of fishermen. Satellite remote sensing application in Indian fisheries helped to make maps of Potential Fishing Zones (PFZ), which in turn helped the fishermen to reduce search time and significantly increase catch per unit effort (Solanki et al., 2003).

The increase in fish production over the years has been the result of increased vessel number and capabilities, availability of large and more efficient gear systems, developments in electronic, navigational and acoustic detection equipment which increased the area of operation of the mechanised fishing fleet.

The FAO Code of Conduct for Responsible Fisheries

The Code of Conduct for Responsible Fisheries (CCRF) sets out the principles and international standards of behaviour for responsible practices to ensure long term sustainability of living aquatic resources, with due respect for the ecosystem, biodiversity and environment. It covers conservation; management and development of fisheries; capture, processing and trade of fish and fishery products; aquaculture; fisheries research; and integration of fisheries into coastal area management. The key principles of the Code include (i) management of stocks using the best available science; (ii) application of the "precautionary principle," using conservative management approaches when the effects of fishing practices are uncertain; (iii) avoiding overfishing and preventing or eliminating excess fishing capacity; (iv) minimisation of bycatch and discards; (v) prohibition of destructive fishing methods; (v) restoration of depleted fish stocks; (vi) implementation of appropriate national laws, management plans, and means of enforcement; (vii) monitoring the effects of fishing on the ecosystem; (viii) working cooperatively with other states to coordinate management policies and enforcement actions; (ix) recognizing the importance of artisanal and small-scale fisheries, and the value of traditional management practices.

Article 8 of CCRF: Fishing operations

Article 8 in the Code of Conduct of Responsible Fisheries is elaborated in *FAO Technical Guidelines for Responsible Fisheries 1: Fishing Operations* (FAO, 1996a). Article 8 contains 11 Sections and 52 sub-sections dealing with the Code of Conduct for Responsible Fishing Operations. The Article 8 include Sections (8.1) Duties of all states, (8.2) Flag State duties, (8.3) Port State duties, (8.4) Fishing operations, (8.5) Fishing gear selectivity, (8.6) Energy optimization, (8.7) Protection of aquatic environment, (8.8) Protection of the atmosphere, 8.9) Harbours and landing places for fishing vessels, (8.10) Abandonment of structures and other materials, and (8.11) Artificial reefs and fish aggregation devices.

Article 8 of the Code of Conduct for Responsible Fisheries which covers Fishing Operations and Article 12 on Fisheries Research have a number of provisions which are of direct relevance to the fishing gear research, design, development and operations. Section 8.4 on Fishing operations, says that states should ensure that fishing is conducted with due regard to the safety of human life relating to the organisation of marine traffic, protection of marine environment and prevention or loss of fishing gear. It also seeks to prohibit destructive fishing practices such as dynamiting and poisoning, it also explains the need to minimise loss of fishing gear and ghost fishing effects of lost and abandoned fishing gear through development of technologies, materials and operational methods; and emphasises the need for environmental impact assessment prior to the introduction of new fishing gear and practices to an area.

Section 8.5 on Fishing gear selectivity focuses on the development and wide spread adoption of fishing gear and methods which would minimise waste, discards, catch of non-target species. The article on Fisheries Research, also seeks to ensure investigations on selectivity of fishing gear, the environmental impact of fishing on target species and behaviour of target and non-target species in relation to fishing gears. (Boopendranath, 2010).

Section 8.6 deals with appropriate standards and guidelines which would lead to the more efficient use of energy in harvesting and post harvesting activities within the fisheries sector and Section 8.7 deals with the pollution and disposal of waste generated during the vessel operation

Section 8.11 seeks to promote the development and use of artificial reef and fish aggregation devices. Responsible fishing technologies have been reviewed by Boopendranath (2009) and Boopendranath and Pravin (2009).

CIFT's initiatives in Responsible fishing

Fishing vessel design

Fishing craft mechanization in India progressed through four stages, beginning with motorization of some of the existing designs of traditional crafts, followed by introduction of mechanised craft, introduction of more specialized crafts, broadening to a full-fledged fishing fleet. ICAR-CIFT in collaboration with FAO naval architects introduced several standard designs of fishing crafts for different types of fishing operations. Twelve standard designs of wooden fishing boats in the size range of 7.67 to 15.24 m were developed and introduced by ICAR-CIFT, which gave a major fillip to the mechanization programme of Indian fisheries. It has been estimated that over 80% of the mechanized wooden fishing crafts in the Indian fishing fleet conformed to the popular ICAR-CIFT designs or its later adaptations. Designs of boats for fishing in rivers and reservoirs, pole and line fishing vessel, trawler-cum-carrier vessel, steel trawler-cum purse seiner, gillnetter were also developed by ICAR-CIFT. Design of a steel fishing trawler (15.5 m) with energy saving features has also been introduced by the Institute.

Solar powered FRP boat for inland waters

Institute has recently developed a solar powered FRP boat which can be operated in reservoirs, small rivers, and aquaculture ponds and can also be used for recreational fishing activities. The boat is capable of running for 2.5 to 3.0 hours after full charge and attains a speed of nearly 4.0 knots in calm waters. Considering the 240 days of fishing in a year the fuel saved compared to an equivalent diesel powered boat is about Rs. 48,000. The boat has wider space, a canopy for protection from rain and sun, low rolling characteristics during fishing, and also has provision of navigational lights to facilitate fishing in the night.

Fuel efficient multi-purpose fishing vessel

ICAR-CIFT has been instrumental in introducing designs of commercial, research and multipurpose vessels as per requirements of Governments and other organizations. Latest in these initiatives has been the introduction of fuel efficient multi-purpose fishing vessel FV Sagar Harita. The vessel built under the project "Green Fishing Systems for the Tropical Seas" (GFSTS) funded by National Agricultural Science Fund (ICAR-NASF) was officially launched on 18 April, 2016. The hull of this vessel is made of marine grade steel and the cabin and wheelhouse is made of FRP to reduce weight and to improve the carrying capacity and speed. The main engine power is 400 hp which is about 20% lower than vessels of comparable size. The fishing gear handling equipment such as split trawl winch, long line setter and hauler, and gillnet hauler designed at ICAR-CIFT with hydraulic power were installed onboard. RSW tanks (0 ^{0}C to -1 ^{0}C) of 2 tonne capacity have been provided for fish preservation onboard. A 600 watt solar power panel has been installed for emergency lighting and navigational aids to promote the utilization of renewable energy resource and conserve the diesel consumption. Acoustic fish detection and trawl monitoring system with underwater sensors have also been installed onboard.

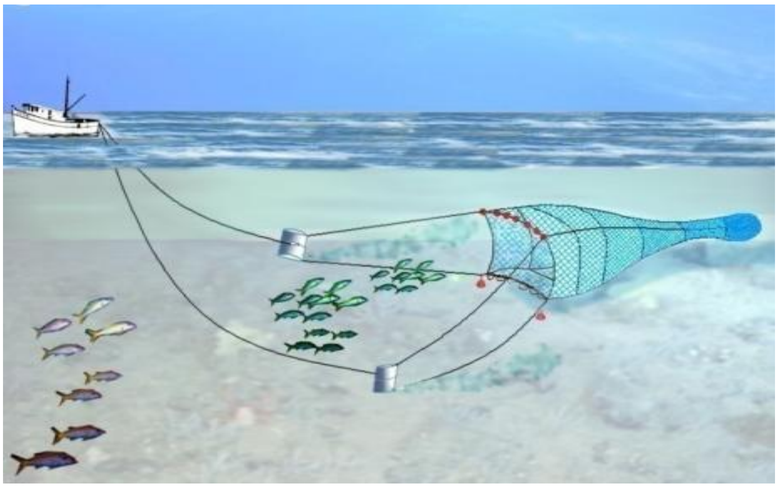
'Target catch' is the species or species assemblage primarily sought in a fishery, 'incidental catch' is the retained catch of non-targeted species and 'discarded catch' is that portion of catch returned to the sea because of economic, legal or personal considerations (Alverson et al., 1994). Bycatch includes both discarded and incidental catch. In addition to the non-targeted finfishes and invertebrates, bycatch also involve threatened and protected species like sea turtles.

Responsible Fishing Gear

ICAR-CIFT has been in the forefront of developing technologies for responsible fishing and fisheries conservation.

Eco-friendly trawls

Demersal trawls are generally non-selective and a large number of non-target species and juveniles are landed during trawling, in addition to its impact on benthic communities. Resource specific trawls for semi-pelagic resources have comparatively low impact on the benthic biota. CIFT Semi-pelagic Trawl System (CIFT-SPTS) otherwise known as the off bottom trawl system has been developed as an alternative to shrimp trawling in the small-scale mechanized trawler sector, after extensive field-testing. The system consists of an 18 m four panel semi-pelagic trawl with double bridles, front weights and vertically cambered high aspect ratio otter boards of 85 kg each. It is capable of attaining catch rates beyond 200 kg h^{-1} in moderately productive grounds and selectively harvest fast swimming demersal and semi-pelagic fin fishes and cephalopods, which are mostly beyond the reach of conventional bottom trawls, currently used in commercial trawl fisheries in India.



Eco-friendly off bottom trawl system

Selectivity of fishing gears

Information on fishing gear selectivity is important in biological investigations, fish stock assessment, fisheries management and for fishing gear design and development. Selectivity characteristics such as mean selection length, selection range, selection factor and selection curve of square mesh and diamond mesh with respect to demersal catch components have been determined through covered codend experiments.

Bycatch Reduction Technologies

Among the different types of fishing, shrimp trawling accounts for the highest rate of bycatch, of which a significant portion is constituted by juveniles that are generally discarded. Further, higher the quantum of bycatch the less will be the economic benefit accruing from the fishing operation. Bycatch is unavoidable in any fishing operation and only its quantities vary according to the type of the gear and its operation. Therefore, one of the important areas of research of the institute has been the development of bycatch reduction technologies. Devices developed to exclude the endangered species like turtle, and to reduce the non-targeted species in shrimp trawling are collectively known as Bycatch Reduction Devices (BRDs). These devices have been developed taking into consideration variation in the size, and differential behaviour pattern of shrimp and other animals inside the net. BRDs can be broadly classified into three categories based on the type of materials used for their construction, viz., Soft BRDs, Hard BRDs, and Combination BRDs. Soft BRDs make use of soft materials like netting and rope frames for separating and excluding bycatch. Hard BRDs are those, which use hard or semi-flexible grids and structures for separating and excluding bycatch. Combination BRDs use more than one BRD, usually hard BRD in combination with soft BRD, integrated to a single system. Oval rigid grid BRD, Fish eye BRD, Big eye BRD, Sieve net BRD which have given bycatch exclusion rates of 11-63% with an accompanying shrimp loss of 1-8%, have been recommended for shrimp trawls, for bycatch reduction and protection of juveniles. Juvenile Fish Excluder cum Shrimp Sorting Device (JFE-SSD) is a Smart Gear award winning design (WWF) developed by CIFT for protecting juveniles and for pre-sorting of the catch (Boopendranath et al., 2008; WWF, 2009).

Square mesh codend

CIFT has for long been advocating the use of square meshes for trawl codend as a conservation measure. As the meshes in the square mesh codends remain open under tension during trawling, water flow will not be restricted and filtration will be efficient and resultant drag will be comparatively less which minimizes fuel consumption. As the mesh lumen remains open, it is easy for small fishes and juveniles to escape through the meshes which reduces the quantum of bycatch enabling the conservation of aquatic resources. In addition to these benefits, the quantity of net required for fabricating square mesh codend is less than the requirement for diamond mesh codend of the same dimensions, resulting in lower fabrication costs. As per CIFT recommendations, Gujarat Marine Fishing Regulation Act (GMFR Act-2003) has prescribed the use of 40 mm square mesh codends in the trawl nets. The use of square meshes have been successfully demonstrated by CIFT in the Sindhudurg District of Maharashtra under a UNDP – GEF project. Most recently the Govt. of Kerala has adopted 35 mm square mesh cod end for fish trawl and 25 mm cod end for shrimp trawl through amendment of the Kerala Marine Fisheries Regulation Act.

Juvenile Fish Excluder cum Shrimp Sorting Device (JFE-SSD)

Trawl fishermen in India and other tropical fisheries depend on both finfish catches and shrimp catches to keep the commercial operations economically viable. CIFT has developed a unique solution for this issue by developing Juvenile Fish Excluder cum Shrimp Sorting Device (JFE-SSD), which retains mature shrimp in the bottom portion of the net while allowing juvenile shrimp to swim out through the mesh unharmed. The device also retains mature finfish in the upper codend of the device, while allowing small sized fish of low commercial value and juveniles of commercial species to be safely excluded. JFE-SSD has bycatch exclusion rate of 43% with a shrimp retention of 96-97%. The sorting of the shrimp and the finfish between the lower and upper parts of the net enhances profitability because it reduces sorting time on the deck which increases the useful fishing time of the trawler fishermen, and it prevents shrimp from becoming crushed under the weight of fish and bycatch hauled on deck which increases the shrimp's market value.

Turtle Excluder Device (TED)

Sea turtles are endangered species. Incidental catches of turtles have been reported in the trawl landings of India particularly from West Bengal, Orissa, Andhra Pradesh, Tamil Nadu and southern parts of Kerala. CIFT has developed an indigenous design of the turtle excluder device which is appropriate for the Indian conditions. CIFT-TED is a single grid hard TED with top opening of 1000x800 mm grid size for use by small and medium mechanized trawlers operating in Indian waters. In the TED developed by CIFT, great care has been taken to ensure 100% escapement of the turtles while exclusion of fish and shrimp is at the minimum possible level. MPEDA, Kochi has adopted the technology and distributed about 2900 CIFT-TEDs to trawler fishermen and operators in states affected by sea turtle mortality, *viz.*, West Bengal, Orissa, Andhra Pradesh, Tamil Nadu and Kerala. Demonstration cum training on fabrication, installation, operation and maintenance of CIFT-TED were conducted at several centres in West Bengal, Orissa, Andhra Pradesh and Kerala, in collaboration with MPEDA, Department of Fisheries, Department of Wildlife and NGOs.

Bycatch reduction in gillnets, purse seines, hooks and lines, and traps

Bycatch in drift gill nets may include marine mammals, sea turtles and sea birds, in addition to non-targeted fish species. Optimisation of gill net mesh size and hanging coefficient according to the target species and size group and judicious deployment of gill net in terms of fishing ground, fishing depth and season in order to minimise the gear interaction with the non-targeted species are important bycatch mitigation measures for gill net fisheries. One approach to minimise ghost fishing by lost gill nets, is to use biodegradable natural fibre twines or time release elements to connect the netting to floats (Hameed and Boopendranath, 2000).

Bycatch incidence in purse seine is said to be mostly due to accidental pursing of juvenile shoals. Selection of mesh size for the purse seine appropriate for the target species, proper choice of fishing area, depth and season could also lead to better selectivity of purse seines. Special escape panels known as Medina panels, which are sections of fine mesh that prevent dolphins from becoming entangled in the gear, and back down manoeuvre have been deployed to prevent capture of dolphins in purse seines (Ben-Yami, 1994). Optimized hook design and size and selection of bait type and bait size appropriate for the target species and size class, proper choice of fishing ground, depth and time of fishing are approaches for mitigation of bycatch issues in hook and line fisheries and minimise gear interaction with other species. Optimised trap design according to the target species and provision of escape windows for juveniles and non-target species in the design side and appropriate choice of bait type, fishing area, fishing depth, fishing time also help to minimise juvenile catch in traps.

Green Fishing Concept

The green fishing concept encompasses energy conservation in fishing and minimising environmental impact of fishing gears in all fisheries.

Energy conservation in fishing

Motorised and mechanised fishing operations are dependent on fossil fuels, which are non-renewable and limited. Fossil fuels produces increased levels of carbon dioxide in atmosphere contributing to green house effect and other pollutants which are detrimental to the environment and human health. Green house effect leads to irreversible climatic and oceanographic changes. Moreover spiraling oil prices may severely affect the economic viability of fishing as a means of food production. World capture fisheries consumes about 50 billion litres of fuel annually (1.2% of the global fuel consumption) releasing an estimated 134 million tonnes of CO_2 into the atmosphere at an average rate of 1.7 tonnes of CO_2 per tonne of live-weight landed product (Tyedmers et al.,2005). Annual fuel consumption by the mechanized and motorized fishing fleet of India has been estimated at 1220 million litres which formed about 1% of the total fossil fuel consumption in India in 2000 (122 billion litres) releasing an estimated 3.17 million tonnes of CO_2 into the atmosphere at an average rate of 1.13 tonnes of CO_2 per tonne of live-weight of marine fish landed (Boopendranath, 2009).

Studies on GHG emmission from fishing vessel conducted in CIFT has shown that the fuel consumption is the major factor contributing to GWP in both single day and multi day trawler operations and hence offers scope for impact reduction through operational fuel savings. The GWP was incrementally higher for multi-day trawler operation corresponding to increase in size of trawlers. Global warming potential ranged from 2165 to 4328 kg CO_2 Eq. in wooden trawlers and from 2824 to 6648 kg CO_2 Eq. in steel trawlers depending on the size. The GWP was higher in very large trawler due to inorganic emission to air especially carbon dioxide. The GWP had a negative value for renewable resources i.e., wood for construction, wooden otter board, marine plywood and cotton. Among the materials used for construction of a 40 m trawl net GWP was maximum for iron sinker (64.6%) followed by high density polyethylene (HDPE) webbing (17.0%), polypropylene (PP) rope (10.3%), HDPE float (5.0%) and lead sinker (3.1%).

Various approaches to energy conservation in fish harvesting such as (i) fishing gear and methods; (ii) vessel technology; (iii) engines; (iv) reduction gear, propeller and nozzle; (v) sail-assisted propulsion; (vi) adoption of advanced technology; (v) conservation, management and enhancement of resources, have been discussed by May et al. (1981), Gulbrandson (1986), Wileman (1984), Aegisson and Endal (1993), Boopendranath (1996), Wilson (1999, Boopendranath (2009). Other methods of energy conservation can be through use of Fish Aggregating Devices (FAD) the Institute has developed and standardized low-cost designs of floating FADs and benthic Artificial Reef (AF) modules, based on experiments off Andhra Pradesh coast, in order to make the fishing operations energy efficient and cost-effective, for the benefit of traditional fishermen operating fishing gears such as gill nets and lines. Potential fishing zone (PFZ) advisory is important service, since fishermen can use less time and fuel in searching for areas of fish abunadance. PFZ advisory mainly rely on Chlorophyll and sea surface temperature retrieved from satellite. Fishing Technology Division, ICAR-CIFT has been working on this aspect for 8 years. The main objectives are to provide *in-situ* database on chlorophyll, coloured dissolved organic matter, detritus and nutrients along with other physical parameters of coastal waters of Kochi, validate the *in-situ* measured Chlorophyll, coloured dissolved organic matter and detritus with satellite data and development of regional algorithms based on these *in-situ* and satellite data to improve PFZ advisory.

Minimising environmental impact of fishing gears

Dragged gears as trawls, particularly when they are heavily rigged, could cause severe damage to benthic fauna and flora, which occupy the bottom substratum and contribute to the productivity of the region. Direct and indirect impacts of bottom trawling on marine environment and benthic communities are well known (Hall, 1999; Kaiser and de Groot, 2000; Barnes and Thomas, 2005; Meenakumari et al., 2009 and others).

Conclusion

The implementation of responsible fishing methods starts with the research on design, development and operation of fishing vessel and fishing gear. A country like India has already a wide range of technology for bycatch reduction, minimising environmental impact and energy conservation based on FAO- CCRF. Creating awareness among stakeholders with suitable incentives will result in faster adoption of such technologies. Policy initiatives and amendment of existing legislation will facilitate sustainable fishing in India.

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Chapter 3

Recent trends in fishing gear materials

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Introduction

Netting yarns for the fabrication of fishing gear are either of textile or non-textile origin. Textile materials compose of netting, twine and rope while non-textile origin materials,constitute floats, sinkers, hooks etc. Different kinds of fibres originating from plant and animal body parts have been used for production of textiles and other products are termed as natural fibres. Raw material for fish netting consists of fibres which can be distinguished into two groups: natural fibres and man-made fibres. Traditional fishing gears used earlier were mainly with natural fibres such as cotton, manila, sisal, juteand coir were the materials exclusively used in earlier days for fishing gear fabrication.

Later, the invention of polymers resulted in synthetic fibres which revolutionalized the fishing industry. In recent decades advances have taken place in fiber technology, along with the introduction of other modern materials. With the introduction of man-made synthetic fibers in India in the late 1950s, natural fibers used for the fishing gears have been substituted by these synthetic materials due to their high breaking strength, high resistance to weathering, low maintenance cost, long service life and better uniformity in characteristics. Most important synthetic fibres used in fisheries are polyamide (PA), polyester (PES),polyethylene (PE) and polypropylene (PP). Other synthetic fibres, which are less widely used and generally restricted to Japanese fisheries, are polyvinyl alcohol (PVA), polyvinyl chloride (PVC) and polyvinylidene chloride (PVD). Earlier, netting used to be fabricated manually, which is laborious and time consuming while the introduction of synthetic fibres paved way for machine made nettings which are almost exclusively used in fishing net fabrication.

Fishing Gear materials

Natural Fibres

Fibres of plant origin such as that of cotton, manila, sisal, hemp, linen, ramie, coir etc. and of animal origin such as silk, hair etc are termed as natrural fibres. Animal fibres are either too expensive or are not suitable for the fabrication of fishing gear. As far as the fishing industry is concerned, the plant/vegetable fibres are very important. Based on the source of origin, vegetable fibres come as seed fibre, fruit fibre, leaf fibre and bast fibre. Seed fibre is available from cotton (*Gossipium* sp.) while coir (*Cocosnucifera*) is a source of fruit fibre. Sisal (*Agavesisalana*), Abaca/Manila (*Musatextiles*) and pineapple leaf (*Ananascomosus*) are sources of leaf fibre.Examples of bast fires are true hemp (*Cannabissativa*), Indian hemp (*Crotalariajuncea*) and jute (*Corchoruscapsularis*).

Natural fibres have the advantage of ecofriendliness and reasonable weather resistance. But being cellulose in origin, vegetable fibres are subjected to biodeterioration by cellulose digesting bacteria/fungi when exposed to water. Thus vegetable fibres have the major disadvantage of a very short useful life time. To increase their service life, various preservative treatments and protective measures are required. This is a major drawback to the fishermen for effective utilization of fishing seasons. More ever, preservation does not offer the best solution. Natural fibres on wetting absorb water and increase in weight. This results in difficulty of handling by fishers and also limit the size of the gear that can be handled from a boat.

Man- made fibres

Natural polymers and synthetic polymers constitute man-made fibres. Natural polymers are manufactured by the alteration of natural polymers like cellulose and protein while synthetic polymers obtained by synthesis or chemical process. Man-made fibres derived from cellulose eg: rayon, are susceptible to microbial deterioration while synthetic fibres are very resistant to micro-organisms. For fishing gears, synthetic fibres only is suitable.

Synthetic fibres

Compared to vegetable fibres, synthetic fibres have better uniformity, continuity, higher breaking strength and are more resistant to rotting. These materials have greatly extended the endurance of fishing gears, and together with the mechanized vessels, have increased the size and complexity of nets. Developments of new synthetic materials and fabrication techniques played an important role in improving fishing gear efficiency. It is stated that synthetic fibres brought to one of man's oldest occupations, the miracle of science and in doing so provide easier living for the fishers.

The development of synthetic fibre was based on the discovery that all fibre materials consist of long chain molecules in which a great number of equal simple units are linked together. This structure gives the fibre the properties required for a textile fibre. Synthetic fibres are produced entirely by chemical process or synthesis from simple basic substances such as phenol, benzene, acetylene etc.The chemical process involves the production of macromolecular compounds by polycondensation or polymerization of simple molecules of a monomer. The raw materials are petroleum, coal, coke and hydrocarbon. Depending on the type of polymer, synthetics are classified into different groups and are known by different names in different countries. Altogether seven groups are developed; Aramid fibres, Ultra high molecular weight polyethylene andliquid crystal polymer are later additions to this group.

Polyamide (PA): Polyamide, a synthetic polymer, popularly known as nylon, is invented in 1935. Nylon refers to a family of polymers called linear polyamides. Nylon consists of repeating units of amide with peptide linkages between them. There are two common methods of making nylon for fibre applications. In one method, molecules with an acid (COOH) group are reacted with molecules containing amine (NH_2) groups. Thus nylon 66 widely used for fibres is made from adipic acid and hexamethylene diamine. In the second method, a compound containing an amine at one end and an acid at the other is polymerized to form a chain with repeating units of (-NH-[CH2]n-CO-)x. This type called nylon 6 is built with caprolactam. The number usually following the PA part refers to the number of C-H units between the reactive ends of the monomer. With regard to the fisheries, there is no difference between PA 66 and PA 6. In India, PA 6 is used for netting materials. The softness, lightness, elastic recovery, stretchability and high abrasion and temperature resistance are superior properties inherent to nylon. However, high moisture absorption along with dimension instability and requirement of UV stabilization are its disadvantages. On wetting, nylon loses up to 30% of elastic tensile strength and 50% of tensile modulus.

Polyolefines:PP and PE are often collectively called "polyolefines". Polyolefin fibres are long-chain polymers composed (at least 85% by weight) of ethylene, propylene or other olefin units. Polyolefin fibres are made by melt spinning. They do not absorb moisture and have a high resistance to UV degradation.

Polyethylene (PE):PE fibre is defined as: “fibres composed of linear macromolecules made up of saturated aliphatic hydrocarbons”.PE fibres, used for fishing gear, are produced by a method developed by Ziegler, in the early 1950s.The monomer ethylene, the basic substance of polyethylene, is normally obtained by cracking petroleum. PE has a very simple structure, a molecule of PE is a long chain of carbon atoms, with two hydrogen atoms attached to each carbon atom. Linear polyethylene or high density polyethylene has high crystallinity, melting temperature, hardness and tensile strength.

Polypropylene (PP):PP fibre is defined as: “fibres composed of linear macromolecules made up of saturated aliphatic carbon units in which one carbon atom in two carries a methyl side group”. Natta, developed the process for the synthesis of polypropylene in 1954. This is an additive polymer of propylene. PP was commercialized in 1956 by polymerizing propylene using catalysis.

Polyester (PES): The principal PES fibres are made from polymerization of terepthalic acid and ethylene alcohol. It was first synthesized by Whinfield and Dickson of Great Britain in 1940-41 and named the fibre "Terylene”.

Basic terms in netting

Fibre: It is the basic material of netting. Its length should be at least 100 times its diameter.

Netting yarn is the standardized universal term for all textile material which is suitable for the manufacture of netting for fishing gears and which can be knitted into netting by machine or by hand without having to undergo further process. Yarn is made into a netting by twisting or braiding. Monofilaments are used directly for making into netting without further process.

Netting twine: or folded yarn is a netting yarn which is made of two or more single yarns or monofilaments by only one twisting operation.

Cabled netting twine: Combines two or more netting twines by one or two further twisting operations. Fibres are combined to form single yarns. Several single yarns are twisted together to form a netting twine. Several of these folded yarns or netting twines are twisted together by a secondary twisting operation to form a cabled netting twine.

Braided netting yarns: These are produced by interlacing a number of strands in such a way that they cross each other in diagonal direction. These braids are usually in the form of tubes. The braided netting yarns are available with or without core. Core is the term used for single yarn, twisted yarn or monofilaments which do not belong to the braided tube but fills the space inside the tube.

Netting: Nettingis defined by ISO as a meshed structure of indefinite shape & size, composed of one yarn or one or more systems of yarns inter laced or joined or obtained by other means for example by stamping or cutting from sheet material or by extrusion

Basic yarn types

Fibre is the basic material used for the fabrication of netting yarns. By twisting, braiding or plating, yarns are made into twine. For twine construction, there are two steps, first is the twisting together of two or more single yarns to form a strand/ply and the second step involves the twisting together of two or more strands to form a twine. The basic forms in which most synthetic fibres are produced are continuous filaments (multifilaments), staple fibres, monofilaments and split fibres. Continuous filaments are fibres of indefinite length. A quantity of continuous filaments is gathered up, with or without twist to form a filament yarn termed as multifilament. Staple fibres are discontinuous fibres, prepared by cutting filaments into short lengths usually 40-120 mm suitable for the yarn spinning fibres. Staple fibres are twisted to form a spun yarn. These have a rough surface due to the numerous loose ends of fibres sticking out from the twine. Monofilament is a single yarn strong enough to function alone as a yarn without having to undergo further processing. Unlike fine continuous filaments and staple fibres, this can be directly used as individual fibres for netting. Split fibres, developed from oriented plastic tapes (flat tape) which are stretched during manufacture at a very high draw ratio resulting in the tapes splitting longitudinally when twisted under tension.

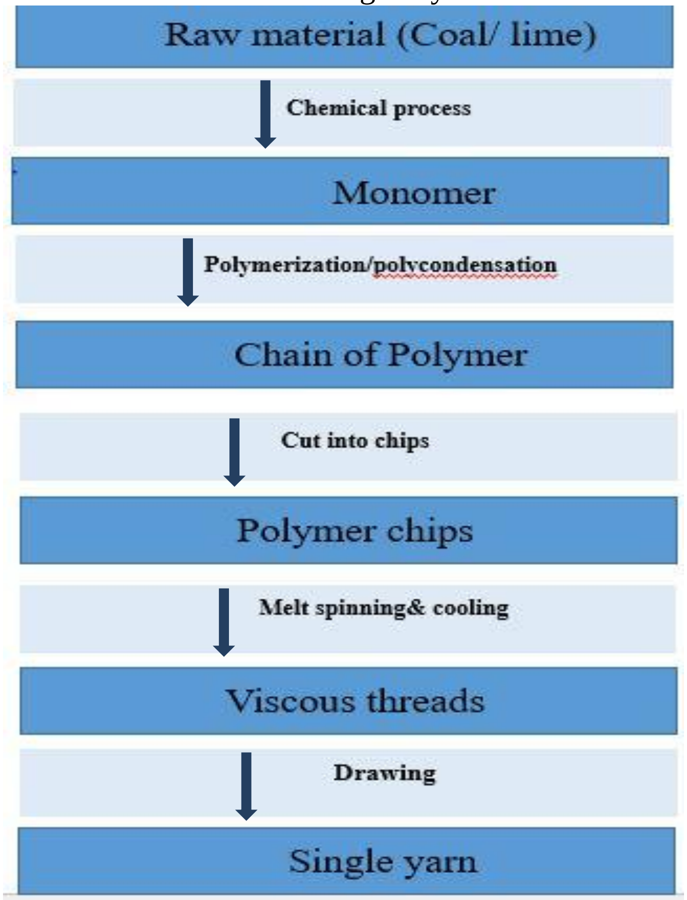
Probable Yarn types in each polymer group

All fibre types are not available/suitable as netting yarns from all the chemical groups. PA is available as multifilaments, staple and monofilaments yarn. PE is available as monofilaments (twisted) but not as staple fibres or as multifilaments while split fibres are not common. In the case of PP, fibres as multifilaments, split fibres and monofilaments for ropes are available. PES only as multifilament fibres and not as split fibres.

Synthetic netting yarns used in Indian fishing sector are polyamide, polyethylene and polypropylene. PA and PE are the most commonly used fibres for netting while PP and PE are used for ropes. Of these, PA is mostly used in the gill net line and purse seine sector while PE is used in the trawl net sector and deep-sea gill net sector.

Manufacturing process:

The basic steps involved in the manufacturing of synthetic fibres are depicted in Fig. 1.



Designation of yarn

In the case of monofilament yarn, diameter is used for designation. In the case of twisted twines, runnage (length of twine against a standard weight) or stating (i) the yarn size, (ii) the number of yarns in the strand, and (iii) the number of strands in the twine are used for designation.

Example: 200x4x6; indicates that the yarn size is 200 denier, there are 4 yarns in one strand and 6 such strands are twisted together to form the twine.

Identification

Identification of synthetic fibres by appearance alone is not possible. Different physical and chemical test methods are employed to identify groups of synthetic fibres.

Specific gravity

PA :1.14; PE: 0.96; PP: 0.91; PES: 1.38

Burning test:

In the burning test, the nature of burning and smoke in the flame as well after leaving the flame are considered as detailed in Table 1.

Table 1. Identification of different polymers by burning test

Material	PA	PE	PP	PES
In flame	Melts, burns with light flame, white smoke, melting drops fall down.	Shrinks, curls, melts and burns with light flame, drops of melting fall down.	Shrinks, melts and burns with light flame melting drops fall down.	Melts, burns with light flame, sooty black smoke, melting drops fall down.
After leaving the flame	Stops burning, melting drops can be stretched into fine thread	Continues to burn rapidly hot melting substance cannot be stretched.	Continues to burn slowly hot melting substance can be stretched.	Stops burning, melting bead may be stretched into fine thread

Solubility test:

Solubility test is used to identify different synthetic fibres. PA is soluble in 37% Hydrochloric acid in 30 min at room temperature.PA and PES are soluble in sulphuric acid 97-98% in 30 min at room temperature.PE and PP are soluble in Xylene on boiling for 5 min (Inflammable).

Yarn numbering system

For designation of the size of the yarn, a `yarn numbering system' is developed. The size of the yarn is given by yarn numbering system. This is based on the length-weight relationship of the yarn. There are two types of yarn numbering systemsviz., direct and indirect systems.

1. **Direct System:**In this system, the weight of the yarn against a standard length is taken. For example the length of yarn is kept constant and the weight changes.

i. Denier

9000 m of yarn weighing 1 g is 1 denier
9000 m of yarn weighing 210 g is 210 denier

ii. Tex: This is the internationally accepted system of numbering for all textile yarns.

1000 m of yarn weighing 1 g is 1 tex.
1000 m of yarn weighing 20 g is 20 tex

2. ***Indirect system:*** Here the length of yarn for a standard weight gives the yarn number or the weight is kept constant and the length varies.

   i. British Count (Ne)

   840 yards weighing 1lb is 1 Ne
   20x840 yards weighing 1 lb is 20 Ne

   This is commonly used for cotton and synthetic staple yarns.

ii. Metric Count (Nm)

1000 m of yarn weighing 1 kg is 1 Nm
20x1000 m of yarn weighing 1 kg is 20 Nm.

In the direct system of numbering the more the yarn number, the thicker the yarn would be and in the indirect system the more the yarn number, the finer the yarn would be.

For conversion from one system to another, the following conversion formula is used.

Tex = 590.5 = 1000 = 100000 = 496055 = 0.11 denier

Ne Nm m/kg yds/lb

Properties

Synthetic netting materials generally are resistant to biodeterioration i.e., they are resistant against destruction by mildew in air and bacteria in water. This is the major advantage of synthetics over natural fibres and it is the prime requisite for a fibre for consideration as a fishing gear material. Besides, synthetic fibres have high breaking strength, better uniformity in characteristics, long service life and low maintenance cost. However, unlike natural fibres, they are prone to degradation under sunlight at a much faster rate. As far as the fishing gear purpose is concerned, properties which are of importance are linear density, diameter, specific gravity, knot stability, breaking load, elongation, weathering resistance and abrasion resistance.

Diameter: The diameter of netting material is an important factor influencing the fishing gear performance. The ratio of diameter of twine to mesh bar is an important criterion to be considered while designing gill nets. Thicker twines are more visible and are easily detectable by the lateral line sense organs of the fish. Thickness and rigidity of the material influences the resistance of fishing gear to water flow and hence the power required or the speed obtained in towing gears are depended on it. Thinner twines offer less resistance. Diameter of a material is dependent on the type of polymer, type of yarn, size of yarn, specification and construction. Diameter is expressed in mm and is measured using a travelling microscope or a micrometer.

Linear density: It is the mass per unit length of the material. The mass in g of 1000 m length of a material is expressed as R tex and mass of 9000 m of the material as R denier. While comparing different types of yarns, the Rtex values serve as a relative measure for the mass of netting. For the same kind of material, lower Rtex means thinner material and generally costs less while buying on a mass basis.

Specific Gravity*:* Specific gravity of most of the synthetic fibres is less than the natural fibres. Specific gravity influences the fishing gear as fibres with lesser specific gravity allows a greater length of netting for a given weight of yarn and helps in savings in handling and power. However, for a gear such as purse seine, material with very low specific gravity is not the suitable one as quick sinking of the net is a prime requisite to capture a shoal of fish.

Twist: The number of turns or twists imparted to a twine per unit length is important as it influences many properties especially the breaking strength, diameter, linear density, resistance to abrasion and general wear and tear of the twine. As the amount of twist increases the breaking strength also increases upto a critical degree of twist beyond which it would weaken the twine. The stability of a twine depends on the correct amount of twists per unit length. The twine has an inner/strand/primary twist and outer/ secondary/ twine twist. Balance between these two twists ie primary twist for making strands from yarns and secondary twist to make twine from strands is important. Twines with a well balanced twist do not have a tendency to snarl.

The relation between inner twist and outer twist is:

$$\text{Inner twist} = \text{outer twist} \times \sqrt{\text{No. of yarns}}$$

The amount of twist decides the softness or hardness of the twine. Based on the amount of twist, the twine is termed as soft, medium, hard and extra hard types. The number of strands in a twine can vary from 2 to 4 but generally 3 strand twines are used for fishing purposes as they possess stability, are free from distortion and round in appearance. The twist can be in two directions, viz., left hand (S twist) or right hand (Z twist). In S twist, the slope of the twisted product follows the direction of the central portion of the letter `S'. Similarly in Z twist, it follows the central portion of `Z'. Generally, the yarns and strands are twisted in the opposite directions for stability. In a double twisted twine, the direction of twist can be SZS or ZSZ for yarn, strand and twine respectively.

Twist coefficient is the measure of twist hardness and is determined by the formula

$$K = (t/m) \times (\sqrt{tex}/1000)$$

where K is the twist coefficient, t/m is the twist per meter and tex is the count in the direct system of numbering.

A coefficient of twist of 110-140, 150-160 and 200 denote degrees of soft, medium and hard twist respectively in PA multifilament netting twine.

Breaking load and elongation: The breaking strength/load of a material denotes the ability of a material to withstand the strain. It depends on the type of polymer, type of yarn, degree of twist and thickness of the material. Tenacity is the breaking load in terms of yarn denier while tensile strength is the force in terms of unit area of cross section. The strength of fibre changes in the wet condition; in natural fibres the wet strength is higher while the reverse is true of synthetic fibres. Knoting also causes reduction in the breaking strength. This is dependent on the type of polymer, type of yarn and knot, twine construction and also on the degree of stretching. Breaking load is expressed in Newton (N).

Elongation is the increase in the length of a specimen during a tensile test and is expressed mostly in percentage of the nominal gauge length. Extensibility is the ability of a netting material to change its dimension under a tensile force. It involves a reversible and an irreversible elongation. Irreversible or permanent elongation is the part of the total increase in length which remains after the removal of the stress. Reversible or elastic elongation is the part of the total increase in length which is canceled again, either immediately or after a long period of removal of stress.

Weathering Resistance: Even though all fibres, irrespective of natural or synthetic are prone to degradation on exposure to weathering, the problem is severe with synthetic fibres. The main factor responsible for weathering is the sunlight, i.e. the ultra violet part of the sun's radiation. Different synthetic fibres show variation in their susceptibility to and rate of deterioration by sunlight. It depends on the type of polymer and type of fibre. The rate of deterioration is generally assessed by the loss in breaking strength. The effect of weathering depends on the thickness of yarn, as thicker twines show better resistance. This is because the layers below are protected by the degraded outer layers and generally UV rays do not penetrate more than 1mm. By dyeing the weathering resistance can be improved.

PVC has very high resistance against weathering, while PES has high and PA and PE, have medium resistance against weathering. Among different types of fibres, monofilament form is more resistant than multifilament and staple yarn.

Abrasion Resistance: The resistance of netting materials to abrasion, ie, abrasion with hard substances such as boat hull, sea bottom and net haulers, or abrasion between yarns/twines is important in determining the life of a net. The resistance to abrasion depends on the type of fibre, thickness and construction of the material. Polyamide has the maximum abrasion resistance, followed by PP, PES and PVC. The better abrasion resistance of PA is due to the inherent toughness, natural pliability, and its ability to undergo a high degree of flexing without breakdown. Among different types of materials, monofilament is better than multifilament, and between staple and multifilament, the latter is better. Abrasion can cause rupture of the material as also reduction of mesh size due to the internal abrasion caused by the friction of the fibres against each other.

Table 2. Properties of important synthetic materials used for fishing gear.

Properties	PA	PE	PP	PVC	PES
Specific gravity	1.14	0.96	0.91	1.35-1.38	1.38
Melting point C	240-250	125-140	160-175	180-190	250-266
Weight g/m	104.5	157	81.2	-	97.8

Breaking strength	Very high	High	Very high	Low	High
Extensibility	Medium	Medium	Low	High	Low
Resistance against weathering	Medium	Medium	Low	Very high	High

Suitability of yarn types to different fishing gear

Even though different types of synthetic fibres are available, an ideal material satisfying all the requirements of different fishing gears does not exist. The various types of synthetics having different qualities provide a range of choice for selecting the best suited material for each type of gear. The choice of material depends not only on the technical properties but also on the local availability and price. For each type of gear, a particular property of the material may be important; for example, sinking speed for purse seine, transparency and softness for gill nets, high breaking strength and abrasion resistance for bottom trawls etc.

Fishing gears are classified into three main groups based on the strain the net material has to undergo. The classes are: Group 1-Low strain (Fine gill nets); Group 2-Medium strain (Fishing line, traps, scoop nets, dragged nets including small bottom trawls); and Group 3- High strain (Large bottom trawls, gape nets in fast flowing rivers). The material indicated as suitable for each group by Japan Chemical Fibre Association is given in Table 3.

Table 3. Synthetic fibres suitable for different fishing gears

Material	Groups	Fishing Gear
PA	Group 1,2	Gill nets, purse seines (sardin
PE	Group 2,3	Trawls
PP	Group 1	Entangling nets
PVC	Group 2	Set nets, Lift nets
PVA	Group 2	Purse seines (Tuna, horse mackerel)

Gill Nets: The material should be fine, strong, flexible and be invisible in water.

Trawl nets: Material should be strong, and cheap to buy.

Purse seines: Should possess good sinking speed and should be strong.

Nylon multifilament nettings are available as knotless and knotted while nylon monofilament nettings are available as knotted only. Nylon multifilament nettings are commonly used for the fabrication of various types of gill nets, ring seine, purse seine, cast net, chinese nets, drift nets etc. Common specifications of nylon multifilament twine for fishing ranges from 210x1x2 to 210x12x3. The mesh size commonly required ranges from 8 mm to 450 mm for different fishing gear. It is more effective for fishing than polyester because of the better sinking speed and extensibility. Nylon monofilament is better for long lining and various types of gill netting. The twine range for fishing purpose is from 0.10 to 0.50 m dia and for long line fishing 1.5 to 3 mm. The mesh size normally starts from 16 to 450 mm dia. Thinner monofilament nets are more effective for fishing but are less durable and not repairable.

HDPE twine is of two types; braided and twisted. Twisted twine is available normally in the range of 0.25 to 3.00 mm dia while braided twine is available in the range of 1.0 to 3.0 mm dia. HDPE netting is mainly used for the fabrication of trawl nets.

Recent advances in synthetic fibres

Introduction of synthetic materials with high tensile strength properties has made it possible to bring out changes in the design and size of fishing nets. As the fishing industry became highly energy intensive, the search and research for new generation materials which give better strenght for less thickness resulted in invention of new materials. Besides, the non-biodegradable nature of synthetic fibres leads to environmental and biodiversity threat to the aquatic bodies and ecosystem. Fishing related plastic debris in water bodies, ghost fishing etc are few such threats from the fishing sector. Aramid fibres, Kevlar, UHMWPE, biodegradable plastic etc are recent introductions to the fishing gear material sector. These materials have many advantages especially less drag which results in fuel efficiency. The performance of UHMWPE webbing and rope in the Indian context is being studied by ICAR-CIFT.

Aramid fibres:

Aramid fibres are fibres in which the base material is a long-chain synthetic polyamide in which at least 85% of the amide linkages are attached directly to two aromatic rings. Two types of aramid fibres are produced by the DuPont Company: Kevlar (para-aramid) and Nomex (meta-aramid), which differ primarily in the substitution positions on the aromatic ring. Generally, aramid fibres have medium to very high tensile strength, medium to low elongation-to-break, and moderate to very high modulus.

KEVLAR® is one of the most important man-made organic fibres ever developed in the early 1970s. It is a polymer containing aromatic and amide molecular groups. Because of its unique combination of properties, KEVLAR® is now used in a wide variety of industrial applications including in the fishing sector as netting and fishing line. Fibres of KEVLAR® consist of long molecular chains produced from poly (p-phenyleneterephthalamide). The chains are highly oriented with strong interchain bonding, which result in a unique combination of properties. It is produced as continuous filament yarn, staple fibre (38-100 mm in length), short fibre (6-12 mm in length) or pulp (2-4 mm in length), all with a nominal diameter of 12-15 µm. The strength to weight ratio of Kevlar is high; on a weight basis, it is five times as strong as steel and ten times as strong as aluminum. It has high tensile strength at low weight, low elongation to break, high toughness (work-to-break), and excellent dimensional stability. In sea water, ropes with KEVLAR® are upto 95% lighter than steel ropes of comparable strength.

Ultra high molecular weight polyethylene

UHMWPE is a type of polyolefinsynthesized from monomer of ethylene processed by different methods such as compression molding, ram extrusion, gel spinning, and sintering. The fiber made by gel spinning have a high degree of molecular orientation resulting in very high tensile strength. The fibre is made up of extremely long chains of polyethylene, which attain a parallel orientation greater than 95% and a level of crystallinity of up to 85%. The extremely long chains have molecular weight usually between 3.1 and 5.67 million while HDPE molecule has only 700 to 1,800 monomer units per molecule.

Ultra high molecular weight polyethylene (UHMWPE), also known as high modulus polyethylene (HMPE) or high performance polyethylene (HPPE) is a thermoplastic. It has extremely long chains, with molecular weight numbering in millions. The high molecular weight results from a very good packing of the chains into the crystal structure. This results in a very tough material, with the highest impact strength of any thermoplastic presently made. It has extremely low moisture absorption, very low coefficient of friction, is self lubricating and is highly resistant to abrasion (10 times more resistant to abrasion than carbon steel). To make fibres, they are dissolved and drawn into fibres and as the solvent evaporates, cause the polymer chains to orient in the direction of the fibre.

This is available as Dyneema and Spectra produced by two different companies. Polyethylene with an ultra high molecular weight (UHMWPE) is used as the starting material. In normal polyethylene, the molecules are not orientated and are easily torn apart. In the gel spinning process, the molecules are dissolved in a solvent and spun through a spinneret. In the solution, the molecules that form clusters in the solid state become disentangled and remain in that state after the solution is cooled to give filaments. As the fibre is drawn, a very high level of macromolecular orientation is attained resulting in a fibre with a very high tenacity and modulus. Dyneema fibres are produced in commercial grades, Dyneema SK 60, SK 62, Sk75 and SK 78 which are the multi-purpose grades. SK 60 and SK 75 are specially designed for ropes, cordage, fisheries and textile applications. It can be made into microfilament braided twine of fine diameter. Netting of simple knot, double knot and knotless are available. A comarison of properties of UHMWPE to other synthetic fibres is given in Table 4.

Table 4. Comparative properties of synthetic fibres

Chemical/physical characteristics	Fibre					
	PA 6	PA 6,6	PES	PP	PE	Dyneema SK75
Tenacity (g/den)	9	9	9	7	5	40
Elongation at break (%)	23	20	14	18	20	3.5
UV rays resistance	medium	weak	mediu m	medium	medium	good
Specific weight	1.14	1.14	1.38	0.91	0.97	0.97
Resistance to alkalis	good	good	weak	good	good	good
Acid resistance	weak	weak	good	good	good	good
Moisture absorption% (65%-20°C)	3.5-4.5	3.4-4.5	0.2-0.5	0	0	0

(Source: Badinotti, 2011)

Dyneema is 15 times stronger than steel and up to 40% stronger than Kevlar. Netting uses include trawl nets, purse seine nets and aquaculture nets. The low diameter of these twines and their favourable weight/strength ratio produce up to 40-percent less drag than conventional fibre structures as the net is pulled through the water or set against tide/currents. This allows fishing vessels to increase their catch — potentially by as much as 80 percent — by trawling faster or using larger nets, or to reduce fuel consumption. Dyneema trawl nets result a fuel saving upto 40%.The resistance of Dyneema nets to UV light, and abrasion is high, guaranteeing that nets last longer. With low elongation - as little as <5% - and no shrinkage in water, the mesh size remains stable during normal use of the netting allowing better filtering resulting in reduced bycatch. Besides, less deck space is required due to lower bulk volume of the net. Purse seines made of dyneema would facilitate 40% increase in sinking speed due to better filtering and reduced drag. Larger net for the same weight can be made. The net has better durability with negligible wear & tear.

Ropes made from UHMWPE have a higher breaking strength than that of steel wire ropes of the same thickness, but have only one-tenth the weight. Fishing uses for these high-strength polyethylene ropes include warp lines, bridles and headlines.UHMWPE ropes can be used in trawling to substitute wire ropes which helps in weight reduction and drag reduction resulting in fuel saving. By using UHMWPE ropes, the frequent oiling & greasing required for wire ropes can be avoided which would facilitate a clean and safe deck and free the crew from greasing the rope frequently. It also helps in a clean catch devoid of oil and grease contamination. From the safety point of view, while using UHMWPE rope, if it breaks there won't be any backlash unlike in steel wire rope in which the backlash on snapping can be fatal.

UHMWPE also finds good application in the aquaculture sector as a cage netting material due to the low diameter, favourable weight/strength ratio, low elongation and nil shrinkage in water which helps the mesh size to remain stable during normal use of the netting.

Liquid Crystal Polymer Fibre

Vectran® — a high-performance thermoplastic multifilament yarn spun from Vectra® liquid crystal polymer (LCP) — is the only commercially available melt-spun LCP Fibre in the world. Vectran fibre is five times stronger than steel and 10 times stronger than aluminum. The unique properties that characterize Vectran fibre include: high strength and modulus; high abrasion resistance; minimal moisture absorption; and high impact resistance. Although Vectran is lacking UV resistance, this limitation can be overcome by using polyester as a protective covering.

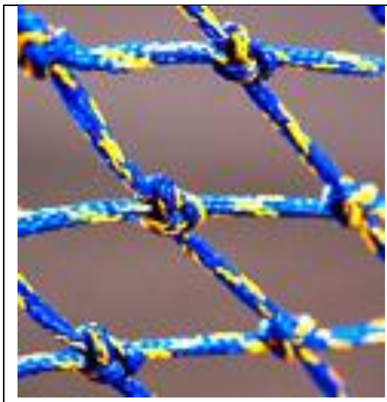
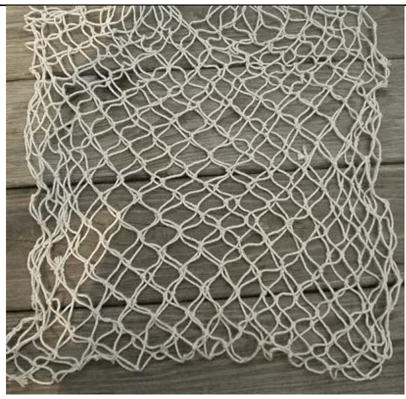
Fluorocarbon fibre

Fluorocarbon fibre is a new material that can be used in angling and high speed jigging lines. It has very high knot strength, almost invisible in water, has high breaking strength and abrasion resistance.

Sapphire

Sapphire PE netting manufactured from specialized polymers available in twisted and braided form is suitable for tawl nets and for cage culture. It has the highest knot breaking strength, knot stability and dimensional uniformity. Braided twine having compact construction restricts mud penetration and provides lesser drag.Sapphire is used on a limited scale for fabrication of large mesh gillnets targeting large pelagics in Maharastra region of India.

Sapphire ultracore is a knotless HDPE star netting with an outerlayer of heavier sapphire ultracore which features strands of marine grade stainless steel as an integral part of the netting twine. The stiffness and cut resistance enable it to be used as a predator protection net cum cage bag net where the predation problem is not very high.

		
Sapphire Ultracore	Kevlar	UHMWPE

Biodegradable polymers

As synthetic fibres are non biodegradable, the environmental threats it causes due to ghost fishing is an important problem. Environment friendly fishing line made of biodegradable polymer is a solution to this problem. Biodegradable polymers made from poly butylene succinate (PBS) are recent developments in this area. `Bioline'is a commercial fibre made from poly(butylene succinate) or PBS.This material retain its strength and durability for few months of use and then completely degrade in water (salt or fresh water) through the enzymatic reactions of naturally occurring microorganisms in the water.It does not deteriorate when kept clean and dry, but when exposed to bacterial activity underwater or underground, it deteriorates viz., it retains its strength and durability for the first 10-12 months of use and then completely degrade in water or on land within five years.

FIELDMATE™ is another example for biodegradble polymer. If exposed for three months in salt or fresh water, it decomposes through the enzymatic reactions of naturally occurring microorganisms, before eventually being reduced to water and carbon dioxide.

Conclusion

Among the new fibre types, only Sapphire and UHMWPE are used on a commercial basis for fishing gear viz., trawls and purse seines in Australia and Alaskan waters. Sapphire is also used on a limited scale as large mesh gillnets targeting large pelagics in Maharastra region of India.The introduction of synthetic fibres has revolutionized the fishing industry and it can be considered as the major single factor which led to the development of today's efficient fishing gears. Research and development in this industry is a continuing process and better materials suitable for the diverse fish harvesting implements can be expected in the future

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Chapter 4

Design and operation of trawls

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Introduction

Bottom or demersal trawling continues to be one of the most important fishing methods of the world.In Indiamore than 35,230 trawlers of various sizes ranging from 9 to 24 m L_{OA} with engine power ranging from 45 to 450 hp @ 2000 rpm are in operation. Trawl is a bag net towed through water to filter out fishes, the mouth of which is kept open horizontally by means of a beam or otter boards and vertically by means of floats, kite and sinkers. Horizontal mouth opening is also effected by dragging the net from two boats known as bull trawling or pair trawling. The main principle of trawling is the movement of the net under water filtering the water through the mesh in the netting, without either permitting the fish to escape or gilling them. Trawl net is fabricated using polyethylene netting after cutting and shaping the panels as per the design Fig.1.

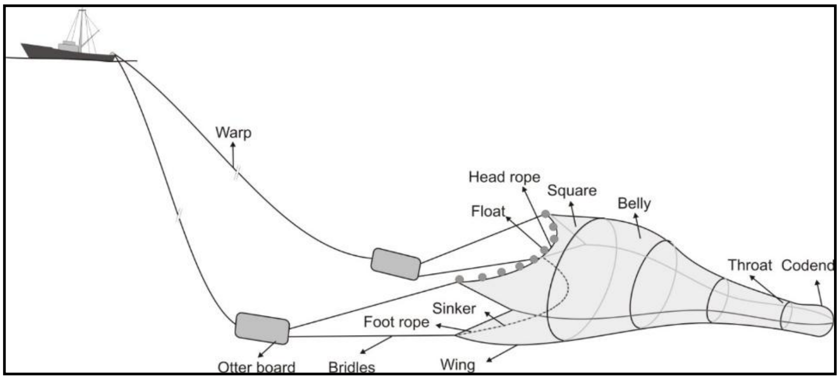

Fig.1 A demersal trawl in operation

In India, trawling was first attempted during exploratory surveys conducted from S.T. Premier off Bombay coast in 1902. Several designs of demersal trawls have been introduced in Indian fisheries in subsequent years.

The most important issue in this sector is the excess capacity in terms of number of trawlers. The size of the trawlers has also increased over the years. Since the in introduction of Chinese engines in the Indian waters, the horse power of the vessel has also increased tremendously and as a result of these changes there is a tough competition out at sea within and between the sectors, which is leading to overexploitation of the resources.

Classification of trawls

Trawls are classified based on the device used for mouth opening, number of panels used for fabrication, depth of operation and based on target species.

Beam trawl

Beam trawl was the forerunner of all trawl gears. In beam trawls, mouth of the net is kept open using a rigid and curved metal frame with a shoe at the bottom known as beam. This is the simplest method of bottom trawling practiced mainly in the North Sea for flatfish and shrimps. Since the shoe penetrates the seabed and the marks remains for a long period, beam trawling adversely affects bottom ecosystem. Due to the plowing effect, resistance is high resulting in more fuel consumption than otter trawling. Moreover, a large net requires a large beam which is very difficult to safely handle onboard a fishing boat.

Otter trawl

In otter trawls, the most popular method of trawling, the mouth opening of the net is achieved by the attachment of two otter boards, through bridles, on each side of the net. The towing warps are attached to these boards at an angle, so that while towing the water force acting on them tends to diverge them resulting in the opening of the net mouth.

Pair trawls

In pair trawling or bull trawling the net is towed by two boats cruising on a pre-arranged parallel course and speed. The distance between the two boats is also maintained constant, so that the diverging warps keep the mouth of the net open. Main advantage of this method is that a much larger net can be used, as two boats are engaged. As the vessels are operated from a distance from each other scaring effect due to vessel noise is also minimal. Pair trawling is banned in many countries as it generates huge quantity of bycatch.

Trawl types based on number of panels:

Two seam netshave only two major parts, *i.e.,* upper and lower panels and these two are seamed together laterally to form the two seams. The upper part invariably includes the overhang or square. Cross section of the net is elliptical in shape and since the vertical opening is comparatively less, these nets were mainly operated for shrimps. Presently all the trawls are two seem.

Four seam nets are having upper, lower and two side panels with or without overhang. Cross section of the net is rectangular in shape and hence the vertical opening of the trawl may be influenced by the width of the side panels.

Six seam nets have six panels and cross section of the net generally acquires oval shape. The six and eight seam nets are designed to have more vertical opening and hence suitable for catching fishes.

Main parts of the demersal trawl

Square: Square is defined as the front portion of the upper section of a trawl, which is fitted between the body and the two upper wings so that it partially overhangs, the lower parts of the trawl. Square prevents the fish from escaping the path of the trawl by swimming upward.

Wings: Wings are the forward extension of netting on both side of trawl mouth for guiding the fish towards the bag of the net. Wings and front part of the net are fabricated with netting having larger meshes to reduce the drag.

Bosom: It is the centre portion of trawl between the wings on upper and lower sections.

Jibs: Jibs are the two triangular pieces of webbing attached on either side of upper and lower bellies at their junction with wings to present a smooth shaping to the mouth of the net.

Quarters: They are two junctions where the top wings join the square.

Side panels: These are two identical pieces of webbing attached on both sides of the belly to join the upper and lower portion of a four-seam trawl. The portion of the webbing that comes above the belly is termed "top wedge" and the portion placed adjacent to the belly is termed as "lower wedge" or "side wedge".

Belly: The channel of trawl body through which fishes move to the codend is known as belly. Upper belly is also called "top body" or "baiting".

Throat: It is the portion of webbing placed in between the belly and cod end. It is also known as "lengthener" or extension piece.

Codend: It is the narrow rectangular end section of the trawl usually made of thicker twines with small meshes. A piece of rope is inserted through the meshes of the lower periphery of the codend is used to close the cod end while trawling and it is removed to release the catch.

Apron: Apron is the codend cover used to protect the net from rough bottom particularly with catch. It is also known as “Hula skirt” or “Chafing gear”. Net panels with large mesh made of thicker twines are used for fabrication of the cover. It is an optional component for the trawls operating in known grounds.

Head rope (head line): Rope line forms the upper lip of the trawl to which the upper edge of the net is finally attached. Polypropylene ropes are usually used as head rope in small trawls and combination ropes are used in large trawls. The ends of the line are spliced and mostly thimbles are inserted into the eyes. The vertical opening of the net depends mainly on the length of headline and footrope. Head rope and foot rope are attached along the upper and lower wings and across the square. Length of the net is expressed as length of head rope

Foot rope: It is also known as ground rope or fishing line, which forms the lower lip of the trawl to which the lower edge of the net is finally attached. Foot rope protects the lower edge of net mouth. Eyes are spliced to both ends of these ropes by which it is connected to the bridles using a shackle. Foot rope with attached sinker line serves as ballast preventing the trawl from rising. Length of foot rope is usually more than the length of head rope.

Bolch line: Prior to rigging of net to the head rope and foot rope it is hung to a thin rope known as bolch line. Bolch line is attached to the head rope and foot rope at constant intervals with uniform slack.

Design of trawls

The efficiency of a trawl mainly depends on the symmetry of construction of the body and mouth configuration. A trawl is designed in such a way that (i) it offers minimum resistance during tow (ii) total drag matches available towing force of the trawler, (iii) it achieves maximum mouth opening, and (iv) offers least hindrance to the movement of fish within the net towards the codend. While designing a new gear, different factors have to be taken into consideration such as strength and elasticity of webbing, resistance to the water flow, weight and bulk, speed of operation, cost of materials and conditions of fishing ground. A selective, environment friendly and energy efficient trawl system is generally the aim in design process.

Important design considerations in the design of trawl gear involve biological and behavioural characteristics of the target species; fishing conditions in the trawling ground where the system is to be used; and characteristics of the fishing vessel from which the gear is to be operated. Length of the trawl is measured along the lastridges (side lines) from wing (jib) end to tip of codend and it varies from 1.1 to 1.5 times the head rope length. Right size of a trawl for a particular vessel can be selected according to the total twine surface area or by comparison with a trawl of the same type used by a vessel in the same horse power. Design drawing of the trawl net is prepared to provide all information relating to the size, shape, material and construction using recognized nomenclature and symbols, prior to the fabrication of the net.

Fabrication

The netting is cut to give shape to the required panels as per the design of the trawl. The different panels are laced together and the net is prepared. The mouth of the net is hung to a thin rope and the upper section is mounted to the head rope and foot rope is attached to the lower edge of the mouth. Eyes are spliced on both ends of the head rope and foot rope. Later side ropes are laced along the seams to strengthen the trawl body.

Rigging of trawls

Floats and sinkers are to be carefully distributed to head and foot rope to avoid excess sagging. For medium sized trawls the weight requirement of foot rope per feet is 0.2 to 0.5 kg.

The total buoyancy of floats required is between 1/2 to 2/3 of the total weight of sinkers and their size and strength depend on the size of net as well as hydrodynamic factors.

Various methods are in vogue for achieving comparatively higher vertical opening like the use of kite and triangular gusset, insertion of triangular wedges on the wings or splitting the wings along the selvedges (Dickson, 1959) or use of float or float like devices having higher lift drag ratio.

Resistance of trawl gear

The drag of trawl gear determines the power required to overcome the hydrodynamic resistance of the gear towed at a particular speed. Hydrodynamic resistance or drag is estimated from model studies and by scaling up the results so obtained, to the actual size. It is also estimated through theoretical calculations by adding up the drags of individual components of the trawl gear.The bollard pull (towing power) of a trawler should be higher than the total drag at the maximum speed at which the trawl is towed. Trawl drag is contributed by netting (68%), otter boards (24%) and sweeps and warps (8%), approximately.

Trawl accessories

Otter boards

Otter boards are gear accessories used for keeping mouth of the trawl net open horizontally and its invention has revolutionized the stern trawling from single boat (Fig.2.). As already mentioned prior to the introduction of otter boards, a rigid metallic beam was used to keep the mouth of the trawl open, which creates lot of problem in handling.

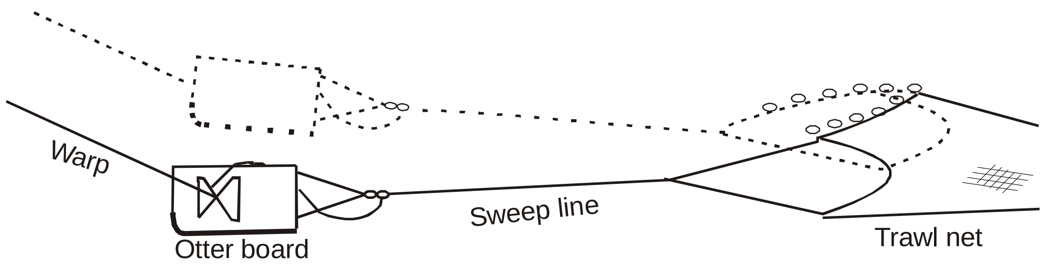

Fig.2. Rigging of otter boards in the trawl system

In the beginning, the boards were attached directly to the legs (Hoover Rigging) of the trawl. Since the introduction of Vigneron Dahl system, long bridles were introduced in between the net and otter boards. In the latter case the sweep lines are connected to the board by a back strop and the net by a bridle or danleno. The conventional type of otter board consists of a flat or curved surface for developing necessary shear force by diverting the flow of water, a bracket or chain for attaching the trawl warp, rings or back strop rings for attaching the legs or bridles and a heavy shoe to prevent the otter board raising off the ground and to provide stability. The following parameters influence the performance of otter boards.

Different types of otter boards used in bottom trawls

Rectangular flat otter boards

This is the widely used otter board for bottom trawling (Fig. 3.). In India all hard woods which can withstand sea water are used for fabrication. The board is assembled by joining wooden planks horizontally and fixing them together with long bolts or mild steel straps. A wide metallic shoe is used to maintain bottom contact and also to prevent digging into the mud. Some times a gap is left in between the planks which is said to prevent turbulence on the other side of the board. Though the boards are cheaper, easy to fabricate and handle they are not hydro-dynamically very efficient and can not slide over obstacles.

Rectangular curved otter boards

These boards are hydrodynamically more efficient than flat rectangular boards due to streamlined flow of water (Fig.4.). Boards are fabricated by arranging wooden planks vertically and joining them by iron frames. Main advantage of this board is that greater spread can be achieved at low towing power. These boards work at smaller angle of attack, which results in a lower towing resistance and may also reduce the tendency of otter board to dig into soft ground. Though cambered boards are expensive they are hydro-dynamically efficient and durable. Greater spread can be achieved with a smaller board at low towing speed.

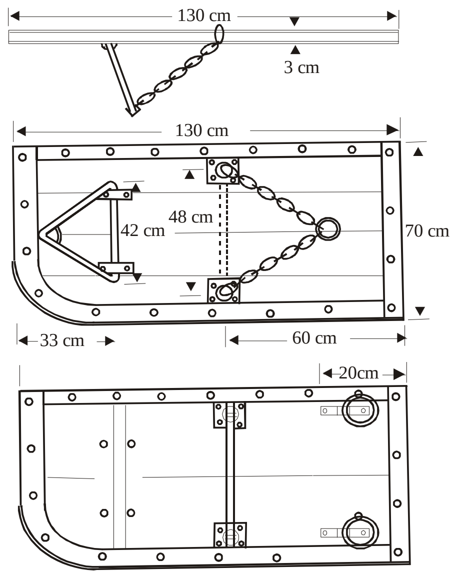

Fig. 3. Flat rectangular otter board

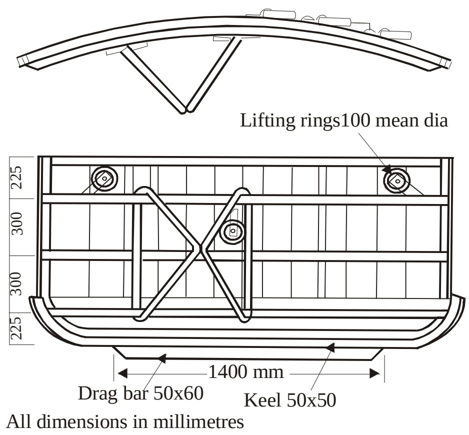

Fig. 4. Horizontally curved otter board

Oval flat slotted otter boards

These otter boards are also known as Russian type because these boards are very popular in Russia (Fig. 5.). They are designed for rough grounds. Hydro-dynamically it is slightly better than rectangular flat boards. The rounded lower edge though adversely affects the spreading performance, improves overall performance on uneven or hard ground because it reduces ground friction and mechanical stress.The vertical slot opening is intended to increase the hydrodynamic efficiency of the board by reducing the turbulence. The main limitation is its lower spreading force on clean ground as compared to cambered board of same area. This board is not suitable for midwater trawling. Hard wood is used for the construction.

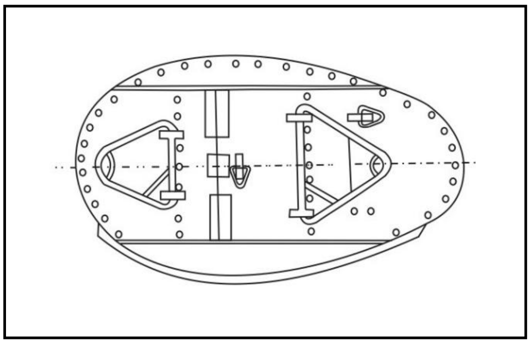

Fig. 5. Oval otter board

Oval curved slotted (Polyvalent)

As the name indicates it is a combination of the oval board and curved board, giving the increased spreading efficiency and ability to traverse the hard ground. They were first introduced in France with full steel body. A slot is cut in the main plate for generating a suitable angle for water flow through the slot. The polyvalent boards are relatively expensive but handling onboard is easy. These boards can be used for bottom and midwater trawling. It is reported that due to lack of proper ground contact they are also found to be unstable in bottom trawling.

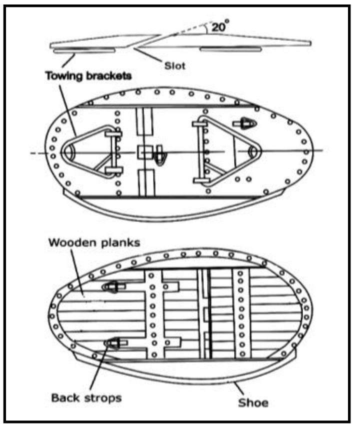

Fig.6. Oval otterboards

V-form otter board

V-form steel boards are the most popular boards in bottom trawling in many states of India. These boards are simple in construction relatively inexpensive, durable and stable on uneven grounds (Fig.7.). The interchangeability of the towing bracket is an important factor of this board, because spare board can be either way around to make either a port or starboard otter board. The V-form boards are heavier in weight but this is necessary to counter act the upward shear component which comes to play due to the shape of the board. Boards weighing 60-85 kg each can be used in vessels having 200-230 hp.

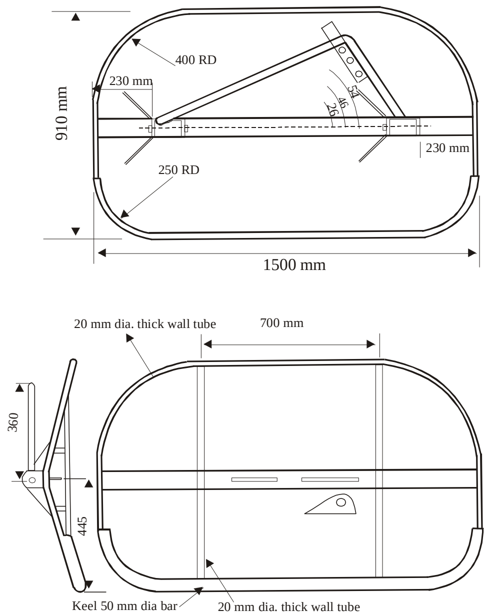

Fig. 7. V-form otter board

Suberkrub Otterboards

Suberkrub otterboards are used for semi-pelagic and midwater trawling. Thyboron boards are used for midwater trawling for krill and mesopelagics.

Floats

Floats are essential component of the trawl net for maintaining the head rope always upward. EVA (ethylene vinyl chloride), ABS (acrylonitrite-butadiene-styrene) and high density polyethylene (HDPE) are the most common floats used in trawls. Size of floats generally ranges from 100 to 300 mm. EVA is having maximum pressure withstanding capacity and buoyancy and hence most suitable for trawls. Trawl plane float, hydrodynamic float, up thruster float and siamese twin floats were developed to maintain the head line lift while trawling at great speed. Heavy duty plastic floats are used in the net made for deep sea trawling to withstand the pressure.

Sinkers

They are used for stretching the ground rope down to obtain the vertical gape and bottom contact. Iron having cylindrical shape and 250g weight and barrel or bean shaped lead with 100-200g weight are the commonly used sinkers at present.

Pennants

Pennants, also known as lazy line (since there is no strain on these lines when the trawl is being towed), serves as the connection between shackle and connecting link of the warp. It is made of galvanized steel wire, with same thickness of warps and bridles or PP rope. The pennants, one with each otter board, are used for hauling the net after the otterboards are detached.

Bridles

Bridles or sweep lines are the connecting wire linking the otter board and the legs of the net in order to widen the fishing path. Polypropylene ropes of about 20 m length are used in smaller vessels where as steel wire rope having 20-60 m length are used in large vessels for achieving better horizontal spread of the net. Where trawls are worked at towing speeds exceeding 3 knots, it is advisable to increase the length of sweep lines. At lower towing speed, long sweep lines sag badly and are dragged over the ground and thus wear out fast. Ground contact can be increased by lengthening the lower bridle or shortening the upper bridle. To increase the vertical height, lengthen the upper bridle or shorten the lower bridle.

Trawl warps

They are well lubricated steel wire ropes of identical length with marking at intervals, fully wound on the winch drum when not in use. While shooting the net the warps are connected to the otter boards by means of G-link assembly. The diameter of the warp may vary from 9 to 16 mm, depending on the size of the vessel and net. The length of warp to be released while towing the net depends on the depth of the fishing ground. Usually the depth and warp length ratio (scope ratio) is 1:5 or more depending on depth and bottom conditions. In deep sea trawling scope ration used is 1:3, plastic coated steel ropes and UHMWPE ropes are also being used as warps.

Bobbins

For fishing on rocky and coral areas an additional rope with rollers or bobbins has to be fastened to the ground rope to protect the net. The rollers or bobbins can be plastic or rubber or any other hard materials. They may be of various shapes, mainly round, disc or spherical.

Trawling operation

Demersal trawls can be operated from a few meters to more than around 1000 meters in the sea. The demersal trawl is designed and rigged to have bottom contact during fishing and is, depending on the bottom substrate equipped with different kinds of ground rope rigging. This is for the purpose of shielding lower leading margin of the trawl from ground damage whilst maintaining ground contact and easy move on the bottom.

The trawlers must have sufficient towing force for towing the gear and require a winch or mechanical hauling system. However, in some small-scale operations hauling is done manually. The methods adopted for demersal trawling are beam trawling, side trawling, stern trawling, double rig trawling, bull trawling and multi-rig trawling. Stern otter trawling is the most popular method in India.

Beam trawling

On arrival at the fishing ground, the beam trawls are hoisted on the booms which are then swung out. The operation is undertaken while the fishing vessel sails on a straight course. When hauling, the net is heaved in until it is at the boom tips. The cod end is taken by the line attached to the cod end strap and the catch is emptied out directly.

Otter trawling

The Vigneron-Dahl system was introduced during 1920s where the otter boards were attached to the wings by means of sweep lines and bridles. This helped in increasing the effective swept area and thus increased the catch due to the herding effect of sweep lines and otter boards. In larger trawls, in addition to the weight on the foot rope, iron bobbins or rubber discs are attached depending upon the nature of fishing ground. The towing warps are provided with markers at distinct intervals for facilitating the release warp, in small-scale operations. In large scale operations it is hydraulically or electrically controlled with metering arrangements. The length of warp released in bottom trawling depends on the depth of the fishing ground and nature of sea bottom. The ratio of depth of fishing ground and the warp released is known as scope ratio or in other words, it is the warp-length ratio. The length of warp to be released is generally (i) 5-6 times the depth in shallow waters below 50 m, (ii) 4-5 times the depth in off shore waters of 50-100 m, (iii) 3-4 times the depth in deep waters of 100-200 m and (v) 2-3 times the depth in deep sea of 200 m and more

The speed at which the trawl is towed over the bottom range from about 2 to 2.5 knots for slow swimming species to 3- 4½ knots for fast swimming fish. Towing a particular trawl too slowly may cause the otter boards to close together, providing insufficient spreading power to the net which tends to sag on to the bottom. Towing too fast may result in the net lifting off the bottom and floating which may lead to fouling of gear.

Winches are used to pay out and haul the warps. The winches have two drums, one for each of the two warps; an additional drum is provided for operation of try net in shrimp trawling. In larger trawlers, single drum split winches are used for each of the warps. Hauling speeds could vary from 30 to 60 $m.min^{-1}$. Stern ramps are provided in larger stern trawlers, which facilitate the shooting and hauling up of the large trawl gear with less manpower. In large trawlers net drums are used to haul up, pay out and store the sweeps, bridles and net with its rigging. The factors such as (i) availability of fish (by using echo-sounders, fishery charts and fishery forecasts), (ii) depth and nature of sea bottom of the fishing ground, (iii) current and wind speeds are to be taken into consideration before the commencement of fishing operation.

On reaching the ground the warps are attached to the net and the codend is closed properly. The codend is the first part to be released, followed by the main body of the net. The vessel steams forward slowly releasing the net and the otter boards. The winch is stopped after releasing few meters of the warp to ensure the proper spreading of the bridles and otter boards. The gear is then lowered to the desired fishing depth by releasing sufficient length of warp. The net is dragged for a duration of about 1 to 4 hours, depending on the concentration of catch.

The net is hauled by heaving in the trawl warps evenly on to the winch drums, until the otter boards reach the gallows. Sweeps and bridles are then hauled up followed by the main body of the net and finally the codend. In small trawlers, the sweeps and the net are shot and hauled in manually and sweeps may remain connected to the otter boards. In large trawlers, a Kelley's eye, independent wire and back-strop is used for facilitating the hauling of the sweep lines and net on to the net drum after the otter boards have reached the gallows.

Conservation Strategies: Design improvements

Large mesh trawls*:* In these trawls, the front trawl sections are made using large mesh panels which results in reduction of trawl resistance. The reduced drag permits greater trawling speed and operation of a large trawl with the available installed engine power. Trawls with a mesh size up to 5 m is now under operation in Kerala. Such trawl use only 3 large floats for lifting the head line.

Rope trawl: In rope trawl, the front trawl sections are replaced by ropes, which as in the case of large mesh demersal trawl, results in reduction of trawl resistance with the same advantages as in large mesh trawls. Finfishes are retained due to the herding effect of the ropes.

High opening trawls*:*High opening demersal trawls are designed to harvest off bottom fishes, which are beyond the reach of conventional demersal trawls, along with bottom resources. It has been reported that the large mesh high opening trawls offer 18% lesser resistance compared to conventional bottom trawls which in turn results in utilization of lesser horse power.

High Speed Demersal Trawls: Commercial exploitation of active fishes with low population density fishery resources requires high speed trawling. High speed demersal trawls (HSDTs) have been developed with light material, large meshes, smooth tapering along the belly facilitating even distribution of stress along the framing and strengthening ropes facilitating smooth filtration and herding.

Bulged belly trawl: In the bulged belly design, wide side panels are provided to increase the vertical opening, and at the same time tapering of the belly is streamlined so as to improve herding and filtration efficiency. The improved bulged belly trawl fitted with tapering jibs consistently landed better shrimp catches.

Technological Strategies

Increasing awareness on responsible fishing methods has resulted in studies to improve the selectivity of the trawls. Size selectivity in bottom trawls can be achieved by controlling the mesh size and shape. Species selectivity can be achieved using separator panels and grids by making use of the behavioral differences in species in the fishing area.

Separator trawls*:* It is designed to separate shrimp from fishes based on the difference in their swimming behaviour. Insertion of a horizontal panel in the separator trawl, separates the fish and shrimp catch, leading them to separate codends. The selection process of this device is based on the fact that shrimps which are usually distributed close to the bottom move to the lower codend while the high swimming species usually end up in the upper codend. Separator trawls reduce the sorting time, as the catch is landed in a pre-sorted condition.

Short body shrimp trawl*:* CIFT has developed and successfully field tested a 27 m shrimp trawl with relatively short body and large horizontal spread suitable for selective retention of shrimp. The width and length of the trawl funnel has been reduced by increasing the tapering ratio and the vertical opening of the mouth has been reduced to eliminate bycatch. Because of the larger horizontal spread of the mouth the effective sweep area is more, which is the most vital requirement for a shrimp trawl.

Trials carried out along the coastal waters off Cochin with a prototype of short body shrimp trawl reveals considerable reduction in the catch fish due to the behavioral difference of the targeted species.

Cut-away top belly shrimp trawl: A shrimp trawl without top belly has been developed and field test at CIFT. Results reveal that considerable reduction in the quantity of bycatch landed. The net was able to cover more area within the stipulated speed and time due to reduced drag.

Semi-pelagic trawls: 27m four panel CIFT-SPTS in combination with high aspect ratio Suberkrub otterboards weighing 85kg each with front weights is designed to catch fishes, which are up to 4 m above the ground, with minimum impact to the sea bottom (Fig.9).

Krill trawl

Krill (*Euphausia superba*) is a small crustacean found in the Antarctic waters of the Southern Ocean. Large trawls with small mesh inner lining is operated in Antarctic waters for krill fishing (Fig.10).

Mesopelagic trawls

Mesopelagics are small fishes in the size range of 3 to 30 cm inhabiting the disphotic oxygen minimum zone in world oceans in the depth range of 200 to 1000 m. Large trawls are used in Oman and South Africa for commercially harvesting mesopelagics mainly for making fishmeal and fish oil (Fig.11).

Environmental impact of bottom trawling

Bottom otter trawls interact physically with the bottom sediment, which might result in removal or damage of sedentary living organisms (including seaweed or coral) and in the case of uneven bottom surface displacement of stones or other larger objects. On flat sandy/muddy bottom the sediments might be whirled up into the water masses and suspended. The short and long-term impact on the bottom environment is still poorly documented. The major negative impact of bottom trawling is the capture and discarding of huge quantity of juveniles of fishes and other aquatic organisms.

Conclusion

Trawls are non-selective fishing gears creating plowing effect on the sea bottom leading to the destruction of benthic ecosystem. In trawl design and improvement, the aim should be to produce a trawl system which can selectively and efficiently catch the target fish, eliminating juveniles and other aquatic organisms with minimum environmental impacts. Since trawling is an energy intensive fishing method, development of low drag trawl systems to save energy and cost of operation is imperative. Resource specific trawls like semi-pelagic trawls should be popularized to minimize the impact on ecosystem. Excess capacity in terms of number of trawlers, size, engine power and trawl efficiency are major issues which needs to be addressed to make the trawling economical and sustainable.

Further reading

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Fig.8. Suberkrub otterboards and Thyboron type-7 otterboard

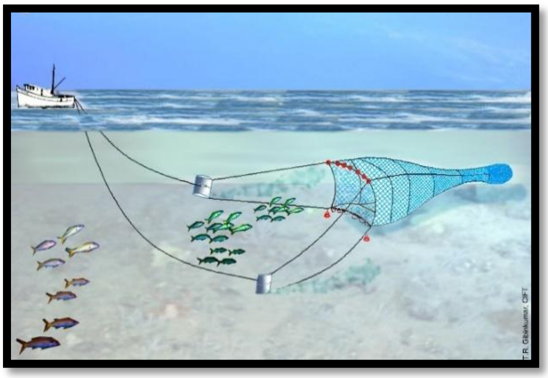

Fig. 9. Semi-pelagic trawl

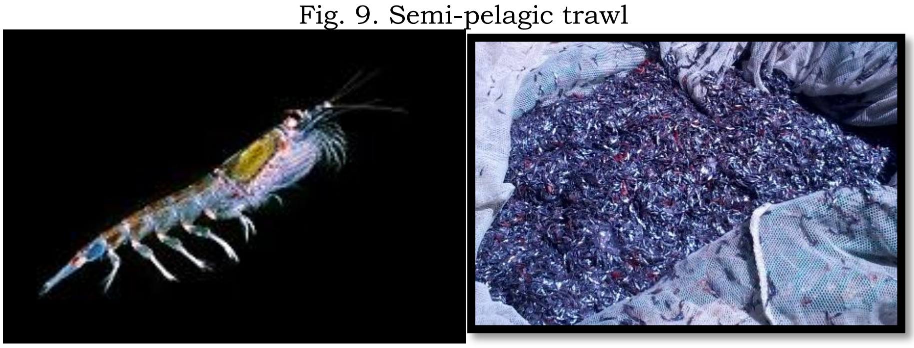

Fig.10. Antarctic krill and krill trawl with nylon inner lining

Fig.11. Myctophids and mesopelagic trawl

Chapter 5

By-catch reduction devices in trawling

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The 20th century had seen an increase in the fishing capacity, in terms of the number of vessels, the increase in size of the vessels and advances in the electronic and navigational equipment coupled with easily manufactured and durable fishing nets. The effect of these innovations sequentially, was the burgeoning in the fish production, plateauing of catches and the myth of inexhaustibility of fishery resources in the sea was proven wrong. A large number of stocks world over have declined and the status of many of the stocks now are alarming, but still the trend towards larger, more powerful and faster vessels continues.

Global fisheries production has reached a plateau and is now hovering around 80 million tonnes during the last decade. It is also noted that the status of world's marine fish stocks have not improved overall. About 31.4% of assessed fish stocks are fished at a biologically unsustainable level and therefore overfished. Fully fished stocks accounted for 58.1% and underfished stocks 10.5%. It is evident that most of the stocks are fully fished with no further potential for increase in production.

The importance of reducing bycatch and minimizing ecological impacts of fishing operations has been emphasized by scientists and fishery managers and recognized by fishermen. Trawl fisheries in different parts of the world are now being required to use bycatch reduction devices as result of pressure from conservation groups and legal regimes introduced by the governments. The Code of Conduct for Responsible Fisheries (FAO, 1995), which gives guidelines for sustainable development of fisheries, stresses the need for developing selective fishing gears in order to conserve resources, protect non-targeted resources and endangered species.Although the problems of using non-legal gears often with smaller mesh sizes and designs that are not appropriate for the region, most of the problems due to generation of bycatch and damage to the ecosystem function, has been implicated due to the use of trawls.

Bycatch from harvesting systems

The term bycatch refers to the non-targeted species retained, sold or discarded for any reason (Alverson et al., 1994). Target catch is the species that is primarily sought after in the fishery and incidental catches is the retained catch of non-targeted species and the discarded catch is that portion of the catch that is returned to the sea due to economic, legal or personal considerations. Global bycatch by the world's marine fishing fleets was estimated at 28.7 million t in 1994, of which 27.0 million t (range: 17.9-39.5 million t) were discarded annually and shrimp trawling alone accounted for 9.5 million t (35%) of discards annually (Alverson et al., 1994). In 1998, FAO estimated a global discard level of 20 million t (FAO, 1999a). Average annual global discards, has been re-estimated to be 7.3 million t, based on a weighted discard rate of 8%, during 1992-2001 period (Kelleher, 2004). Davies et al. (2009) redefined bycatch as the catch that is either unused or unmanaged and re-estimated it at 38.5 million tonnes, forming 40.4% of global marine catches.

Globally, shrimp trawling contributes to the highest level of discard/catch ratios of any fisheries, ranging from about 3:1 to 15:1, and the amount of bycatch varies in relation to target species, seasons and areas (EJF, 2003). Trawl fisheries for shrimp and demersal finfish account for over 50% of the total estimated global discards. Globally, estimated discards increased from under 5 million t/year in the early 1950s to a peak of 18.8 million t in 1989, and gradually declined thereafter to levels of the late 1950s of less than 10 million t/year (Zeller et al., 2017).

The reduction in bycatch discards globally, in recent years could be attributed to (i) increased use of bycatch reduction technologies, (ii) anti-discard regulations and improved enforcement of regulatory measures, and (iii) increased bycatch utilization for human consumption or as animal feed, due to improved processing technologies and expanding market opportunities.

Also equally important as the issue of bycatch is the un-quantified impacts of different fishing systems on the ecosystem. The ecosystem impacts of fishing are more for the active fishing gears like trawls.

Trawl bycatch, in the tropics is constituted by high proportion of juveniles and sub-adults, particularly of commercially important fishes, which needs serious attention in development, optimization and adoption of bycatch reduction technologies (BRD).

FAO has brought out International guidelines on bycatch management and reduction of discards, in view of its importance in responsible fisheries (FAO, 2011). Life under water (14^{th} Goal) among the Sustainable Development Goal (SDG) has different targets for sustainable use of fisheries resources.

Bycatch Reduction Devices

Devices developed to reduce the capture of non-targeted species during trawling are collectively known as Bycatch Reduction Devices (BRDs). These devices have been developed taking into consideration variation in the size, and differential behaviour pattern of shrimp and other animals inside the net.Different types of bycatch reduction technologies have been developed in the fishing industry around the world (Prado, 1993; Brewer et al., 1998; 2006; Eayrs et al., 1997; Broadhurst, 2000; CIFT, 2007; Eayrs, 2007; Boopendranath, 2007; 2009; 2012; Boopendranath et al., 2008; 2010a; 2010b; Kennelly, 2007; Broeg, 2008; Boopendranath & Pravin, 2009; Pravin et al., 2011; Suuronen et al., 2012).

BRDs can be broadly classified into three categories based on the type of materials used for their construction, *viz.*, Soft BRDs, Hard BRDs, and Combination BRDs. Soft BRDs make use of soft materials like netting and rope frames for separating and excluding bycatch. Hard BRDs are those, which use hard or semi-flexible grids and structures for separating and excluding bycatch. Combination BRDs use more than one BRD, usually hard BRD in combination with soft BRD, integrated into a single system.

Use of BRDs is one of the widely used approaches to reduce bycatch in shrimp trawls. Some of the advantages in reducing the amount of unwanted bycatch caught in shrimp trawls by using BRDs are (i) Reduction in impact of trawling on non-targeted marine resources, (ii) Reduction in damage to shrimps due to absence of large animals in codend, (iii) Shorter sorting times, (iv) Longer tow times, and (v) Lower fuel costs due to reduced net drag (Boopendranath et al., 2008; Boopendranath & Pravin, 2009). The effects of BRD installation on total drag of the trawl system and hence on fuel consumption has been reported to be negligible (Boopendranath et al., 2008).

Soft Bycatch Reduction Devices

The soft Bycatch Reduction Devices use soft structures made of netting and rope frames instead of rigid grids, prevalent in hard BRDs, for separating and excluding bycatch. Based on the structure and principles of operation they are classified into five categories viz., (i) Escape windows, (ii) Radial Escapement Section without Funnel, (iii) Radial Escapement Section with Funnel, (iv) BRDs with differently shaped slits and (v) BRDs with guiding/separator panel. Soft BRDs have advantages such as ease of handling, low weight, simplicity in construction and low cost, compared to hard BRDs.

Hard Bycatch Reduction Devices TED

Various designs of hard BRDs are in operation around the world which includes (i) Oval grids, oval shaped metallic grid with exit opening like Georgia-Jumper, Saunders grid , Thai Turtle Free Device (TTFD),Oregon grate, CIFT-TED ,Seal Excluder Device and Halibut Excluder Grate; (ii) Slotted grid BRDs which provide slots for the passage of non-targeted organisms such as Hinged grid and Anthony Weedless; (iii) Bent grids in which grid bars and grid frame are bent at one end near the opening such as Juvenile and Trash Excluder Device (JTED), NAFTED; (iv) Flat grid BRDs such as Nordmore grid, Wicks TED, Kelly-Girourard grid, and EX-it grid.

Fisheye BRD is considered as an important hard BRD around the world. There are several design variations of fisheye BRD such as Florida Fish Eye (FFE) used in the Southeast US Atlantic and in the Gulf of Mexico. Other designs in this categories are Snake-eye BRD used in North Carolina Bay, Fish slot, Sea eagle BRD and Popeye Fish excluder or Fishbox BRD.

Hard BRDs also include TEDs like NMFS hooped TED, Fixed angle TED and Cameron TED (Oravetz and Grant, 1986; Prado, 1993; Mitchell *et al.*, 1995; Talavera, 1997, Rogers *et al.*, 1997), Matagorda TED, Georgia-Jumper, Super Shooter, Anthony Weedless, Jones TED and Flounder TED (Talavera, 1997; Mitchell *et al.*, 1995; Dawson, 2000; Belcher *et al.*, 2001; CIFT, 2003) that are devices used for the conservation of Sea turtles.

Semi-flexible BRDs

Semi-flexible BRDs made of semi-flexible or flexible materials such as polyethylene, polyamide and FRP are used in the North Sea brown shrimp fishery, Polyamide grid devices provided with hinges to facilitates operation from net drums have been used in the Danish experiments in the North Sea shrimp fishery and Polyamide-rubber grid design are used in Denmark.

BRDs with guiding or separator panel

Guiding or separator panels are used to achieve separation of the bycatch by using differences in their behaviour or size. BRDs with guiding panels lead the fishes to escape openings, making use of the herding effect of the netting panels on finfishes. The shrimps are not subjected to herding effect and hence pass through the meshes towards the codend. BRDs with separator panels physically separate the catch according to the size, with the use of appropriate mesh size. Shrimps pass through the panels to the codend while bycatch such as fishes and sea turtles are directed towards the exit opening Fig: (1).

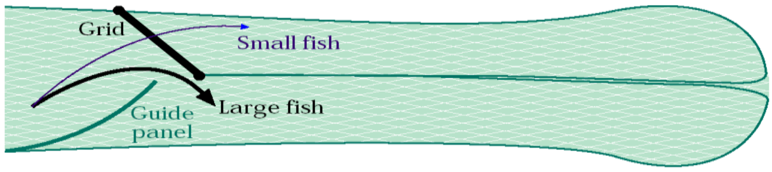

Fig. 1 Separator panel BRDs

BRDs in India

A number of BRDs have been developed and field tested in India. The BRDs evaluated include hard BRDs *viz.*, Rectangular Grid BRD, Oval Grid BRD, Fisheye BRD and Juvenile Bycatch Excluder cum Shrimp Sorting Device (JFE-SSD) and soft BRDs *viz.*, Radial Escapement Device (RED), Sieve net BRD, Separator Panel BRD and Bigeye BRD (Boopendranath et al., 2008). The efficacy of square mesh codends for selective fishing is widely reported and the selection parameters for a large number of fishes have been derived. The conceptual simplicity and the ease of installation of square mesh codends make its adoption much easier in the small scale fisheries. The mesh lumen (opening) of the diamond meshes tend to close during fishing due to various forces acting on the net, whereas the square meshes remain open and retain their shape, thus allowing non-targeted catch like small fish and juveniles to escape through the mesh openings. Studies using square mesh codends in India, have demonstrated the improvements in the selection properties. (Kunjipalu,1994; Boopendranath and Pravin, 2005; Madhu et al., 2016).

Conclusion

Studies using bycatch reduction devices have shown to reduce the incidence of bycatch in trawling considerably. Different BRD designs have been tried and the efficacy of a particular design depends on the composition of bycatch in the area. Experimental trials for optimization are needed before the designs are released for field trials among the fishers for adoption. A small loss in revenue, as a result of reduced bycatch is often negated when the overall future gain is considered in the fishery as a result of increase in the yield per recruit from the stock. Benefits like subsidies in the fishery can also be linked with the adoption of good practices in the trawl fishery.

Use of BRDs for resource conservation is one of the many strategies for sustainable harvest of the fishery resources. Adherence to the norms in the marine fisheries regulations acts, reduction of fishing effort (interms of capacity and size of the vessels and gear), spatial and temporal fishing area restrictions and strict monitoring, control and surveillance are required for the gear based technical measures like BRDs to be effective.

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Chapter 6

Nano application in material protection

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Material size below 100 nm size usually considered as nano materials and it is considered as an emerging area of science and technology last 20 years. The nano materials as powders, nanotubes or nano 2D sheets were extensively employed for different applications. Nano materials were synthesised either top to bottom or bottom up methods. These materials were characterized by SEM, TEM, FT Raman and XRDs. Nano materials used mainly in fisheries to develop antifouling strategies, slow release nutraceuticals, material protection from degradation and sensors.

Introduction:

The term nanotechnology was coined by Prof Taniguchi, Japan in 1974 conference of the Japanese Society of Precision Engineering [1,2]. Nano technology is a domain of scientific activity oriented on synthesis, characterization, application of devices and materials and technical systems which functions at nano structures having 1 to 100 nm size [1]. Prof R. Feynman [3] American Physicist and Nobel Prize winner was the first person pointed out the importance and promising outlook for nano particles during his lecture entitled "There's Plenty of Room at the Bottom. An Invitation to Enter a New Field of Physics," delivered on December 29th 1959 at the California Institute of Technology. He pointed out that "... when we have somecontrolof the arrangement of things on a small scale wewill get an enormously greater range of possible propertiesthat substances can have, and of different thingsthat we can do ... The problems of chemistry and biologycan be greatly helped if our ability to see what weare doing, and to do things on an atomic level, is ultimately developed". Later scientists realized the potential of nano particulate materials during the last decade has tremendous advancement in nano research. Governments and private sectors of the world invested huge sums to reap the benefits from novel applications of nano materials.

Nanotechnology: The principle of nano technology is that the material with known properties and functions at normal size exhibit different behaviour and functions at nano scale. By decreasing the size of the material the surface area per unit material will increase enormously and this helps greater interactions with reactive sites. Nano technology implied that the process of fabricating and/ or controlling the material sized between 1 to 100 nm.

Classification of nano materials

The 7th International Conference on Nanostructured materials recommended the following classification of nano materials

- Nano particles
- Nano porous structures
- Nano tubes and nano fibers
- Nano dispersions
- Nano structured surfaces and films
- Nano crystals and clusters.

Among the different types of nanomaterials, nanoparticles, nano tubes and nano fibres are the most economically important items and they are extensively used.

Carbon nano materials

The fullerene was discovered in 1985 by Robert Curl, Harold Kroto and Richard Smalley [3,4]. It is shaped like a footballs with an empty core. The number of carbon atom in fullerene was ranged from 20 to several hundreds. SimioLijima [5-7] and it has quasi one dimensional tube structures, which are formed by wrapping basic planes of graphite hexagonal lattice into seamless cylinders. CNT are single or multi layered and they can be opened and closed. These CNTs have an array of interesting magnetic, electronic and mechanical characteristics. It is light weight with higher strength and can conduct electricity better than copper. CNTs are extensively used in packaging material and added as additive to prepare anti-static packaging material. CNTs are considered as unique since it has stronger bonding between the carbon atoms and the tubes can have extreme aspect ratios. The characteristics of CNTs different and it depends on how graphene sheets rolled up to form the tube causing it to act either metallic or as a semiconductor. carbon nanotubes do not have free chemical bonds, therefore despite their small sizes, they do not display surface effects. CNTs are studied thoroughly and the countries like Japan commercially manufacturing hundreds of tons of CNTs.

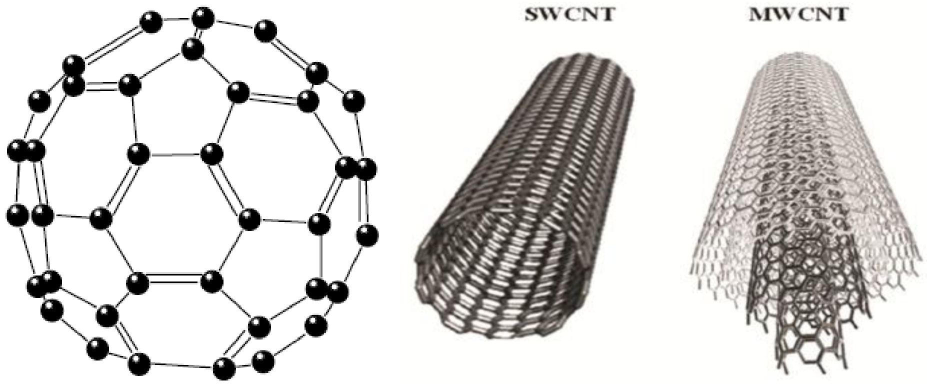

Fig 1. A) Fullerene C60 molecule B) SWCNT and C) MWCNT.

There are different types of carbon nanotubes viz single walled (SWCNTs) and multiwalled carbon nano tubes (MWCNTs). SWCNT has one layer whereas MWCNTs are having a collection of nested tubes of continuously increasing diameters. There may two or higher number of tubes or walls. Each wall is separated at a certain distance between the inner and outer tubes through interatomic forces. Carbon nanotubes are extensively applied for strengthening the rebar to concrete.

Synthesis of nano materials:

There are two approaches used for the synthesis of nanomaterials, viz., top-down principle and bottom-up approach [5,6]. The bottom up technology is based the development of nanomaterials of desired structure directly from “lowest level” elements (atoms, molecules, structure blocks etc). Here we have to identify the desired material in advance.The carbon nanotubes are synthesised by passing simple carbohydrates (eg acetylene) through a volume containing catalysts at a temperature of 600 – 800^{o}C. CNTs are formed on the catalysts [7]. Development of nanomaterials from larger size particles to lower sizes is termed as top-down approach.Eg. Synthesis of nano cerium oxide from cerium chloride. Dilute solutions of cerium nitrate were oxidized using ammonia under controlled environment and then calcined at 400 ^{o}C will give nano cerium oxide.

Equipments for testing nanomaterials

The instruments used for characterization of nanomaterials are

- Transmission Electron Microscopes
- Scanning Electron Microscopes and its variants like Scanning Tunneling Microscope,
- Near field Scanning Optical Microscope etc.
- X – Ray Diffraction,
- Atomic Force Microscopes

- FT Raman spectroscope,
- UV- Vis Spectrophotometers
- Particle size analyser with zeta potential etc.

Characterisation of nano materials

Nanostructures have interesting features and physico-chemical characteristics and successful use of nanotechnology is possible only after a careful study of their properties. Some of the properties to be studied generally are mechanical, thermo physical, electrical, magnetic, optical and chemical properties. The details are available in different text books of nanotechnology [9].

Applications of nano technology

Material science:
The major application in material science is the development of new materials. CIFT is doing research on development of new aluminium metal matrix composites by incorporating nano cerium oxide, nano samarium oxide, nano titanium oxide etc.

Antifouling strategies:

Fig 2. A) PE cage net b) PE cagenet after 3 months c) PE cagenet treated with PANI+nano CuO after three months exposure in the estuary.

Biofouling is a major problem in the aquaculture cage nettings and its management measures are very expensive. CIFT carried out research on nano material coated aquaculture cage nets and tests revealed that the coatings were efficient in preventing the biofouling in cage nets. Polyethylene cage nettings surface was modified with polyaniline and the nano copper oxide coating prevented the attachment of foulers.

Medicine and bio-nanotechnology: Nano materials can be used for precise drug delivery, to the the targeted organs or body parts or tissues.

Nano sensors: Design of nano sensors and nano devices of autonomous or as administered inside the human body. This will help the recognition of molecules of specific types like cancer and its treatment [13-16]. Nano materials like gold and other organo polymeric composites were successfully employed for the development of thermochromic sensors, colourimetric sensors and electrochemical sensors for detection of contaminent in the human body or food products or adulterants. Nano engineered biodegradable material incorporated with insulin used for slow release insulin to control blood glucose concentrations [18]. Applications of nano materials in medicine are like mucosal lining treatment [19,20] and inflammatory bowel treatment using nano pharmaceuticals [21].

Food science:

Nano materials were potential to apply as food supplements For example, antioxidant nutrients may be included in nanocomposites,nanoemulsions, nanofibers, nanolaminate sand nanofilms, or nanotubes etc.

Societal Issues

As with any emerging technology, the full consequencesof pervasive incorporation into society are currently unknown.For example, what are the outcomes if the byproductsof nanoshells or nanoparticles, or the nanoparticles themselves, used in cancer treatment enter circulation and healthy tissues and cells. Other issues like free radical formation during sun exposure [22], health environment and safety issued [23]. The ethical andlegal ramifications of nanotechnology are primed forpublic consideration.The greater the awareness and understanding ofnanotechnology among the society is essential for safe application and reaping the benefits. The society must be more informed about advantages and disadvantages of nanotechnology through public deliberations, discussions and suitable decisions by the public and government for brighter tomorrow.

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Chapter 7

Energy saving in fishing vessels

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Introduction

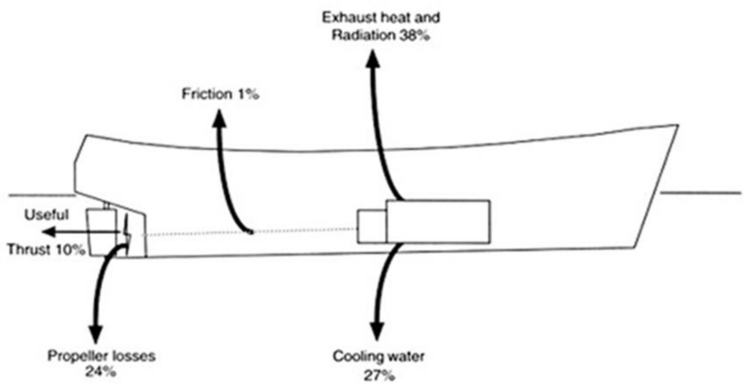
Fishing is the most energy-intensive food production method in the world today and depends almost completely on internal combustion engines based on oil fuels. Energy is spent during the design, construction and operation of vessels. Energy loss can take place during different stages such as design, construction, operation and maintenance of boats and at harbor.

The energy costs for a particular fishery is determined principally by the technology in use, the local economic conditions, including taxes, subsidies, labour cost and operational cost. (O.Gulbrandson, FAO, 2012)

Only about one-third of the energy generated by the engine reaches the propeller and, in the case of a small trawler, only one-third of this is actually spent on useful work such as pulling the net.

Materials and methods

The approximate distribution of energy created from the burning of fuel



A long liner or gill netter, the total energy gets distributed as follows:

35 % is used to turn the propeller;
27 % to overcome wave resistance;
18 % to overcome skin friction;

17 % to overcome resistance from the wake and propeller wash against the hull; and3 % to overcome air resistance.

Energy produced by the main engine

Most of the energy generated by the fuel burnt in the engine is lost as heat via the exhaust and cooling system and the operators are helpless to usefully recuperate this energy. Some of this can be regained through the use of a super charger and turbocharger but, in general, the thermal efficiency of small higher-speed diesel engines is low and little can be done to improve this. However, some engines are significantly more fuel-efficient than others, especially among different types of outboard motors.

The effect of wave resistance, determined principally by the dimensions and hull form of the vessel, increases dramatically with speed. Significant fuel savings can be made by maintaining a reasonable speed for the hull, irrespective of vessel type.

Fishing operations also influence energy consumption and efficiency through gear technology and operating patterns, particularly trip length.

Hull roughness

The amount of weed and marine growth that is allowed to accumulate on the hull. Both of these factors are under the direct influence of the operator's maintenance programme but, depending on the type of vessel and fishery, a significant expenditure on hull finish is not always worthwhile.

To improve fuel efficiency the operator of the vessel can contribute to reduce fuel loss by selecting a proper engine and gear box combination. The selection of a matching propeller and shaft also can lead to minimize the fuel loss.

Speed is the most important factor to influence fuel consumption.

As a vessel is pushed through the water by the propeller, a certain amount of energy is expended in making surface waves alongside and behind the boat. This generates wave-making resistance. As the vessel's speed increases, the wave resistance also increases very rapidly - disproportionately to the increase in speed. To double the speed of a vessel, it burns much more than double the amount of fuel. At higher vessel speeds, not only is more fuel lost to counteract wave resistance, but also the engine itself may not be operating at its most efficient, particularly at engine speeds approaching the maximum number of revolutions per minute (RPM). These two effects combine to give a relatively poor fuel consumption rate at higher speeds and, conversely, significant fuel savings through speed reduction.(O.Gulbrandson, FAO, 2012)

The choice of operating speed is usually under direct control of the skipper. Vessel speed during fishing may be constrained by other parameters such as optimum trawling or trolling speeds and may not be so freely altered.

Saving fuel through speed reduction is achieved by the awareness of the Skipper about what could be gained by slowing down and he must be prepared to go more slowly in spite of the fact that the vessel could go faster.

So by slowing down the vessel slows down and the journey takes longer the efficiency of the engine will change, but it will consume less fuel per hour. By this the resistance of the hull in the water drops very rapidly the efficiency of the propeller changes.

Engine performance

The amount of fuel that a diesel engine consumes to make each horsepower changes slightly according to the engine speed. A normally aspirated diesel engine (without a turbocharger) tends to use more fuel per horsepower of output at lower engine speed. At a lower RPM the engine may actually be working less efficiently.

A turbocharged diesel engine that is fitted with a small compressor to force more air into the engine has slightly different characteristics. This type of engine may work more efficiently at slightly lower speeds, but efficiency may drop rapidly as the speed is further decreased.(O.Gulbrandson, FAO, 2012)

Hull resistance: Rapid build-up of wave-making resistance takes place with increase in speed. The change in resistance of the hull is much more significant than the change in efficiency of the engine. A large increase in power is required to achieve a small increase in speed; and a small decrease in speed can result in a large decrease in the power requirement.

An outboard powered vessel will require approximately 50 percent more power, primarily on account of the low efficiency of outboard motor propellers. It is important to realize that the fuel consumption of both a diesel engine and a petrol outboard motor is approximately proportional to the rated power output, and high horsepower requirement equates directly to high fuel consumption.

For small changes in speed, an approximation of the change in fuel consumption per nautical mile can be made using the following equation:

- $$\text{New fuel consumption} = \text{original fuel consumption} \times \left(\frac{\text{new vessel speed}}{\text{original vessel speed}}\right)^2$$

Saving fuel by reducing speed is cost to the vessel operator in terms of time, and a difficult decision has to be made as to whether it is worth slowing down. A reduced speed could imply less time for fishing, less free time between fishing trips or even lower market prices owing to late arrival.

Considering only the resistance of a vessel in the water, maximum operating speeds can be recommended as follows:

For long thin vessels such as canoes, the operating speed (in knots) should be less than $2.36 \times \sqrt{L}$

For shorter fatter vessels such as trawlers, the operating speed should be less than $1.98 \times \sqrt{L}$

Fouling: The loss of speed or the increase in fuel consumption owing to the growth of marine weed and small molluscs on the hull is a more significant problem for fishing vessel operators than hull roughness. The rate of weed and mollusc growth depends on the mode of operation of the vessel;the effectiveness of any antifouling paint that has been applied, and local environmental conditions, especially water temperature - the warmer the water, the faster weed grow. Estimates indicate that fouling can contribute to an increase in fuel consumption of up to 7 percent after only one month, and 44 percent after six months (Swedish International Development Authority/FAO, 1986b), but can be reduced significantly through the use of antifouling paints. A Ghanaian canoe, for example, was found to halve its fuel consumption and increase its service speed by 30 percent after the removal of accumulated marine growth (Beare in FAO, 1989a).

Roughness: Wooden vessels, and even to a certain extent glass fibre vessels, experience an increase in hull roughness with age (primarily owing to physical damage and the build-up of deteriorated paint), the effect is more significant with steel which is also subject to

The operational pattern of vessels will influence on the fuel efficiency. Larger fishing vessels, with endurance of several days or more at sea, tend to limit the length of fishing trips to the time necessary to fill the available hold space. In smaller-scale fisheries the tendency is to restrict the length of a fishing trip to a single day, often owing to the lack of storage facilities on board or long established routines. In many such cases, effective fuel savings could be made by staying longer at the fishing grounds, particularly if a considerable part of the day is spent travelling to and from the fishery. For example, if trips could be made in two days instead of one, the catch over those two days would be made at the cost of the fuel for one return journey rather than two. This would effectively cut the cost of the fuel expended on travelling to and from the fishing grounds, per kilogram of fish caught, by up to 50 percent.(O.Gulbrandson, FAO, 2012)

Use of technology to save fuel:
The technological steps such as optimization of hull form to reduce the resistance in water, use of light materials for the construction of vessels can save fuel. Also the use of solar power for the propulsion of fishing vessel will eliminate the use of fossil fuel. This will reduce the carbon foot print also.

Fig.1. Solar powered inland fishing boat designed and constructed by ICAR-CIFT in gill net operation

The solar panel on F.V.Sagar Harita of ICAR-CIFT

ICAR-CIFT has designed and constructed a 19.75 m Loa fuel efficient multipurpose fishing vessel. This vessel has been powered with a 400 h.p main engine whereas similar sized vessel in commercial operation is using a 500 h.p main engine. This saving is the out come of analysis and optimization of hull form through Computational Fluid Dynamics software. Another fuel saving feature onboard this vessel is the solar panel which gives 600 W power for emergency lights onboard.

Navigational aids auto pilot, chatrs and echo sounde helps reduce unnecessary cruising and can contribute to fuel savings of up to 10 percent (Hollin and Windh, 1984), depending on the type of fishery and the difficulty in locating small, focused hot spots. Not only can the equipment assist the vessel skipper in easily relocating fishing grounds (thereby reducing fuel wastage), but it can also identify new grounds and contribute to increased navigational safety. Both satellite navigators and echo sounders require a reasonable navigational ability and are most effectively used with maritime charts.

The propeller designer must strike a compromise based on the time the vessel spends operating in the two situations. For vessels working a great distance from their home port, the benefits to be gained from designing a propeller with increased towing power (and therefore catching capacity in the case of a trawler) may well be outweighed by the increased cost of fuel for the transit journey, and the design will err towards a higher-pitched propeller. A day boat operating relatively close to its home port would inevitably have a propeller optimized for towing.

Nozzle: A nozzle around the propeller significantly improve the efficiency of a propulsion system.

The duct is close fitting to the propeller, slightly tapered with an aerofoil cross-section. First, the duct helps to improve the efficiency of the propeller itself. The nozzle itself generates driving force in a similar way to the lift produced by the wing of an aeroplane.

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Chapter 8

Handling and chilled storage of fish

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Quality of fish raw material plays an important role for the quality of the end-product. Once the fish raw material freshness and nutrition value is lost, it cannot be recovered in the processing stages. Products that are processed from low quality raw material are not always a safety risk, but the quality (nutrition value) and shelf life is significantly decreased. The quality deterioration can start right away during fishing and it continues all the way to the final user. Time-temperature abuse should be avoided at all stages of handling till landed fish reaches the consumer or the processor. In tropical countries more care in handling is necessary as fishes thrive in high ambient temperature has high body temperature and hastens spoilage.

Fish is highly perishable because of their chemical composition. It has high content of soluble substances in the flesh (many of which contain nitrogen and triglycerides characterized by polyunsaturated fatty acids) and high level of autolytic enzyme. After the death of the fish, spoilage starts due to the action of microbes, enzyme and oxidation. It is therefore, necessary to preserve fish after harvest if not consumed or disposed immediately.

Influence of time and temperature on shelf life of fish

For fish, shelf life is defined as the time from when it is taken from the water until it is no longer fit to eat. The effect of time/temperature storage conditions on product shelf life has been shown to be cumulative. The shelf life at different storage temperatures (at t°C) in comparison to 0°C (melting ice) as been expressed by the relative rate of spoilage.

$r = (O.1\ t + 1)^2$, where r is the relative rate of spoilage and t is temperature (in °C).

For example,

When fish is well chilled and has a temperature of 0°C, then r is 1.

If the fish is at 4°C, Then, $r = (0.1 \times 4+1)^2 = 1.96$ (~2.0). Thus, spoilage is twice as fast at 4°C as it would at 0°C.

Hence, the temperature history of a fish can help to estimate the remaining days of shelf life of the fish (Table 1).

Table 1: Relative rate of spoilage and lost of equivalent days on ice for different temperatures and times (*Source*: Doyle, 1995)

Temperature (°C)	Relative rate of spoilage (r)	Equivalent days on ice with time							
		4 hr	8 hr	12 hr	18 hr	24 hr	36 hr	48 hr	72 hr
-2	0.64	0.11	0.21	0.32	0.48	0.64	0.96	1.28	1.92
0	1.00	0.16	0.33	0.50	0.75	1.00	1.50	2.00	3.00
2	1.44	0.24	0.48	0.72	1.08	1.44	2.16	2.88	4.32
4	1.96	0.33	0.65	0.98	1.47	1.96	2.94	3.92	5.88
6	2.56	0.43	0.85	1.28	1.92	2.56	3.84	5.12	7.68
8	3.24	0.54	1.08	1.62	2.43	3.24	4.86	6.48	9.72
10	4.00	0.66	1.33	2.00	3.00	4.00	6.00	8.00	12.00
12	4.84	0.81	1.61	2.42	3.63	4.84	7.26	9.68	14.52
15	6.25	1.04	2.08	3.12	4.69	6.25	9.38	12.50	18.75

Chilled storage

Chilling is a preservation technique which helps to extend the shelf life of the fish at low temperature. It should be practiced carefully and hygienically as soon as the fish is caught. It helps to reduce the spoilage rate by reducing the temperature without reaching freezing. The shelf life of the fish can be extended as more as it is kept at lower temperature by minimizing the bacterial and enzymatic activity.

The important chilling methods of fish and fish products are:

- Iced storage.
- Chilled seawater (CSW) storage.
- Chilled freshwater (CFW) storage.
- Mechanically Refrigerated seawater (RSW) storage.
- Air chilling

Iced Storage

Ice when used for chilling has the advantage of reducing the temperature in large quantity because the latent heat of fusion of ice is more and melting of this ice helps in maintaining the temperature at 0°C**.** However, ice is needed to maintain the temperature as well as to accommodate the heat from the environment. Hence in tropical conditions a 1:1 fish to ice ratio is ideal for ice storage. However, a theoretical weight of ice required to chill the fish as per the body temperature of the fish is given in Table 2: It is recommended that icing should be done immediately after the fish is being caught. It should be done in orderly manner so that there occurs a uniform chilling effect throughout the storage conditions. Usually small particles of ice (flake ice) are recommended rather than larger one, as larger one may cause damage to the flesh and will not give a uniform cooling effect. Smaller ice particles also provide a better contact between the ice and fish. Some general conclusions have been made based on the experimental work on several species of marine and freshwater fish.

- Non fatty fish keeps longer than fatty fish
- Freshwater fish keeps longer than marine fish.

Fish from tropical conditions keeps longer than those from temperate conditions

Table 2.Theoretical weight of ice needed to chill 10 kg of fish to 0°C from various ambient temperatures

Temperature of fish (°C)	**Weight of ice needed** (kg)
30	3.4
25	2.8
20	2.3
15	1.7
10	1.2
5	0.6

(*Source*: FAO, 1984)

Types of Ice:

Block Ice

Here the ice is manufactured in block form which are then crushed into smaller pieces before use. Crushing helps in reducing the size and helps in increasing the surface area of contact. Water in ice making cans are immersed in refrigerated sodium or calcium chloride solutions. Time of ice block formation can vary from few hours to 24 hours depending upon the ice plant. The ice formed are released from the can by hot gas defrost method.

Flake Ice

Flake ice is formed as smooth contours and as thin flakes of an area of 100-1000 mm^2 and a thickness of 2-3mm. Flake ice has a very high area per unit mass and can cover large quantity of fish for a given weight when compared to crushed block ice. Water is sprayed on the refrigerated drum to make the flake ice. The ice sheet is then scraped off in dry sub-cooled flakes. The temperature of the refrigerant is -20 to -25°C.

Plate Ice

Water is sprayed on vertical hollow plate through which refrigerant is passed. Flat sheet of ice is made on the surface of this plate and is separated from the plate by supplying hot gas once the ice sheet reaches the required thickness. The process of making plate ice is much faster and the thickness can be varied accordingly

Tube Ice

Ice is made as hollow cylinder. A series of hollow cylinders are arranged in which the ice is formed in the inner surface. The hollow cylinders will be surrounded by refrigerant. Hot gas is passed to defrost the ice from the cylinders. Tube ice will have to be crushed to the required size before icing and has all the advantages of the flake ice.

Liquid ice or Flow ice

Liquid ice or flow ice is having a jelly like appearence. It actually consists of amorphous ice micro particles suspended in a non-corrosive, non-toxic solution. It requires smaller flow rates for the same cooling capacity because of liquid ice cooling system. The liquid ice at about 50% ice concentration is pumped into the fish box. Hence it is liquid form it can make more contact with the fish surface to be cooled.

Soft Ice

Soft ice is made by freezing a weak brine or seawater in a drum provided with refrigerated walls. The crystals of fresh water ice forms slurry in the brine as temperature falls and it is pumped into a storage tank. Ice crystals are skimmed off from the tank to be used as soft ice slurry.

Chilled Sea Water (CSW)

Ice is introduced in water where it brings down the temperature of water. When sufficient temperature is reached (0°C) fish is introduced. In this case, the fish is surrounded with a mixture of ice and water. The water will remove the heat from the fish. The transfer of heat from fish to water and from water to ice will continue until the system is brought to a state of equilibrium. The surface contact of the fish and chilling medium will be maximum in CSW than in ice alone.

The cooling rate of the fish in CSW is higher than that of fish in ice. CSW can be adopted in fishing vessels as it has many advantages over ice storage. The main advantages of the CSW system are listed below:

- Faster cooling rate.
- Maintenance of a uniform temperature.
- Less damage to fish.
- Easy unloading of fish using pumps.

Refrigerated Sea Water (RSW)

Mechanical refrigeration system is adopted in RSW to cool the seawater. The advantage of RSW over CSW is that there is a reasonable control of temperature over a range, which is not possible in CSW. At 3.5% salt, the sea water has a freezing point of about -2°C and if refrigerated it is possible to reduce the temperature to -1°C where maximum storage life for chilled fish can be obtained. Although it is complicated in operation, it is much cheaper to adopt.

Air chilling

In air chilling, cold air is blown over the fish in a chill room. However, the use of cold air is less satisfactory. When cold air alone is used, as in a chillroom, the heat taken from the fish will rapidly warm the air. The warm air rises and is cooled by contact with the coils of the cooler and then moves by natural convection or fan circulation back to the fish. Thus, it is important to remember that for air cooling to be effective, a good circulation of cold air must be blown over the fish. However, even when a fan is fitted in a chillroom it is difficult to achieve the rapid cooling rates possible with ice and chilled sea water. Another disadvantage of air chilling is that, without the use of ice, the fish becomes dry. Continuous air movement evaporates water from the fish surface and deposits it as frost or condensate on the coils of the evaporator. In addition, the air in some parts of the chillroom will be colder than in others. For example fish close to the evaporator, may in time become partially frozen. Slow freezing of the fish can be detrimental, since appearance, flavour and texture of the fish may be affected. Air chilling however, can be used for prepackaged fish products.

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Chapter 9

Low temperature preservation of fish products

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Maintaining the quality of fish begins with harvest and carries through the harvest -to- consumption chain. Careful handling of fish and shellfish while harvesting and during transport to the processing plant is critical if the high quality of the product is to be maintained. There are, however, several constraints on handling the fish; the important among them are the bacteriological, chemical and physical processes that cause degradation of fish. The surface of dead fish is an ideal growth habitat for bacteria and the end result of such activity is spoiled fish. Reduction of temperature can prevent the growth of many bacteria that cause the spoilage. Chemical breakdown due to oxidative and enzymatic reactions can lead to off odours and flavours and rancidity. Digestive enzymes can initiate decomposition in the dead fish. Physical factors can enhance the bacteriological or chemical processes: bruising, tearing, cutting etc. can expose fish muscle to more rapid bacteriological growth, cause internal bleeding which darkens the fillets and expose greater surface area for chemical oxidation.

Since fish is a highly perishable item of food, it has to be immediately processed to various products to preserve the quality and to increase the shelf life. Fish requires proper handling and preservation to increase its shelf life and retain its quality and nutritional attributes. The objective of handling, processing and preservation is to control or reduce the spoilage process so that the final product is wholesome and safe for the consumer. Fish and fishery products brought to market in a well-preserved condition will generally command higher prices, both at wholesale and retail levels, and thus give better returns to the fishing operation.

Low temperature preservation by chilling and freezing methods are widely practiced to maintain the quality and freshness of fish and fish products. Chilled storage method, i.e., keeping the fish in the unfrozen condition has only limited shelf life and it will vary between 4 and 20 days depending on the condition and species of fish. In frozen storage also the shelf life is restricted but it varies from few weeks to years. The various factors that affect the frozen storage shelf lives are condition of fish at the time of catch, handling, processing and product development, packaging and glazing of the product, freezing method adopted, frozen storage temperature, stacking methods and transportation techniques. These factors can be put together and can be termed as ‘Product, Processing and Packaging’ (PPP) and ‘Time Temperature Tolerance’ factors (TTT).

Chilled storage

Chilling is an effective way of reducing spoilage in fish if it is done quickly and if the fish are kept chilled and handled carefully and hygienically. Immediate chilling of fish ensures high quality products (Connel, 1995: Huss, 1995) .For every 10 ^{0}C reduction in temperature, the rate of deterioration decreases by a factor of 2-3 (Hardy,1986) . The objective of chilling is to cool the fish as quickly as possible to as low a temperature as possible without freezing. Chilling cannot prevent the spoilage together but in general, the colder the fish, the greater the reduction in bacterial and enzyme activity.

The important chilling methods of fish and fish products at non-freezing temperature are:

- ❖ Iced storage.
- ❖ Chilled seawater (CSW) storage.
- ❖ Chilled freshwater (CFW) storage.
- ❖ Mechanically Refrigerated seawater (RSW) storage.
- ❖ Cold air storage.

The most common means of chilling is by the use of ice. Although ice can preserve fish for some time, it is still a relatively short-term means of preservation when compared to freezing, canning, salting or drying, for instance. When used properly it can keep fish fresh so that it is attractive in the market place.

Ice is available in several forms such as blocks, plates, tubes, shells, soft and flakes . Of these, flake ice is the most popular form for industrial use because of its cooling efficiency. It is also relatively dry and will not stick together to form clumps when stored. Cooling capacity is more for flake ice due to a large surface area for heat exchange. It also cause minimum damage to the flesh To ensure maximum contact of ice with the fish, proper selection of the size of ice particles and good stowage practices are needed. The rate of chilling is governed by:

- The size, shape and thickness of fish;
- The method of stowage;
- Adequate mixing of ice, water and fish (in ice slurries);
- Adequate contact of ice with the fish;
- The size of the ice particles.

Icing is widely employed for chilled storage of freshwater fish in the country. The dressed and cleaned fish is kept in a chill store in insulated boxes with proper icing prior to preprocessing. The major advantage of using ice for chilling the fish is that it has a high latent heat of fusion so that it is capable of removing large amount of heat as it melts without changing the temperature at 0 ^{0}C. During transition from ice to water 1 kg of ice absorbs 80 k cal of heat and this will be sufficient to cool about 3 kg of fish from 30 ^{0}C to 0 ^{0}C. Hence theoretically about 30 % of ice is needed to bring down the temperature from ambient conditions to 0^{0}C. However, ice is needed to maintain the temperature as well as to accommodate the heat from the environment. Hence in tropical conditions a 1: 1 fish to ice ratio is ideal for ice storage. Fish of the same size and species are placed in the same boxes. It is always 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) .The effectiveness of chilling by temperature exchange depends on the thickness of the layers of fish and the distribution of ice. The rates of cooling of fish are given in Table 1.

Table 1. Rates of cooling of fish *

Distance to centre of fish/fish layer (cm)	Time to cool from 25 ^{0}C to 1 ^{0}C (hours)
1	0.33
2	1.25
4	5.00
10	31.25
20	125.00
40	500.00

*Clucas, I.J. and Ward, A.R.(1996) Post – harvest Fisheries Development: A Guide to Handling, Preservation, Processing and Quality. Natural Resources Institute, Chatham, Maritime, Kent ME4 4TB, UK pp 73 – 141.

Chilling versus freezing of fish

There are many factors to be taken into account when considering the differences between chilling and freezing of fish products for various markets. Both chilling and freezing operations can produce stable products and the choice of one or the other depends on many factors.

Table 2 lists some of the advantages and disadvantages of the two methods. It can be used to help decide whether freezing or chilling is the option most appropriate to a particular situation.

Table 2. Advantages and disadvantages of chilling and freezing *

Chilling	Freezing
Short-term storage (up to one month maximum for some species, only a few days for others)	Long-term storage (a year or more for some species)
Storage temperature 0 °C	Storage temperature well below zero, e.g. -30 °C
Relatively cheap	Relatively costly
Product resembles fresh fish	If poorly done can badly affect quality
Relatively low-tech	Relatively high tech
Low skills required	High skills required
Portable refrigeration	Generally static operations

* Shawyer, M.; Medina Pizzali, A.F. (2003) The use of ice on small fishing vessels. FAO Fisheries Technical Paper. No. 436. Rome, FAO,108 p.

Determination of spoilage rates

Spoilage of fish is linearly related to storage temperature since the enzymatic and microbial activities are directly related to temperature. If the shelf life of a fish at 0 ^{0} C and at another temperature (t ^{0} C) are known, their ratio gives the relative rate of spoilage (RRS) at t ^{0} C . The RRS for tropical fish are more than twice as estimated for temperate fish species.

Relative rate of spoilage (RRS) at t °C = shelf life at 0 °C

Factors affecting the rate of spoilage in chilled fish

The main factors that affect the rate of spoilage in chilled fish are:

- Temperature
- Physical damage
- Intrinsic factors

Temperature

It is well known that high temperatures increase the rate of fish spoilage and low temperatures slow it down. Therefore, if the temperature of fresh fish is low, then quality is lost slowly. The faster a lower temperature is attained during fish chilling, the more effectively the spoilage activity is inhibited. Generally, the rate at which fish loses quality when stored in ice (0 °C) is used as the baseline when comparisons are made regarding shelf-life at different storage temperatures. The effect of temperature reduction on the rate of spoilage and shelf life of fish is given in Table 3.

Table 3. Effect of temperature reduction on fish spoilage *

Reduction in Temperature ($0\ ^0$ C)	Rate of spoilage (%)	Extension of shelf life
0	100	-
5	50	× 2
10	25	× 4
15	12.5	× 8
20	6.25	× 16

*Clucas, I.J. and Ward, A.R.(1996) Post – harvest Fisheries Development: A Guide to Handling, Preservation, Processing and Quality. Natural Resources Institute, Chatham, Maritime, Kent ME4 4TB, UK pp 73 – 141.

Physical damage

Fish is soft and easily damaged; therefore rough handling and bruising result in contamination of fish flesh with bacteria and allow releases of enzymes, speeding up the rate of spoilage. In addition, careless handling can burst the guts and spread the contents into the fish flesh.

Intrinsic factors

The intrinsic factors affecting the spoilage rate of chilled fish are shown in Table 4.

Table 4.Intrinsic factors affecting the spoilage rate of chilled fish*

Intrinsic factors	Relative spoilage rate of fish stored in ice	
	Slow rate	Fast rate
Shape	Flat fish	Round fish
Size	Large fish	Small fish
Fat content in the flesh	Lean species	Fatty species
Skin characteristics	Thick skin	Thin skin

*Huss, H.H (1995) Quality and quality changes in fresh fish, FAO Fisheries Technical Paper No. 348. Rome. 195 p.

Shelf life of iced fish

Shelf life can be defined as the maximal period of time during which the predetermined attributes of the food are retained (Daun, 1993).The different expressions of shelf life related to the product, process and context is given as Annexure 1.

The chilled storage life of fish is primarily determined by sensory evaluation. Apart from the factors discussed in the previous session, chilled storage life of fish depends on several factors such as composition, microbial contamination and the type of microflora present in the fish (Venugopal,2006) .The fish spoilage pattern is similar for all species, with four phases of spoilage as outlined in Table 5.

Table 5.The four phases of fish spoilage*

Phase I (Autolytic changes, caused mainly by enzymes)	Fish just caught is very fresh and has a sweet, seaweedy and delicate taste. There is very little deterioration, with slight loss of the characteristic odour and flavour. In some tropical species this period can last for about 1 to 2 days or more after catching.
Phase II (Autolytic changes, caused mainly by enzymes)	There is a significant loss of the natural flavour and odour of fish. The flesh becomes neutral but has no off-flavours, the texture is still pleasant.
Phase III (Bacteriological changes, caused mainly by bacteria)	The fish begins to show signs of spoilage. There are strong off-flavours and stale to unpleasant smells. Texture changes are significant, flesh becoming either soft and watery or tough and dry.
Phase IV (Bacteriological changes, caused mainly by bacteria)	Fish is spoiled and putrid, becoming inedible.

* Shawyer, M.; Medina Pizzali, A.F. (2003) The use of ice on small fishing vessels. FAO Fisheries Technical Paper. No. 436. Rome, FAO,108 p.

There have been many research studies regarding the shelf-life of fish stored in ice. Based on these studies, it is generally accepted that some tropical fish species can keep for longer periods in comparison to fish from temperate or colder waters. The normal life of coldwater fish chilled to 00C immediately postmortem is 1-2 weeks, while fish from tropical waters remain in good condition for longer periods (Venugopal,2006). This can be attributed to differences in the bacterial growth rates, with a 1-2 week slow growth phase (or period of adaptation to chilled temperatures) in tropical fish stored in ice. However, due to differences in the criteria used to define the limit of shelf-life, and methodologies used, comparison between shelf-life of fish from tropical and temperate waters is still difficult. 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 and beyond 9 days of ice storage no high value products could be processed (Venugopal and Shahidi, 1998). Delay in icing also can adversely affect the shelf life (Table 6). The shelf-life of several fresh water fish species stored in ice is summarized in Table 7.

Table 6.Effect of delayed icing on the storage life of some tropical species *

Species	Delay (Hours)	Storage life in ice (days)
Mackerel (*Rastrelliger* spp.)	0 3 6 9	9 7 4 ≈1
Tilapia (*Oreochromis* spp.)	0 4 8 12	16 13 5 < 1
Milk fish (*Chanos chanos*)	0 4 8 12	14 12 6 ≈1
Oil sardine (*Sardinella longicepes*) Nov-Dec. period	0 3 6	7 5 1
Farmed white prawn (*Fenneropenaeus indicus*)	0 3 6 9	16 14 9 4

* Ninan, G. (2003) Handling and Chilled Storage of Fish In: Product development and seafood safety. Central Institute of Fisheries Technology, Cochin, India, pp 43-58.

Table 7.Shelf-life of freshwater fish & shell fish species stored in ice*

Species	Shelf-life (days in ice)		References
	Temperate waters	Tropical waters	
Catfish (Lean)	12-13	15-27	(Huss, 1995)
Trout (Lean)	9-11	16-24	(Huss, 1995)
Rohu, Mrigal & Catla (Lean)		15 - 18	(Joseph et.al.,(1990)
Labeo sps. (Medium)		9-18	Bandhopadhyay et. al.,(1985)
Clarias sps.		10 -15	Bhattacharya et.al.,(1990)

(Medium)			
Channa sps. (Lean)		8-9	Perigreen,et. al.,(1987)
Tilapia (Lean)		10-27	(Santos Lima Dos et. al., 1981)
Common carp (Medium)		24-25	Santos Lima Dos et. al., (1981)
Freshwater prawn (Lean)		10 -12	Ninan et. al.,(2003)

* Fat content and shelf-life are subject to seasonal variations.

Requirement of ice during handling and transportation: The weight of ice needed to chill 1 kg fish (0°C) can be calculated theoretically as shown below in Table 8.(in practice some more ice will be needed).

Table 8.Theoretical weight of ice needed to chill 10 kg of fish to 0 °C from various ambient temperatures *

Starting temperature of fish (°C)	Weight of ice needed (kg)
30°	3.4
25°	2.8
20°	2.3
15°	1.7
10°	1.2
5°	0.6

*FAO (1984). Planning and engineering data 4. Containers for fish handling, J. Brox, M. Kristiansen, A. Myrseth & Per W. Aasheim (Eds.) Fisheries Circular No. 773. Rome, Italy, 53 p.

The necessary quantity of ice required to maintain the fish chilled will depend upon the ambient temperature, the insulative properties of the container, the place of the individual box within the load and the length of the storage. The following table (Table 9) gives an example of ice requirements to chill and maintain the chill condition of fish held in individual boxes and within a stack of boxes.

Table 9. Ice requirements for chilling and storage of fish*

	Melting of ice per box of 50 kg fish					
	1 box			35 boxes		
Surrounding temperature (°C)	+30	+20	+10	+30	+20	+10
Chilling fish (kg)	21	14	7	21	14	7
Keeping chilled (kg/h)	3	2	1	1	0.7	0.3

*FAO (1984). Planning and engineering data 4. Containers for fish handling, J. Brox, M. Kristiansen, A. Myrseth & Per W. Aasheim(Eds.) Fisheries Circular No. 773. Rome, Italy, 53 p.

For practical purposes the following rules of thumb can be given to calculate ice requirements:

l. Fish boxes: Ice to fish ratio in tropics are 1 kg ice to 1 kg fish, and ice to fish ratio in temperate climate and in insulated van are 1 kg ice to 2 kg fish.

2. Insulated tanks: Water to ice to fish ratio in tropics are 1 kg water to 2 kg ice to 6 kg fish and in temperate climate 1 kg water to 1 kg ice to 4 kg fish.

Necessary volume of ice to chill the fish down to a temperature of 0°C is included in the above mentioned rules. If the fish is already chilled the volume of ice can be reduced accordingly.

The fish carrying capacities of various boxes and containers depend on the density of the mixture of ice and fish. Table 10 shows the densities of different types of ice.

Table 10. Density of different types of ice*

Type of ice	Bulk weight $kg/dm^3 = l$	Specific volume m^3/ton
Crushed block	0.690	1.45
Tube	0.565	1.80
Plate	0.570	1.75
Flake	0.445	2.25

*FAO (1984). Planning and engineering data 4. Containers for fish handling, J. Brox, M. Kristiansen, A. Myrseth & Per W. Aasheim(Eds.) Fisheries Circular No. 773. Rome, Italy, 53 p.

Disadvantages of icing

Icing in the conventional method using crushed ice can bruise the flesh which results in leaching of flavour compounds and water soluble proteins. Prolonged ice storage can cause changes in the texture of the muscle, particularly the reduction in breaking strength and hardness of fillets. Muscle proteases including cathepsin D and cathepsin L, calcium activated proteases (calpains), trypsin, chymotrypsin, alkaline proteases and collaginases are involved in softening of fish tissue during storage (Bremner, 2000)

Ice storage has been found to adversely influence protein stability and water holding capacity in salmon and cod fillets*. Icing cannot completely arrest the activities of psychrotrophic organisms in fish, which is a quality problem in refrigerated food (Olssen, 2003).

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). Boxes for land transportation are made of wood, aluminium, high density polyethylene, expanded polystyrene or polyurethane. The ideal fish transportation box should be light weight yet strong enough to withstand the combined weight of fish, ice and stacking and should have good insulating properties. The boxes should be easy to clean. Boxes are usually made of double bottom to collect the melt water. Containers used for air transportation of chilled fish should be water tight.

Air shipment of chilled fish requires a lightweight and protective container. Modern insulated containers are made of high–density polypropylene with polyurethane insulation sandwiched between the inner and outer walls of the double walled container. Instead of ice, pads of nonwoven fabric encapsulating synthetic absorbent powder are used for chilling of air shipped fish. These pads could be soaked in water and deep frozen for use (Venugopal, 2006). Special thermal barrier films are used in combination with the pads to protect fish containers from heat (Subsinghe, 1996)

Freezing

Freezing is the most accepted method for long term preservation of fish and fishery products. Freezing reduces the spoilage activity and extends the shelf life of the product. Freezing represents the main method of processing fish for human consumption, and it accounted for 55.2 % of total processed fish for human consumption and 25.3 % of total fish production in 2010.(Anon.2012). Freezing involves the cooling down of materials from ambient temperature conditions to a temperature below the freezing point .Generally the freezing process has three stages; in the first stage (pre-freezing stage) corresponds to removal of heat from the food, when the temperature is reduced to freezing point. The second stage (freezing stage) is the period of transformation of water to ice through the whole mass of food. Between the first and second stages there is a transitory super cooling period when the temperature falls below the freezing point which is not observed in some cases. In the third stage nearly 75% of the water in the muscle turns into ice which leads to further rapid drop in temperature, as the thermal diffusivity of ice being much higher than water. Bound water, which forms the integral part of the tissue will be frozen at extremely low temperature of about -55 ^{0} C.

As the water in fish freezes out as pure crystals of ice, the remaining unfrozen water contains higher concentration of salts and other compounds which are naturally present in the fish muscle. The increasing concentration of the salts will depress the freezing point of the unfrozen water .Hence unlike pure water, conversion to ice will not occur at 0 ^{0} C but proceeds over a range of temperature. Thus even at -30 ^{0} C, a portion of water in the fish muscle will remain in unfrozen state. Slow freezing produce ice crystals of comparatively larger size and few in numbers which may cause rupture of the cell walls and result in fluid loss and textural changes on defrosting. In contrast fast freezing produce large number of small crystals, thus reducing the possibility of shrinkage or rupture. In fish, however, the cell may be considered sufficiently elastic to withstand excessive damage from the growth of large crystals, therefore this does not account for the drip loss on thawing the frozen fish (Garthwaite, 1997).The drip loss on thawing of fish occur mainly due to denaturation of protein during freezing which result in the loss of water binding capacity of the protein. The optimum range of temperature for denaturation is -1 ^{0} C to -2 ^{0} C; thus in order to reduce the thaw drip to minimum the time spent in this temperature zone should be minimum.

Quick freezing is a general term applied to most of the freezing processes which result 'Individual Quick Frozen' product. If the temperature of fish/fishery product is reduced from 0 ^{0} C to -5^{0}C in 2 hours or less, then it can be termed as a quick frozen product. During freezing process, the temperature of the fish should be lowered to -30^{0}C before it is transferred to the cold store. Most of the commercial freezers operate at temperatures of -40 ^{0} C to -35 ^{0} C. The thermal centre of the fish should attain -20 ^{0} C prior to its removal from the freezer. The time taken to lower the temperature of the thermal centre to -20 ^{0} C is termed as the freezing time.

Freezing systems- *There are three basic methods for freezing fish. These are:*

Air blast freezing: Where a continuous stream of cold air is passed over the product.

Plate or contact freezing: where the product is placed in direct contact with hollow, metal, freezer plates, through which a cold fluid is passed.

Spray or Immersion freezing: where the product is placed in direct contact with fluid refrigerant.

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.

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.

Pre-freezing and Freezing Considerations

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.

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Annexure I

Context	Meaning	Measurement	Product	References
Commercial shelf life	Period fish can be offered for sale	Sensory (Consumer acceptability)	Whole and gutted fish, cooked fillets,	Gelman(1990)
Maximum shelf life	Up to inedibility of fish	Sensory	Whole and gutted fish, cooked fillets,	Gelman(1990)
Predict shelf life	Based on microbial count	*Pseudomonas, Schewanella* and *Photobacterium* counts.	Lightly preserved fish products	Gram, and Huss (1996)
Remaining shelf life	Sensory properties	Quality Index Method	Whole fish	Branch and Vail (1985)
Total shelf life	Until sensory rejection for any food use	Sensory evaluation	Fish	Gelman(1990)
True shelf life	Microbial rejection	Microbial count, mathematical prediction	Fish and other foods	Fu and Labuzza (1997)
Maximum storage time	Sensory (whole and cooked), chemical, scoring texture, odour and flavour	Freshness score, K-value, TVB, TMA	Albacore	Perez-Villarreal and Pozo (1990)
Keeping quality, storage life	Rejection mainly by sensory characteristics.	Water binding capacity, texture measure, sensory tables, sensory panel (for raw and cooked)	Fish in general	Santos Lima Dos (1981)

Chapter 10

Thermal processing of Fish

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Thermal processing also known as heat processing is commonly used processing method which helps in extending the shelf life of the food productswith high safety level, convenience and a healthy product.Seafood as a whole food is highly nutritious. Benefits to human health associated with the consumption of seafood is well recognized for multiple bodily organs and physiological functions but their high perishable nature is a concern. Seafoodundergoes spoilage due to autolytic, microbial action as well as oxidation of lipid. Proper handling and preservation is essential to maintain quality of fish. Heat processing is an age old preservation method practiced in many countries to extend the shelf life of food products. Heat treatment causes the destruction of microbes which increases the shelf life. There are number of thermal processing operations like- baking, blanching, canning, dehydration, extrusion, frying, pasteurization, sterilization, etc. All these operation serves various purposes and helps in manufacture of different food products.

Thermal processing is of utmost importance to low acid high water activity foods, where there are no hindrances to microbial growth. The proper delivery of heat is essential to cause the destruction of microbes to avoid food spoilage. In seafood's processing, thermal processing through canning (retort pouch processing) is a common approach. In canning, the food is preserved by application of heat in hermetically sealed cans (pouches). Hermetic sealing means- complete airtight sealing. This prevents contamination from outside. Heating at very high temperature ranging from 110 to 135^{0}C for a desirable time helps in killing all the vegetative forms of microorganisms as well as most heat resistant microbial spores. The amount of time needed for processing is different for each food type depends on hurdles present in the food and heat transfer characteristics. In thermal processing of seafood products, heat processing is aimed for the destruction of spores of *Clostridium botulinum*. A number of thermally processed ready-to-eat (RTE) products are available on market shelf.

Advantages of thermal processing

- Preservation of food for longer duration
- Ready-to-eat (RTE) food products
- Production of safe foods
- Room temperature storage
- Easy process

Canning Process

The important operations in thermal processing are:

- Raw material preparation
- Blanching/ Precooking
- Filling into containers
- Addition of fill (brine/ oil/ gravy)
- Exhausting
- Seaming/ sealing
- Retorting (heat processing)
- Cooling
- Drying
- Labelling and storage

These operations have been briefly explained below:

Raw material preparation

Most of the fish found in our country are suitable for thermal processing. But appropriate care should be taken while selecting the fish.

- Only fresh fish should be processed- low microbial load
- Proper dressingand washing is very essential
    - ✓ Descaling- removal of scales
    - ✓ Beheading- removal of head
    - ✓ Degutting- removal of gut and visceral organs (liver, kidney, intestines)
    - ✓ Removal of fins, tails
    - ✓ Cutting into appropriate size

For shrimps- peeling (removal of outer shell) and deveining (removal of intestine) is done. Clams, mussels and oysters are depurated before picking the meat. These organisms are kept under starvation for 24 hours in water to reduce the microbiological load and improve the quality.

Blanching/ Pre-cooking

Cleaned and dressed fish is immersed in salt solution (2-5%). The blanching is done either in hot or cold brine depending upon the fish. The blanching gives firmness to the product. Shrimps are blanched in boiling brine solution. This gives them attractive red color.Sometimes, fish are precooked to remove water from them.

Functions of blanching:

- Firm texture of fish
- Reduction in bacterial load
- Inhibition of enzymatic reaction
- Shrinkage for better filling
- Removal of cellular gases

Filling into containers

The blanched material is filled in cans. The most popular are tin plated steel cans or OTS (Open top sanitary) cans. Inside of can is coated with lacquer. For fish, the lacquer is sulphur resistant (SR lacquered cans). This lacquer helps in prevention of black colour in canned fish products.

$$Sulphur(Aminoacidsoffish) + Iron(Tincan) = Ironsulphide\ (blackcolour)$$

Usually cans are denoted by trade name. First digit represents diameter of can (in inches) and next two digits represent measurement in sixteenth of inches.

Apart from OTS cans, other container used in canning are: aluminium cans, tin free steel (TFS) cans, glass containers, retort pouches.

Table 1. Cans used in fish canning industry

Trade Name	**Dimension**	**Overseam dimension**
41/2 OZ prawn cans	301 x 203	77 x 56
8 oz prawn cans	301 x 206	77 x 60
1 lb. jam can	301 x 309	77 x 90
No.1 tall can	301 x 409	77 x 116
8 oz. tuna can	307 x 113	87 x 43

(Adapted from Vijayan, PK (2003) Canning Preservation of fish and Shell Fish)

Nowadays, retort pouch processing is very popular. The retort pouches are flexible in nature and they easily withstand high temperatures used during thermal processing. They also provide good barrier against moisture and gases. The most common retort pouch is 3 layered laminate. The 3 layers are joined with adhesive lamination. These three layers are:

- Polyester: Strength and abrasion resistance
- Aluminium foil: Barrier against moisture, gases and light
- Polypropylene/ polyethylene: Heat sealing

Addition of fill

The cans/ pouches are then filled with liquid medium i.e brine solution, oil, curry, gravy, sauce etc. The functions of liquid medium are:

- Acts as constituent of product
- Taste, flavor
- Helps in heat penetration

While filling with liquid medium a headspace of around 0.7-0.9 cm is left from the top of can. This helps in formation of vacuum in can.

Exhausting

Exhausting is removal of air from the cans/ pouches, before sealing. Removal of air is necessary because presence of air may cause undesirable stress on seams/ seals of the cans/ pouches. This may cause them to burst during the thermal processing. Other functions include:

- Less strain on seams/ seals
- Removal of oxygen- prevention of oxidation
- Helps in uniform heat transfer
- Helps in detection of spoilage

The exhausting is done by heating the product before filling and sealing it immediately. The exhausting temperature is 80--85°C. The exhausting can also be done by injecting the steam into the pouches. The steam takes away the air and vacuum develops upon condensation of steam.

Seaming/ sealing

Cans are sealed by double seaming technique. The retort pouches can be hot bar sealed or impulse sealed. To avoid seal defects in pouches, it is better to double seal them.

Thermal processing

The sealed cans/ pouches are heated for sufficient time to cause destruction of pathogenic micro-organisms and inactivate spoilage causing microbes. The temperature and duration of heat processing depends upon type of food and indicator organism.

For canned fish, *Clostridium botulinum,* is taken as indicator organism. Our aim is to reduce the spore of *Clostridium.* For this, the center of pack (called as cold point) should get a temperature of 121.1°C for 2.52 min. The thermal processing can be carried out by using steam retort or water immersion retort (Fig. 1.)

Cooling

After heat processing cans/ pouches are cooled to the room temperature. The cans/ pouches should be rapidly cooled. This will help in preventing the overcooking of the food material.Additionally, it helps in reducing the excessive strain on the seams of the cans. Water used for cooling should be clean.

Drying

The cans/ pouches are wiped and dried to remove water from the exterior surface. The water on external surface may cause corrosion upon storage.

Labeling and storage

The cans should be properly labelled as per the regulations. The cans/ pouches must not be stored while hot. This provides favorable conditions for thermophilic bacteria, which might have survived heat processing. The cans should be not stored at high humidity conditions. High humidity mayinduce rusting in cans. The product should not be stored at high temperatures at it may lead to the formation of hydrogen swells. The storage area should be clean, cool and dry.

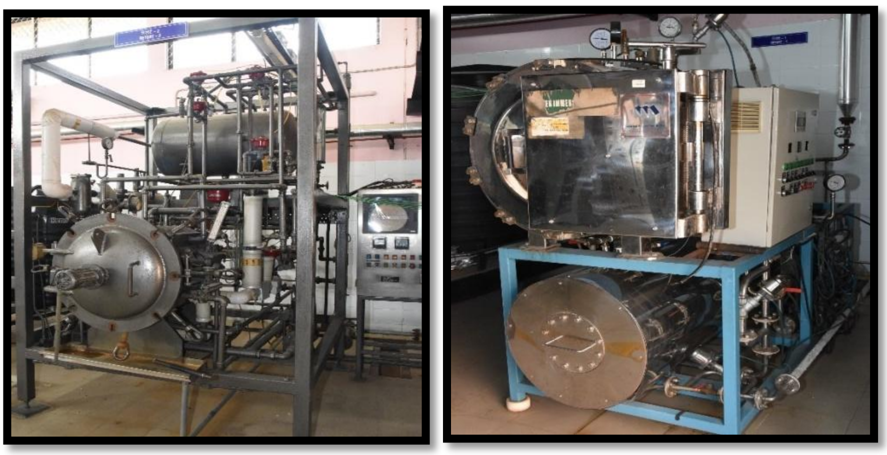

Fig. 1. Steam retort and water immersion retort used for heat processing

Chapter 11

Smoking of Fishes

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Smoking is an ancient method of food preservation, which is also known as smoke curing, produces products with very high salt content (>10%) and low water activity (~0.85). Smoking is a process of treating fish by exposing it to smoke from smouldering wood or plant materials to introduce flavour, taste, and preservative ingredients into the fish. This process is usually characterised by an integrated combination of salting, drying, heating and smoking steps in a smoking chamber. The drying effects during smoking, together with the antioxidant and bacteriostatic effects of the smoke, allow smoked products to have extended shelf-life. Smoked seafood includes different varieties like, smoked finfish and smoked bivalves. Many of the smoked products are in the form of ready-to-eat.

Developments of modern food preservation technology, such as pasteurization, cooling/refrigeration, deep-freezing, and vacuum packaging, have eclipsed the preserving functions of many traditional methods including smoking. Nowadays, the main purpose of smoking has been shifted for sensory quality rather than for its preservative effect.

Depending upon how the smoke is delivered into the food and smoking temperature, four basic types of smoking can be defined: hot smoking, cold smoking, liquid smoking, and electrostatic smoking. Hot smoking is the traditional smoking method using both heat and smoke, which usually occurs at temperatures above 70 °C. For smoked fish and fishery products, a minimum thermal process of 30 min at or above 145 °F (62.8 °C) is required by FDA (2001). Therefore, after hot smoking, products are fully cooked and ready for consumption.

Hot smoking

Torry smoking kiln was introduced in the early 1960s by United Kingdom's Torry Research Station. The Torry smoking kiln is considered as a model for the modern smokers/smokehouses by enabling the precise controls of the heating temperature, air ventilation, and smoke density. Some recently designed smokehouse may also be equipped with more precise time and temperature controls, humidity control, and product internal temperature monitor probes. Thus, the products produced by the modern smokehouses are much more uniform than those produced with traditional smokers. Hot smoking is typically not a single process. Several other steps such as brining, drying and smoking are also involved to produce a product of good quality.

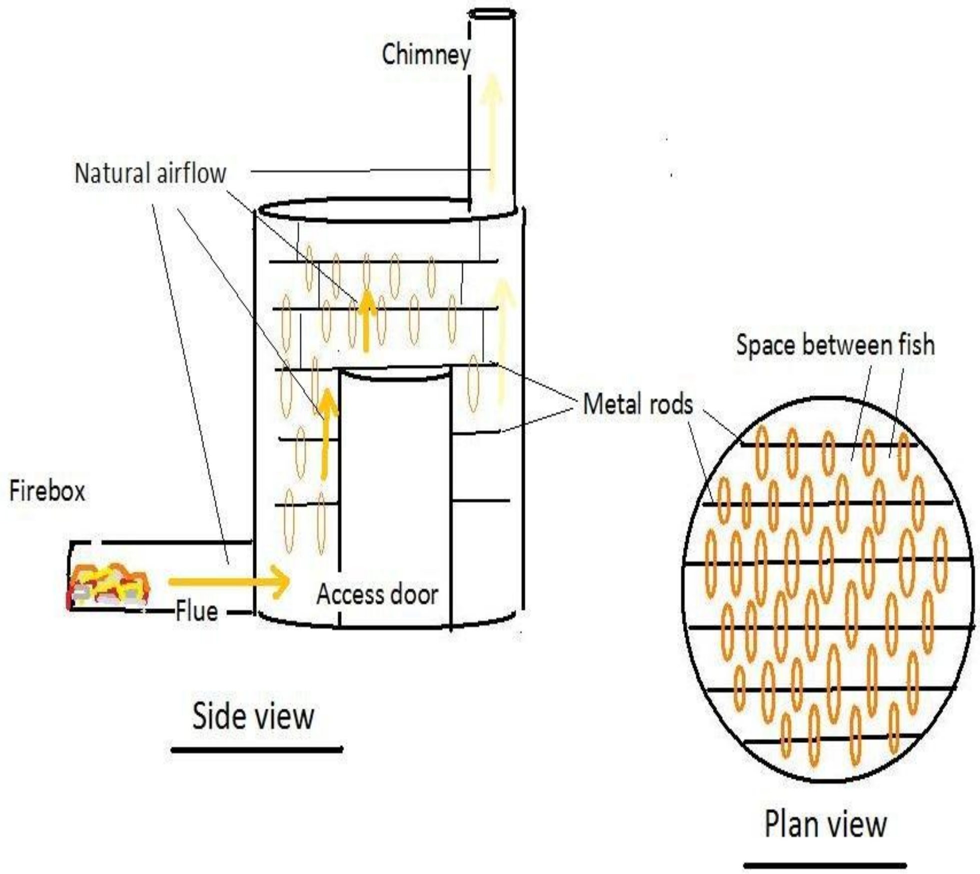

Fig. Illustration of the hot smoke airflow in the smoking chamber

Cold smoking

Fish can also be subjected to cold smoking. Temperatures of cold smoking typically do not exceed 30 °C. Thus, cold smoked products are not cooked and typically heavily salted. Compared to the traditional hot smoking, cold smoking runs longer, has a higher yield and retains the original textural properties much better than the hot-smoked ones. Cold smoking of varied fish species has been reported, including rainbow trout.

Liquid smoking

Liquid smoke is smoke condensate that is dissolved in a solvent, such as water or oil (Maga, 1988). Liquid smoke can be used directly on products by dipping or spraying. It is rapid and much easier to achieve a uniform smoke flavour than traditional cold and hot smoking processes, although the flavour and colour from the traditional smoking cannot be exactly duplicated (Varlet et al., 2007). Some potential harmful ingredients (e.g. polycyclic aromatic hydrocarbons, PAHs) in the nature smoke can be separated out and excluded from the liquid smoke (Chen & Lin, 1997). Other advantages of liquid smoke include easy modification, application to food items that traditionally are not smoked, lower operation cost, and less environmental pollution (Abu-Ali & Barringer, 2007). However, the application of liquid smoking may be expensive compared to other methods. Liquid smoking of fish species had been reported on swordfish, salmon and rainbow trout.

Electrostatic smoking

Electrostatic smoking is another rapid way to smoke. In the electrostatic smoking, fish are sent into a tunnel where an electrostatic field is created. Smoke particles are given a positive charge and deposit onto the surface of the fish which are negative charged. Although this procedure will change the composition of the smoke, the efficiency of smoking is still higher than that of the traditional smoking. It can also be operated continuously. The smoke compound ratio in the vapour phase may be modified by the electrostatic field, which results in increased level of carbonyl compounds (Ruiter, 1979). Factors that may influence the electrostatic smoking operation include the skin thickness, presence of scales, and subcutaneous fat amount (Maga, 1988). This operation may present safety problems to employees. Applications of electrostatic smoking have been reported mainly in salmon and herring.

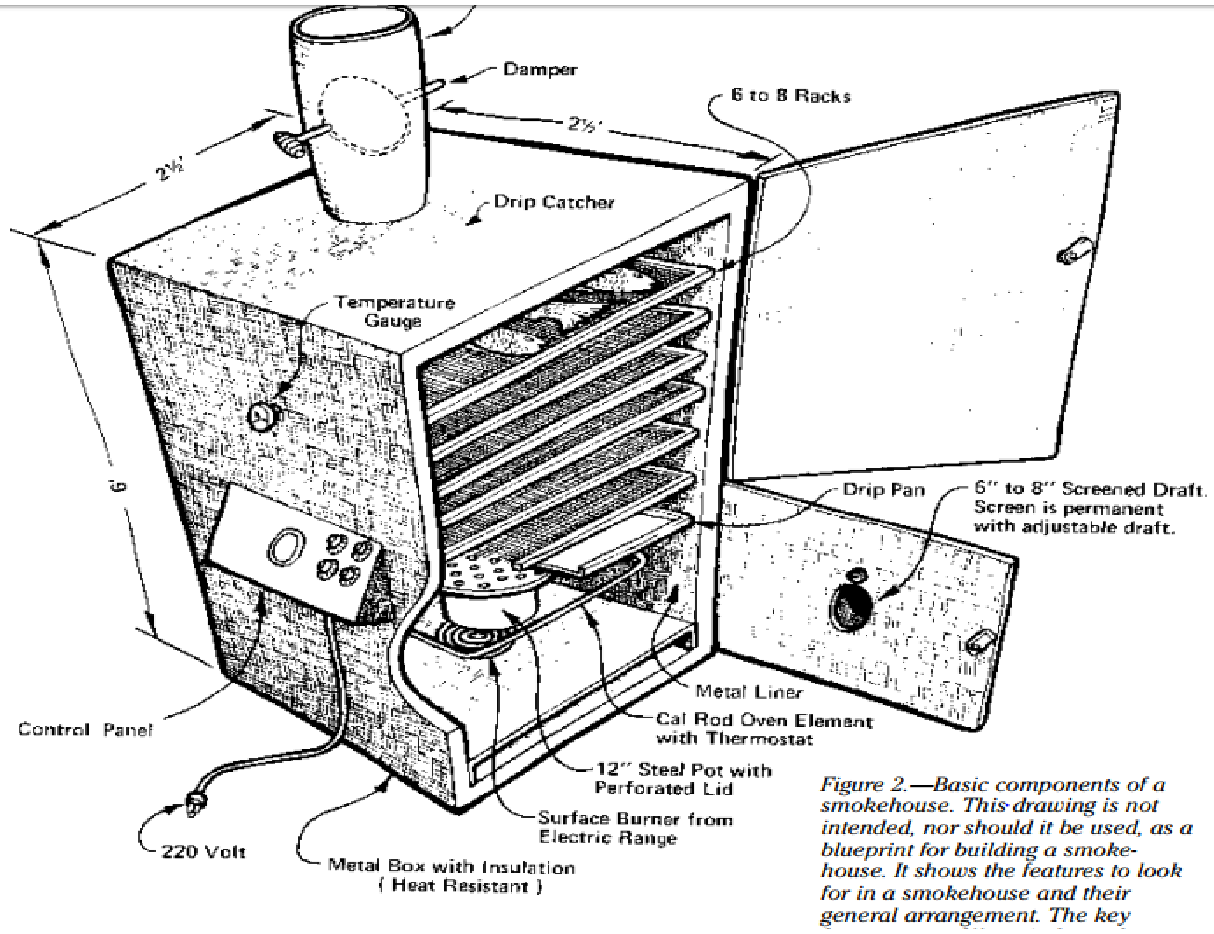

Fig. Schematic diagram of smoke house with basic components.

Hot smoking of fish

Good smoked products can only be obtained from good raw material (Dore, 1993). In addition, control of the smoking procedures plays an equal importance in the production of good products. From raw material preparation to final product storage, smoking includes several operations, such as brining, drying, smoking, packaging and storage.

Brining

This is the stage when the flavours and spices are introduced into the fish. Cleaned fish are submerged under a prepared brine solution for a certain amount of time. A brine time less than 12 hours at 3.3 °C (38 °F) is recommended to minimize the possible spoilage in the fish (Lee, 1977). Salt is an important ingredient to be delivered into the fish tissue at this stage as well as a key hazard analysis and critical control point (HACCP) preventive measure for smoked fish. Not only does it bring the taste but also reduces the water activity (aw) in the product, so that bacterial growth can be inhibited in the smoked fish.

Of all the bacteria that can exist in fish products, *Clostridium botulinum* is a major concern for vacuum or reduced packaged fish products. *C. botulinum* is a strictly anaerobic, gram positive bacillus bacterium. The vegetative cells and their neurotoxins can be easily destroyed by heat (less than five minutes) at 85 °C. However, their spores are very resistant to heat and can survive for up to 2 hours at 100 °C (Caya, 2001). Thus, prevention of botulism from hot smoked fish products depends on the destruction of all *C. botulinum* spores or inhibition germination of the spores that may be present in the products.

Water phase salt (WPS) is used to measure the amount of salt in the fish products.

The WPS is calculated as (FDA, 2001):

$$WPS = \frac{\%Salt}{\%Salt + \%Moisture} \times 100$$

The higher the WPS value, the less the availability of the water. When sodium chloride is the only major humectant in the cured food, the relationship between the aw and WPS can be express as (Ross & Dalgaard, 2004):

$$a_w = 1 - 0.0052471 \cdot WPS\% - 0.00012206 \cdot (WPS\%)^2$$

or

$$WPS\% = 8 - 140.07 \cdot (a_w - 0.95) - 405.12 \cdot (a_w - 0.95)^2$$

Current regulations require at least 3.5% WPS in the loin muscle of the vacuum packaged smoke products; at least 3.0% WPS if at least an additional 100 ppm nitrite exists in the vacuum packaged product; air packaged smoked fish products must contain at least 2.5% WPS (FDA, 2001).

Several salting methods are available to deliver the salt into the fish. The most common techniques used by the industry are dry and brine salting. Dry salting is widely used in low fat fish. Basically, fish are put into layers with dry salt separating each layer. Water removed by salt is allowed to drain away. Periodical reshuffling of the layers may be necessary to make sure all the fish get uniform salting and pressure. Muscle fibre shrinks more during dry salting than brine salting (Sigurgisladottir et al., 2000b). Thus, dry salting of fish typically results in over-dried fish and low yield. A better quality and higher yield is usually obtained from brine salting.

Fish are brine salted by completely being covered in a prepared brine solution for a certain time period. The brine solution can have a salt concentration from relatively low to saturated levels. Brine salting is also used widely for most fatty fish since oxygen cannot oxidize the fish fat easily. Some modern processors inject the brine to speed up the process, therefore lowering the cost and minimizing the chance of fish deterioration. Salt is distributed evenly in the fish when injection brine is used. A higher brine yield can be obtained through injection brine as compared to brine or dry salting. Flavour ingredients can also be incorporated into the injection solution. However, the injecting brine operation has to be carefully controlled to avoid contamination delivered by the needles into the previously sterile flesh. Brine salting is still one of the most widely used salting methods for smoked fish. Efficiency of salt penetration into the fish tissue is affected by several factors, such as species, physiological state of fish (rigor), fish quality (fresh/frozen) fish dimension (thickness), brine concentration, brine time, brine to fish ratio, brine temperature, fat content, texture, etc.

After brining, fish have to be rinsed with clean water to remove the brine solution on its surface because a harsh, salty flavour can develop due to residues of brine solution.

Drying

It is widely known that reducing the water activity (a_w) will result in a reduction of microbial activity. The a_w is defined as:

$$a_w = p / p_0$$

where p is the vapour pressure of the product, and p_0 is the vapour pressure of pure water at the same temperature (Olley, Doe, & Heruwati, 1989).

For ideal solutions (real solutions at low concentrations), water activity can be calculated from the formula:

$$a_w = n_1 / (n_1+n_2)$$

where n_1 is the number of moles of solvent, and n_2 is the number of moles of the solute.

This relationship may become complex due to the interactions between moisture and the fish tissue and also the relatively high solute concentration involved in cured fish. Drying of the fish can still be simulated with the formula in a way that drying the fish will cause a decrease in n_1 and an increase in n_2, which finally decreases the a_w.

A certain amount of moisture has to be lost from fish after brining; so that water activity (a_w) can be decreased and a good texture can be obtained at the end of the smoking process. Drying of fish occurs at the early stage of smoking process. An air flow is applied on the fish; so that moisture in the fish tissue can migrate to the surface and leave the fish by evaporation. The temperature, relative humidity and velocity of the air flow are keys to the rate of drying. Drying with a low relative humidity air at high velocity may not drive the moisture out of the fish fast. If the temperature is too high fish surface may be hardened at the beginning of drying resulting in a blocking layer to the inside moisture migration. The hardened surface may also prevent smoke penetrating into the tissue, which decreases the preservative effects of the smoke. Tissues under the hardened surface will tend to spoil from inside.

Drying at temperatures below 70 to 80 °C was recommended to minimize the damage to protein quality in fish (Opstvedt, 1989). Drying also influences the quality of finished smoked fish product.

Smoking

Smoke is generated from the incomplete combustion of wood at certain temperatures followed by thermal disintegration or pyrolysis of high molecular organic compounds into volatile lower molecular mass (Eyo, 2001). Smoke is composed of two phases: a particulate or dispersed phase and a gaseous or dispersing phase. The major parts of dispersed phase are particles in the droplet form having an average diameter of 0.196 to 0.346 μm (Maga, 1988; Wheaton & Lawson, 1985). These particles are mainly tars, wood resins, and compounds with high or low boiling points. The dispersed phase is the visible part of the smoke. The dispersing phase is responsible for flavouring, colouring, antioxidative, and bacteriostatic roles of the smoke (Hall, 1997). The composition of the dispersing smoke phase is complicated, many of which have yet been identified. More than 200 components have been identified. The most abundant chemicals found in smoke are carbonyls, organic acids, phenols, alcohols, and hydrocarbons.

Quality and composition of the smoke are affected by several factors, such as combustion temperature, wood type, moisture content of wood, air ventilation rate, and wood size.

Cellulose, hemicellulose and lignin are three main components in wood and their contents and compositions vary in different types of wood. Cellulose levels are fairly consistent among different species. Softwoods have higher lignin content than hardwoods. Hardwoods typically contain more hemicellulose than softwoods. Decomposition of hemicellulose happens at the early stage of smoking and produces furan and its derivatives as well as aliphatic carboxylic acids, which drops the pH in the smoked product. Softwoods also contain more resin acids than hardwoods, which typically introduces unpleasant flavor to the fish. Hardwoods, such as hickory, oak, cherry, apple and beech, are preferred in most situations over the softwoods for smoke generation. This is because hardwoods tend to produce more phenols and organic acids which contribute to the flavor and preservation effect of smoking (Hall, 1997).

The amount of air present during the production of smoke also influences the results of wood pyrolysis. Lower temperature and less air produce a smoke with more flavoring and preserving substances. While a higher temperature and more air burn the woods into carbon dioxide and water. Smoke production can be influenced by the size of wood. Wood can be used as chunks, chips or sawdust forms. However, their combustion rates will vary if same ventilation rate is used. Sawdust produces more smoke than chunks or chips due to its self-smoldering effect, which blocks the access of oxygen. Fish is also more likely to be charred with less smoke when chunks or chips are used. Most modern smokers use continuously fed sawdust to maintain a consistent production of smoke.

Although people like the flavour and taste of the smoked product, there are concerns about the negative side of smoked products, which are mainly focused on the carcinogenic substances found in the smoke: the polynuclear aromatic hydrocarbons (PAHs). PAHs are composed of multiple fuzed benzene rings. It can be thermally produced by either high temperature pyrolysis or from the incomplete combustion of materials containing carbon and hydrogen. Up to 100 PAHs compounds have been either identified or detected (Maga, 1988). The level of PAHs can be reduced by decreasing the combustion temperature since the PAHs content was found to change linearly from 5 to 20 µg/100g in temperature range 400 to 1000 °C (Eyo, 2001). Indirect smoking like liquid and electrostatic smoking also significantly reduces the PAHs amount.

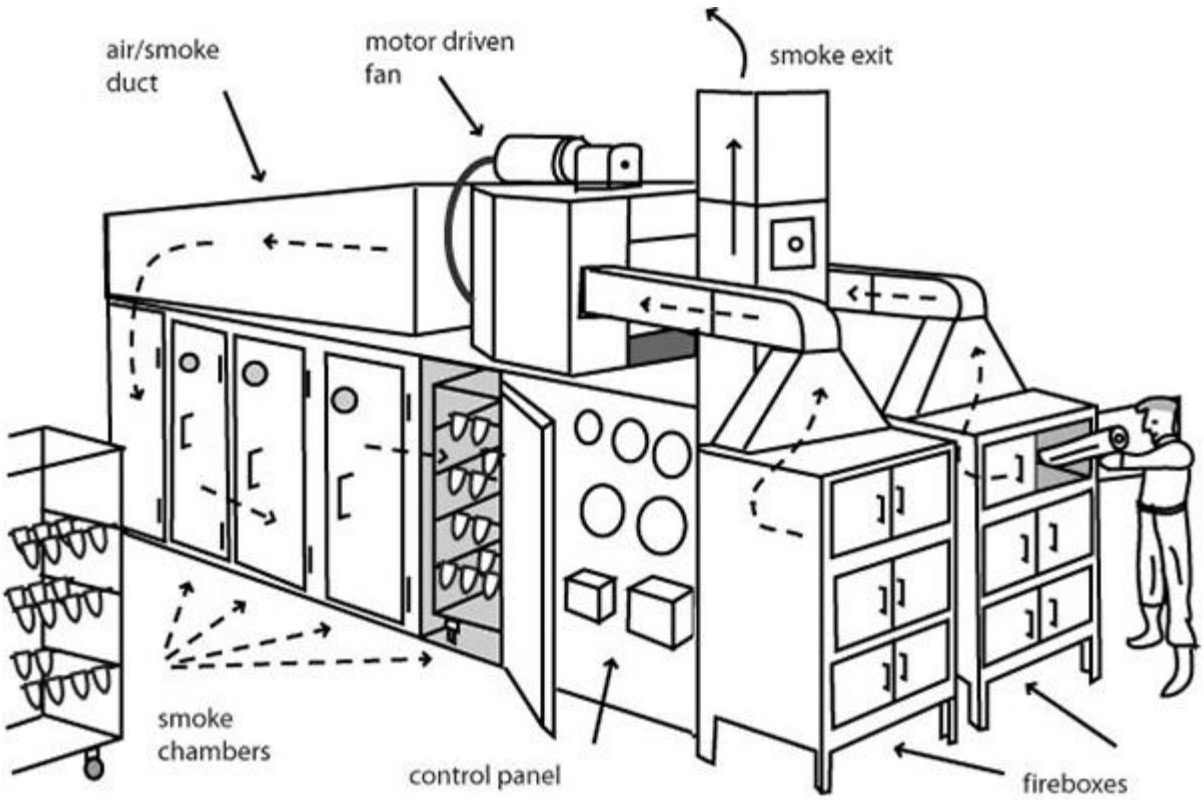

Fig. Smoking kiln

Potential hazards associated with smoking of fish

I. Biological hazards

Generally, Cold smoking will typically reduce the level of microorganism by 90 to 99%. But after the cold smoking there is no such steps to eliminate or reduce the level of microorganisms. Typical temperature used for cold smoking is 22-28˚C. However, this temperature is not sufficient to eliminate the risk from *Listeria monocytogens,* a gram positive, facultative anaerobic, psychrotropicbacteria causing deadly septicaemia, meningitis, spontaneous abortion, and foetal death in adult human beings. Specific high risk categories like persons with altered immune system, pregnant ladies, old aged persons etc. will be more susceptible to listeriosis followed by accidental inclusion. Comparatively high temperature used in hot-smoking process and long-time of exposure to that temperature (60-70˚C for 2-3 h) can inactivate the *L. monocytogens* effectively, provided the raw material is not extra-ordinarily contaminated with the bacteria prior to processing. At the same time listericidal process should be validated to ensure that the treatments are effective and can be applied continuously. But the hot smoked products are susceptible to post-process contaminations from many of the micro-organisms due to improper handling and storage of the products. Sufficient heat treatment, proper hygienic handling and cold chain maintenance during distribution can reduce the risk of biological hazards in smoked fish and fishery products.

Another important biological hazard associated with storage of smoked fish is *Clostridium botulinum.* The toxin produced by *C. botulinum* can lead to botulism, serious illness and death to the consumer. Even a few micrograms of intoxication can lead to ill-health with symptoms like weakness, vertigo, double vision, difficulty in speaking, swallowing and breathing, abdominal swelling, constipation, paralysis and death. The symptoms will start within 18-36 h after consumption of the infected product. By achieving proper salt concentration in processed fish, proper refrigeration during storage and reduced oxygen packaging like Modified Atmosphere Packaging (MAP) and vacuum packaging of the products can prevent the occurrence of *C. botulinum* in smoked fish and fishery products, especially type E and non-proteolytic types B and F. Salt along with smoke effectively prevents the toxin formation from type E, B and F.

In cold smoked fish and fishery products, which undergoes mild heat processing, the presence of spoilage organisms prevents the growth of *C. botulinum* and toxin production. Whereas in hot-smoked products, high temperature application causes damages to spores of *C. botulinum* thus prevents the toxin formation. Same process also prevents the prevalence of spoilage organisms and thus extends the shelf life of the product. Thus, the time- temperature combination for smoking, along with salt concentration plays critical roles in safety and quality aspects of the smoked fish and fishery products.

II. Chemical hazards

1. Polycyclic Aromatic Hydrocarbons (PAHs)

PAHs are large class of organic compounds containing two or more fused aromatic rings made up of carbon and hydrogen atoms. Incomplete combustion (pyrolysis), during smoking can lead to formation and release of PAHs into the smoked product. Some of them are carcinogenic and mutagenic substances causing serious health issues to the consumers. Processing procedures such as smoking, drying, roasting, baking, frying and barbecuing/grilling can lead to formation of PAHs in food items. Many reports indicate that individual PAHs in smoked fish can go up to a level of 200µg/Kg. Among the 33 PAHs evaluated by the scientific committee on Food (SCF, 2002) of EU, 15 were found to be having mutagenicity/Geno toxicity in somatic cells of experimental animal in-vivo. They are benzo[a]anthracene, benzo[b]-, benzo[j]- and benzo[k]fluoranthene, benzo[ghi]perylene, benzo[a]pyrene, chrysene, cyclopenta[cd]pyrene, dibenz[a,h]anthracene, dibenzo[a,e]-, dibenzo[a,h]-, dibenzo[a,i]-, dibenzo[a,l]pyrene, indeno[1,2,3-cd]pyrene and 5-methylchrysene. The carcinogenic and genotoxic potentials of PAH are largest among the high molecular weight PAH, i.e. compounds with 4 rings or more. Among that benzo[a]pyrene regarded as potentially genotoxic and carcinogenic to humans. They can cause long-term adverse health effects following dietary intake of PAH.

The PAH contamination in smoked products can be significantly reduced by using indirect smoking process instead of direct smoking of the fish. In indirect smoking, the smoke generated in an external smoking kiln, under controlled conditions, is used for smoking process. The smoke produced can be even, washed before coming into contact with the food material processed. In addition to that, use of lean fish for smoking, and cooking at lower temperature for longer time can also reduce the PAH contamination significantly. If the smoke condensate is used for smoking, usage of smoke condensate from reputed reliable resources approved by competent authority can effectively reduce the occurrence of PAH contamination in the final product. The formation of PAH in smoked fish can be minimised by following Code of Practice for the Reduction of Contamination of Food with Polycyclic Hydrocarbons (PAH) from Smoking and Direct Drying Processes (CAC/RCP 68-2009) given by Codex Alimentarius Commission. EU No.835/2011 specifies that maximum level of benzopyrene, and PAH4 (benzo[a]pyrene + chrysene+ benz[a]anthracene+benzo[b]fluoranthene) should be 2μg/Kg wet weight and 12μg/Kg in meat of smoked fish and fishery products, 5μg/Kg and 30μg/Kg in smoked sprats and 6μg/Kg and 35μg/Kg in smoked bivalve mollusc respectively.

2. Histamine:

Histamine poisoning is associated with Scombroid fishes and other dark meat fishes. The fishes showing potential treats of histamine poisoning are tunas, bonitos, mackerel, mahi mahi, carangids, herring etc. These fishes having high content of free histidine, which during spoilage are converted to histamine by bacteria like *Morganella morgani, Klebsiella pnuemoniae* and *Hafnia alvei*. Histamine is heat stable, even cooking or canning cannot destroy it. Presence of other biogenic amines like cadaverine and putrescine will act as potentiators for histamine production. As per Codex standards, the maximum allowable histamine content in smoked fishes is 200 mg/Kg for species like *Scombridae, Clupeidae, Engraulidae, Coryphaenidae, Pomatomidae,* and

Scomberesocidae. Low temperature storage of fishes right from catch can effectively reduce the production of histamine in fishes.

3.Biotoxins:

Biotoxins causing a number of food borne diseases. The poisoning due to biotoxins are caused by consuming finfish/shell fish containing poisonous tissues with accumulated toxins from plankton they consumed. Paralytic shellfish poisoning (PSP), diarrheic shellfish poisoning (DSP), amnesic shellfish poisoning (ASP), and neurotoxic shellfish poisoning (NSP) are mostly associated with shellfish species such as oysters, clam and mussels. The control of biotoxin is very difficult. They cannot be destroyed by any of the processing methods like cooking, smoking, drying or salting. Environmental monitoring of plankton and proper depuration process of the bivalves only can reduce the occurrence significantly.

III. Physical Hazards

Presence of parasites like nematodes, cestodes, trematodes and any other extraneous matter can be considered as physical hazards. Particular attention needs to be paid to cold smoked or smoke-flavoured products, which should be frozen before or after smoking if a parasite hazard is present.

IV. Other potential hazards associated with smoking of fish

If wood or plant material is using for smoking of fish, there is a chance of presence of natural toxins, chemicals, paint, or impregnating material in plant or wood used which may result in imparting undesirable odour in processed products. This can be prevented by using sufficiently dried wood or plant material for smoke generation, judicious selection of the species of wood or plant and not using woods having mould or fungus growth for smoking process. Moreover, the material for smoking should be kept in a clean dry place during storage to prevent any kind of contamination, till the usage.

Chapter 12

Value added fish products

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Value addition is the most talked about word in food processing industry, particularly in export oriented fish processing industry because of the increased realization of valuable foreign exchange. 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. As far as fish processing industry is concerned value addition is one of the possible approaches to raise profitability since this industry is becoming highly competitive and increasingly expensive.

There is great demand for seafood/seafood based products in ready to eat "convenience" form. A number of such diverse products have already invaded the western markets. One factor responsible for such a situation is more and more women getting educated and taking up employment. Reasonably good expendable income, education, awareness and consciousness towards hygiene and health, increased emphasis on leisure pursuits etc. are some of the other reasons.

Marketing of value added products is completely different from the traditional seafood trade. It is dynamic, sensitive, complex and very expensive. Market surveys, packaging and advertising are a few of the very important areas, which ultimately determine the successful movement of a new product. Most of the market channels currently used is not suitable to trade value added products. A new appropriate channel would be the super market chains which want to procure directly from the source of supply. Appearance, packaging and display are all important factors leading to successful marketing of any new value added product. The retail pack must be clean, crisp and clear and make the contents appear attractive to the consumer. The consumer must be given confidence to experiment with a new product launched in the market. Packaging requirements change with product form, target group, market area, species used and so on. The latest packaging must also keep abreast with the latest technology.

Chilled fish

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. Chilled fish is another important value added item of international trade. Chilled fish fetches more price than frozen fish. 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. Modern packaging techniques viz., vacuum packaging, modified atmospheric packaging and active packaging significantly enhances the shelf life of chilled fish products.

Frozen fish fillets

Freezing and storage of whole fish, gutted fish, fillets etc. are methods for long-term preservation of these species. Many varieties of fresh water fishes like rainbow trout, shell fishes, catla, rohu, tilapia fillets can be frozen for domestic market and export to developed countries in block frozen and IQF forms. In the importing countries these fillets are mainly used for conversion into coated products. Fish fillets can also be used for the production of ready to serve value added products such as fish in sauce and fish salads.

Speciality products

Stretched shrimp (Nobashi)

Increasing the length of peeled and deveined shrimp and minimising its curling by making parallel cuttings at the bottom and applying pressure using simple mechanical devices is a new technique adopted by the seafood processing industry in recent years. Increasing the length by about 1-2 cms depending on the size of the shrimp is possible by this method. The stretched shrimp will have better appearance compared to conventional PD shrimp and it also fetches higher unit price. The stretched shrimp because of its increased surface area will have more pickup of coating during battering and breading and also good appearance.

Shrimp is washed in chilled water containing 5-ppm chlorine, beheaded, deveined, using bamboo stick and pealed keeping the last segment and tail intact. The tail is then trimmed and the shrimp is stretched using a metallic stretcher after making 2-3 parallel cuttings at the bottom side. Stretched shrimps are then packed in thermoformed trays under vacuum and frozen at -40°C.

Barbecue

Shrimp is washed in chilled water containing 5-ppm chlorine, beheaded, deveined, peeled and again washed in chilled water. Bamboo stick is then pierced into the meat from head portion to tail. It is then packed in thermoformed trays under vacuum and frozen at -40°C.

Sushi (Cooked butterfly shrimp)

Shrimp is washed in chilled water containing 5ppm chlorine, beheaded, deveined and again washed in chilled water. Bamboo stick is then pierced between the shell and the meat from head portion to tail and then cooked in 1% brine for two minutes at 100°C. The cooked shrimp is then cooled in chilled water, bamboo stick removed and then peeled completely, including the tail fans. The ventral side is then gently cut down lengthwise completely using a sharp scalpel. The cut surface is then gently opened up to form the butterfly shape, packed in thermoformed trays under vacuum and frozen at -40°C.

Skewered shrimp

The process is similar to that of barbecue, but piercing is carried out in such a way that 4-5 shrimps are arranged in a skewer in an inverted " U" shape. It is then packed in thermoformed trays under vacuum and frozen at -40°C.

Shrimp head-on (centre peeled)

Shrimp is washed in chilled water containing 5 ppm chlorine, pealed at the centre keeping the head and the last two segments intact, deveined, and the tail is trimmed. It is again washed in chilled water packed in thermoformed trays under vacuum and frozen at -40°C.

Shrimp head-on cooked (centre peeled)

Shrimp is washed in chilled water containing 5 ppm chlorine, deveined and then cooked in 1% brine for two minutes at 100°C. It is immediately cooled in chilled water and pealed keeping the head and the last two segments intact. The tail is trimmed and again washed in chilled water. It is then packed in thermoformed trays under vacuum and frozen at -40°C.

Battered and breaded fish products

Consumers are looking for better alternative for conventional fresh food that offers time-saving preparation. Hence there exists an increased global demand for ready-to-heat frozen foods, especially breaded and battered products with high standards of quality. Battering and breading enhances the consumer satisfaction by improving the nutritional value, organoleptic characteristics and appearance of the products. The most important advantage of coating is value addition as it increases the bulk of the product. Also this paves way for better utilisation of low cost or underutilised fishes. Coating is referred as the batter and/or breading adhering to a food product. Each ingredient in coating offers unique role in development of functionality and characteristics of the product. Polysaccharides, proteins, fat, seasonings and water are the commonly used ingredients. The method of product development differs with the type of product. Mostly this includes seven major steps.

Portioning / forming

A perfectly portioned product is the right starting point. Mechanically deboned fish meat is formed to different shapes and sizes after mixing with ingredients, if needed. The product should keep its consistency with proper weight and shape. The key factor in this production step is speed and accuracy of processing the frozen fish block at minimum costs without any compromise to the product quality.

Predusting

Predusting is usually done with very fine raw flour type material or dry batter itself, sprinkled on the surface of food substrate before coating. This helps to reduce the moisture on the surface of the product so that the batter can adhere uniformly. Flavourings such as salt and spices can be added in minimum amounts.

Battering

Batter is defined as the liquid mixture composed of water, flour, starch, and seasonings into which the fish products are dipped prior to breading. Two types of batter are there- adhesive batter and tempura batter. The adhesive batter is a fluid, consisting of flour and water. Tempura batter is the puff-type batter containing raising/leavening agents. This forms a crisp, continuous, uniform layer over the food. The predusted portions are applied with wet batter and excess batter can be blown off by a current of air. The batter mix helps in governing the amount of bread to be picked up and it contributes to flavour of the final product. Specific ingredients are used to aid viscosity, texture and adhesion.

Ingredients of batter mix

a) Flour- Wheat flour provides structure to the product through gelatinisation of starch as well as through formation of gluten protein matrix. Higher protein levels in flour increases viscosity of batter and produce darker crispy coatings. Corn flour can be added to produce yellow colour and to enhance browning during frying.

b) Water- The ratio of water to dry batter mix is 1.8:1. Formation of gelatinised starch phase, hydration of flow proteins, batter viscosity etc. depends on the purity of water used.

c) Starch- Corn starch is added mainly to control batter viscosity and thus increasing the batter pickup and breading retention.

d) Flavour and flavour enhancers- salt, sugar, spices etc. can be added to improve the organoleptic characteristics of the products.

e) Sodium tripolyphosphate- This lowers the water activity of the product and has bactericidal property. It increases the hydration of proteins and reduces protein denaturation.

Breading

Breading was defined as the application of a dry mixture of flour starch, seasonings having a coarse composition to battered food products prior to cooking. Normally the battered fish portions are dropped in to dried bread crumbs and are turned over to ensure complete coating with bread crumbs. A fine layer or coarse layer of bread crumps will contribute to structure and tastiness of the product. For soft products the crump depth should be fine so as to avoid the product damage on further processing.

Pre-frying/ flash frying

Pre-frying is the process of giving a shallow fry so as to coagulate batter over the product and lock the flavour and juices to the product. The time of frying and temperature of oil are crucial factors. This could be done at 180-200°C for 40-60 sec, thus restricting the actual heat transfer to the surface of the product. The term pre-frying is used as frying will be completed only when the consumers fry the product for 4-6 minutes depending on the product size.

Freezing

The fish portions are air cooled before freezing. This helps the coating temperature to drop while the batter can stabilise itself and recover from the frying shock. Freezing is done at a temperature of -10°C to -20°C in order to preserve freshness and quality of the product over longer storage periods.

Packaging and storage

Proper packaging and storage is essential to prevent/retard desiccation, discolouration and rancidity in coated products. Packaging in thermoformed containers and storage at -20°C are most commonly used for breaded and battered products. The developments in value added product industry demands the packaging that can withstand the higher temperatures of microwave reheating.

Advantages of coated products

- Enhanced nutritional quality
- Moisture barrier during frozen storage and reheating
- Crispy texture and appealing colour and flavour
- Structural reinforcement of the substrate
- Prevents loss of natural juices
- Increased bulk of the substrate and reduced product cost
- Improved overall acceptability of the product

Battering and breading have contributed significantly to the value addition of fishes, shell fishes and molluscs. The first commercially successful coated fish item was fish fingers. Later several other products like fish cutlets, fish balls, fish nuggets, etc. came into the market. Coated butterfly shrimp, squid rings, stuffed squid rings etc. are among the fancy items that cater to the luxury markets. Sophisticated equipments like meat bone separator, meat strainer, portioning and forming equipment, preduster, battering and breading machine, fryer, freezer and packaging machineries are in the market for preparation of a wide variety of coated products.

Fish finger or Fish portion

Fish fingers, or portions or sticks are regular sized portions cut from rectangular frozen blocks of fish flesh. They are normally coated with batter, and then crumbed before being flash fried and frozen. They may be packed in retail or catering - size packs. The typical British fish finger normally weighs about 1 oz. (28 g) of which up to about 50% of the total weight may be batter and crumbs. Food Advisory Committee of the UK government has recommended a minimum fish content of 55% for battered and 60% for the fingers coated with breadcrumbs.

Shrimp products

Battered and breaded shrimp can be prepared from wild as well as from farmed shrimp in different styles and forms. The most important among them are butterfly, round tail-on, peeled and deveined (PD), nobashi (stretched shrimp) etc. The products from farmed shrimp have indicated longer shelf life, 16-18 months compared to those from wild variety 12-14 months at –20 °C

Fish fillets

The brined fillets are battered and breaded. Fillets from freshwater fish are also used for the production of coated products. The only problem noticed in this case is the presence of fin bones; its complete removal is still a major hurdle.

Squid products

Squid rings and stuffed squid are the popular coated products processed out of squid. Cleaned squid tubes are cut in the form of rings of uniform size, cooked in boiling brine (3%) for 1-2 minutes followed by cooling, breading and battering. The coated rings are flash-fried, cooled, frozen and packed. Stuffed squid is generally processed out of small size animals. The cleaned tubes are filled with a stuffing mixture prepared using cooked squid tentacles, potato, fried onion, spices etc. It is then battered, breaded and flash-fried.

Clam and other related products

Meat shucked out from depurated live clams after boiling is blanched in boiling brine, cooled, battered, breaded, flash-fried and packed. Other bivalves such as oyster, mussels etc. can also be converted into coated products by the same method.

Fish cutlet

Cooked fish mince is mixed with cooked potato, fried onion, spices and other optional ingredients. This mass is then formed into the desired shape, each weighing approximately 30g. The formed cutlets are battered and breaded.

Fish balls

Fish balls are generally prepared from mince of low cost fish. Balls can be prepared by different ways. The simplest method is by mixing the fish mince with starch, salt and spices. This mix is then made into balls, cooked in boiling 1 % brine. The cooked balls are then battered and breaded.

Crab claw balls

Swimming legs of crab may be used for this purpose. Crab claws are severed from the body, washed in chilled portable water and the shell removed using a cracker. The leg meat is then removed and mixed with 2 % starch based binder. This is then stuffed on the exposed end of the claw. Alternatively the body meat mixed with the binder also can be used for stuffing. The stuffed claw is then frozen, battered and breaded and flash fried. The coated products are packed in thermoformed containers with built in cavities.

Mince based products

Fish mince separated from skin, bone and fins are comminuted and used for preparation of different products. Battered and breaded products like fish fingers, fish balls, cutlet etc. are produced. Fish cultlets fetch good demand in domestic markets while fish fingers are demanded in export market. Fish cutlets with partial replacement of fish meat with soy protein will increase the acceptability and storage stability of fish cutlets. A ready to eat novel battered and breaded snack product, 'Oyster pablano pepper fritter' have a good scope of attraction in value added markets. Fish finger from Bombay duck adds on to the value addition potential of fish in our markets. Fish rolls with good shelf life can be developed from frame meat of fishes, eg: rohu. Fish sausage, cakes and patties are some other mince based products.

Surimi and surimi based products

Surimi, term for the mince that are deboned and washed, also act as an intermediary in development of various products. It is one among the most consumed product fish. Low cost fishes can be conveniently used for the preparation of surimi. Block frozen surimi and surimi based products are popular. Shell fish analogue products from surimi fetches good demand in both domestic and export markets. The history of surimi in India starts in1990's with the first surimi manufacturing plant was set up in 1994. The Indian company 'Gadre Marine' became the third largest manufacturer of surimi, exporting to 24 countries over the world. This shows the potential for production of surimi and surimi based products in India. The demand of these products are less in domestic markets but is expanding nowadays. These healthy and simple products have great scope in indian markets as people are moving towards different alternatives. Shell fish analogue products from surimi fetches good demand in both domestic and export markets.

Ready to serve fish products in retortable pouch

Ready to serve fish products viz. curry products, in retortable pouches are a recent innovation in ready to serve fish products for local market. The most common retortable pouch consists of a 3 ply laminated material. Generally it is polyester/aluminium/cast polypropylene. These products have a shelf life of more than one year at room temperature. As there is increasing demand in National and International market for ready to serve products the retort pouch technology will have a good future. The technology for retort pouch processing of several varieties of ready to serve fish and fish products has been standardised at CIFT and this technology has been transferred successfully to entrepreneurs.

Extruded products

Fish based extruded products have got very good marketing potential. Formulation of appropriate types of products using fish mince, starches etc., attractive packaging for the products and market studies are needed for the popularization of such products. However, technological studies involving use of indigenously available starches like cassava starch, potato starch, cornstarch and the associated problems need thorough investigation. Such products can command very high market potential particularly among the urban elites. The technology can be employed for profitable utilization of bycatch and low value fish besides providing ample generation of employment opportunities.

Intermediate moisture products (IMF)

The IMF technology is based on the reduction in water-activity of food to a level in which most bacteria in will no longer grow. Intermediate moisture product from fishes can be made from a combination of different techniques like drying, pH modification etc.

Seaweed products/Seaweed incorporated products

Seaweed incorporation in fish products increases the fibre content and retention of PUFA. 'Nutradrink' and fish soup enriched with seaweed bioactive compounds are novel products developed by CIFT. Sulphated polysaccharides with bioactive properties can be extracted from seaweed. Seaweed incorporated semi-sweet biscuits and extruded snack products will also have good nutrirional importance.

Fish caviar substitutes

Polyunsaturated fatty acids and amino acids gives the nutritional importance of fish roe. Besides the commercially available roe from sturgeon, salmon and cod, fish caviar substitute from fresh water carp roe reconstituted with sodium alginate will have a greater potential as value added fish caviar substitute.

Curing

The 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.

Preparation of some popular products

Pickled products

Fish pickle makes use of the non-fatty variety of low cost fish having good meat content. Major ingredients are: fish, garlic, green chilly, ginger, chilly powder, turmeric powder, gingelly oil/ ground nut, salt, vinegar and sugar. The method of preparation of pickle is simple, the preservative being oil, salt and vinegar. The traditional packing is in glass bottles. Modern packing materials suitable for packing fish pickles have also been identified. Pouches and stand packs made of 12 micron polyester laminated with 118 micron LD/HD co-extruded film can be used for packing pickles.

Ingredients	Quantity
Fish (dressed and cut into small pieces)	1 kg
Mustard (shell removed)-Optional	10 g
Green chilly	50 g
Garlic	200 g
Ginger	150 g
Chilli powder	50 g
Turmeric powder	2 g
Gingelly oil/ ground nut	200 g
Vinegar	400 ml
Salt	60 g
Sugar (optional)	10 g
Cardamom, clove & cinnamon (optional)	1.5 g

Process

Mix the dressed fish with salt at the rate of 3% by weight of fish and dry in the sun /dryer for 2 to 3 hours and then deep fry the fish in oil and keep apart. Then fry mustard, green chilli, ginger and garlic in oil. When frying is adequate add turmeric powder, followed by chilli powder under a low flame and immediately remove from the flame and mixed with fried fish and allowed to cool. Vinegar and salt were added and mixed thoroughly and adjust to a slightly salty taste. Finally sugar was added and mixed thoroughly. Stored the pickle in a clean container for at least 2 overnights for maturing and fill in glass bottles or acid resistant packets (12 µ polyester with 250 gauge LDHD polythene co-extruded film pouches)

Fish Soup Powder

Fish soup powder can be formulated from any type of fish having very low fat content. Soup powder prepared from different food materials like vegetables, meat, egg are in use in different parts of the world. These are dry products rich in dietary constituents like protein and minerals. The soup powder prepared out of miscellaneous fish is also a rich source of animal protein and other nutritional factors.

Ingredients used for the preparation of fish soup powder

Ingredients	**Qty**
Cooked fish meat	750 g
Salt	170 g
Fat	120 g
Onion	750 g
Coriander	12 g
Tapioca starch	250 g
Milk powder	100 g
Sugar/glucose	30 g
Pepper powder	15 g
Ascorbic acid	1.5 g
Carboxy methyl cellulose	3 g
Monosodium glutamate	5 g

Method of preparation

Minced fish can be conveniently used for the preparation of soup powder. If whole fish is using it has to be cooked first and the meat is separated from the bones and skin. Cooked pressed meat is the basic raw material for the preparation. Fry the onion till it becomes light brown.

Grind the cooked fish, fried onion and other ingredients in a wet food grinder till it becomes a fine paste. Spread the paste in aluminum trays lined with polyethylene sheet and dried in an electrical drier at 50°C to reduce the moisture content to 8%. Dried material is then pulverized in a mechanical pulveriser. Milk powder is added and packed in airtight containers or laminated polyethylene bags. It has a shelf life of about 8 months at ambient temperature.

Preparation of soup

One-teaspoon full (5 g) of powder is made into a paste with 10 ml cold water. This is added to 90 ml boiling water. Continue boiling for 2 minutes. The soup is ready for use.

Fish flakes or wafers

Fish wafers are partially deodourized thin flakes of cooked fish meat homogenized with starch and salt. On frying the wafers swell to two to three times of its initial size and become crisp and delicious. It is an ideal snack. Fish mince and starch are the base material for the preparation of wafers

Ingredients used for the preparation of fish flakes

Ingredients	**Qty**
Cooked fish meat	2 kg
Refined tapioca starch	2 kg
Corn starch	1 kg
Common salt	5%
Water	3.5 l

Process

The cooked fish meat is homogenized in a wet food grinder. Starch, salt and water are added and continued grinding till they become a fine paste. Small portions of the homogenized mass is poured on to flat aluminum trays and spread to a film of 1 to 2 mm thickness. The material is cooked in a steam chamber for 2 to 3 minutes to gelatinise the starch. After this the film become firm and it can be cut into desired shapes. The gelatinized flakes are dried in an electrical drier at 45-50°C or it can be sun dried. Fry in edible oil and serve hot

Fish paste

Fish paste is a high value convenience food popular in South East Asia prepared by mixing fish and salt and allowing it to ferment. This results in the formation of either a paste or a liquid, which is separated from the residue and is used as a flavoring agent Fish paste can also be prepared with out fermentation. Frozen fish paste is not relished because during storage, texture and spreadability are adversely affected.

Fish paste is prepared by finely grinding texturised cooked fish meat, gelatinized, starch, sugar, milk powder, colouring matter and flavour (Table 5). It was packed in flexible pouches made of co-extruded polypropylene, heat processed in air steam pressure in an autoclave and stored at ambient temperature. The shelf life is 36 weeks. It become unacceptable due to changes in texture and spread ability. The proximate composition of fish paste is given in Table 6.

Recipe of fish paste

Ingredients	**%**
Fish mince	78
Fat	8
Starch	8
Sugar	2.25
Milk powder	2.50
Salt	1.25
Poly phosphate	0.50

Microbiological studies showed that the product is bacteriologically safe for human consumption. Studies showed that the fish paste is acceptable as bread spread or similar types of products. The large quantity of low value fish with low fat and white flesh available in India can be used for making good quality fish paste.

Fish Noodles

This is a product similar to ordinary noodles available in the market, but contains 21% protein. Surimi is used as the base for the production of fish noodles Table 7). Cooked surimi is kneaded with salt and maida. The mix is passed through the extruder. Gelatinised noodles is dried under sun or in an electrical drier at 50°C to a moisture level of 8%. The dried noodle is packed in airtight containers or polythene bags. The product has very good rehydration property.

Ingredients used for the preparation of fish noodles

Ingredients	**Qty**
Cooked fish mince	800 g
Maida	1200 g
Salt	60 g
Water	1-2%

Just like the noodles available in the market only two minutes cooking is required for the preparation of fish noodles.

Chapter 13

Extruded fish products

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Food extrusion technology is a popular means of preparing snacks and ready-to-prepare food items. It is a size enlargement process where in small granular food or powdered particles are reinforced into larger pieces with different shapes, texture, colour etc. Extrusion cooking or thermoplastic extrusion is a common extrusion technology which is considered a HTST (High-Temperature, Short-Time) process. It permits, with little or no modification of the basic equipments and appropriate process control, the production of a great variety of food products. Extrusion cooking is used for starchy and proteinaceous materials for the preparation of nutritious foods. Generally such products are rich in calories and incorporation of protein rich fish improves its nutritional value. Most of the extruded snacks are cereal based and were developed mainly from corn, wheat and rice. But these cereals (eg. rice) have relatively low protein content (6–8 g/100 g db) and an amino acid profile that is high in glutamic and aspartic acid, while lysine is the limiting amino acid. Therefore, addition of proteinaceous food ingredient (eg. fish) in the extruded snack products is recommendable to ensure rich nutritional diets.

Fish is known to be excellent sources of high nutritional value protein with balanced profile of essential amino acids and lipid that contains omega-3 fatty acids, especially, essential fatty acids such as eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA). EPA and DHA are very essential for normal growth and development. These essential fatty acids are found to prevent or moderate coronary artery disease, hypertension, diabetes, arthritis, others inflammatory and autoimmune disorders. The advantages of fish-based extruded products will help in providing nutritious and balanced diets to a large population in the country like India.

Extruders and their classification:

Extruders are the tools used to introduce mechanical shear and thermal energy to food ingredients. Mechanical or thermal energy are used to transport the material through rotating helical screw/screws and the die brings about physical and chemical changes in the feedstock. The extrusion process generally involves the conversion of a plasticized biopolymer based formulation into a uniformly processed viscoelastic mass that is suitable for forming or shaping into products by a die.

Extruders are classified into two categories according to operational temperature: Hot extruder (cooking extrusion) and cold extruders (non-cooking extrusion). ***Cooking extrusion***involves the raw ingredients being cooked by the combined action of heat, mechanical shearing and pressure (up to 250°C and 25M Pa). ***Non-cooking extrusion***transforms the feed into a homogeneous cohesive extrudate without cooking. Based on type of construction extruders are classified into: Single screw and twin screw extruder. ***Single-screw extruders***are most common extruders applied in the food industry. ***Twin-screw extruders*** are used for high-moisture extrusion, products that include higher quantities of components such as fibres, fats, etc. and for the production of more sophisticated products. Twin screw extruders are again classified as ***Co-rotating*** and ***counter-rotating*** types based on the direction of rotation of the screws. In the counter-rotating position the extruder screw rotates in the opposite direction, whereas in the co-rotating position the screw rotates in the same direction.

Extrusion and its principle:

Raw materials (fish mince and flours) are fed into the extruder barrel through a feeder and the screws convey along it. Towards the barrel end, smaller flights restrict the volume and resistance to movement of the food is increased. As a result, it fills the barrel and the spaces between the screw flights and becomes more compressed. As it moves further along the barrel, the screw kneads the material into a semi-solid, plasticized mass. The food is heated above 100˚C and the process is known as extrusion cooking (or hot extrusion). Here, frictional heat and the additional heating that is used cause the temperature to rise rapidly. The food is then passed to the section of the barrel having the smallest flights, where pressure and shearing is further increased. Finally, it is forced through dies (restricted openings) at the end of the barrel. As the food emerges under pressure from the die to normal atmospheric pressure and temperature, it expands to the final shape, gets characteristic texture and cools rapidly as moisture is flashed off as steam.

Product attributes are controlled by following factors:

- Raw materials
- Residence time of the product in the extruder
- Moisture content

- Barrel temperature
- Screw profile and speed
- Feed rate
- Degree of barrel fill

The independent process variables viz. screw speed; barrel temperature and feed moisture content have direct effect on the product quality. Bulk density is linked with the expansion ratio in describing the degree of puffing in extrudates. Characteristics of extrudate made from starchy ingredients depend on physicochemical changes which occur during extrusion process due to the effects of extrusion variables. In extrusion process, hydration of starches and proteins (structure formers) takes place due to heat and shear. Starch and protein are turned into melt where droplets of water are entrapped and thereby hydrated.

Coating:

The flavouring of extruded products follows a similar pattern to colouring. A product may develop flavour by thermal reactions between flavour precursors in the mix or be flavoured by adding synthetic or natural flavorings. The addition of flavouring is usually carried out on the dry extrudate by spraying or dusting, because of the changes caused by the losses of volatiles during extrusion. This can be performed with simple rotating drums with electric heaters installed or with a gas operated hot air installation.

Packaging:

One of the major properties of snacks is the crispness, which is achieved during the manufacture of the product. Retention of desirable texture (crispiness) is directly related to the moisture level in the product. The moisture content of snack is very low, and any increase due to the hygroscopic nature of the product may lead to loss of crispiness of the product. Moisture also accelerates other biochemical changes such as oxidative rancidity. Oxygen inside the package may be replaced by an inert gas like nitrogen. Low water vapour and gas permeability of the package is, therefore, a very critical requirement. Also the packaging material must be physically strong enough to withstand the processes of vacuumising/gas flushing. Metalized Polyester-Polyethylene laminated pouches with Nitrogen flushing are used for the packaging

Storage:

Extruded product can be stored at ambient temperature. Nitrogen flushed pouches can be bulk packed in carton box and stacked inside the store.

Advantages of thermoplastic extrusion:

Versatility, low costs, high production yields, good quality nutrient enriched products and no effluents.

Effect on nutrients:

Protein, lipids, vitamins and minerals are affected according to the independent variables of extrusion process. Higher temperature and pressure will have higher impact on the nutrients.

Flow chart for preparation of extruded fish product

Dressing of fish, meat picking, preparation of minced meat

↓

Mixing of minced meat with other ingredients in blender

↓

Setting of required moisture content in the mixed flour (10-20%) and conditioning for 30 minutes

↓

Hot extrusion through Twin-screw or Single-screw extruder

(High Temperature (100-140 °C), High Pressure, Short Time process)

↓

Drying by hot air (140-150 °C) to moisture content < 5%

↓

Coating of flavour (Dust coating of flavour powder along with hot oil-spray)

↓

Packing in Metalized Polyester-Polyethylene laminated pouches with Nitrogen gas flushing

Chapter 14

Non-thermal processing of fishes

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Food processing involves the transformation of raw materials into consumer-ready products, with the objective of stabilizing them to prevent negative changes in quality and ensure food safety. To consumers, the most important attributes of a food product are its sensory characteristics like texture, flavour, aroma, shape and colour. The aim of food manufacturers is to develop and employ processing technologies that retain or create desirable sensory qualities or reduce undesirable changes which take place during processing. Alternative or novel food processing technologies are being explored and implemented to provide safe, fresher-tasting, nutritive foods without the use of heat or chemical preservatives. The major non thermal technologies gaining importance are High-pressure processing, Pulsed light technology, Pulsed electric field, Irradiation etc.

High pressure processing

The application of very high pressures (upto 87,000 psi, 6000 bar or 600 MPa) for preservation of food substances in combination with or without heat is known as high pressure processing (HPP). This process is also known as high hydrostatic pressure processing (HHP) or ultra-high pressure processing (UHP). When compared to thermal processing, pressure treated foods have a fresher taste, better appearance, texture and nutritional value. High pressure processing can be conducted at ambient or refrigerated temperatures, thereby eliminating thermal effects and cooked off-flavors. The technology is highly beneficial for heat sensitive products. The first high pressure processing line was introduced in Japan for jam manufacture in 1990's and has since been upgraded to several food products. A number of HPP products have been commercialized in North America, Europe and in China. Machines are now available with operating pressures in the range 400-700 MPa and capacities ranging up to 900 kg per batch. Since HP processing affect mainly the non-covalent bonds of the food, the quality characteristics of foods such as color, flavor and nutrients generally remain unaffected (Knorr, 1993).

Principles of High Pressure Processing

The two main principles of direct relevance to the use of high pressures in foods are the Le Chatelier's Principle and the Isostatic Principle. Le Chatelier's applies to all physical processes, and states that when a system at equilibrium is disturbed the system responds in a way that tends to minimize the disturbance (Pauling, 1964). This means that HP stimulates reactions that result in a decrease in volume but opposes reactions that involve in an increase in volume. Any phenomenon (e.g. phase transition, change in molecular configuration, chemical reaction) that is accompanied by a decrease in volume will be enhanced by pressure. Secondly, the Isostatic rule states that pressure is instantaneously and uniformly transmitted throughout a sample under pressure whether the sample is in direct contact with the pressure medium or hermetically sealed in a flexible package that transmits pressure (Olsson, 1995). Pressure is transmitted in a uniform (isostatic) manner throughout the sample; the time necessary for pressure processing is therefore independent of sample size, in contrast to thermal processing.

Mechanism of Pressure Treatment

Each processing cycle consists of an initial pressurization period where the pressure builds up and the processing is undertaken with or without application of heat to the product. The food product to be treated is packed in a flexible or semi flexible container or pouch and placed in a pressure vessel capable of sustaining the required pressure. The product is submerged in pressure-transmitting medium, which is a liquid. Water is commonly used as the pressure-transmitting medium. Other liquids include castor oil, silicone oil, sodium benzoate, ethanol or glycol etc in various combinations with water or separately. The pressure-transmitting fluid should be able to protect the inner vessel from corrosion and liquids base on the manufacturer's specification is usually used. The process temperature range and the viscosity of the fluid under pressure are some of the factors involved in selecting the medium. The hydraulic fluid is pressurized with a pump, and this pressure is transmitted uniformly throughout the packaged 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. Once the pressure is build up to the desired level the product is held at this pressure for a few minutes and then decompression or pressure release takes place. Once there is a fall in pressure the product temperature falls below that of the initial product temperature. During the pressurization process adiabatic heating takes place and there is an increase in the temperature of the food product which is again dependent on the pressure transmitting fluid, product, pressurization rate, temperature and pressure. In the case of water the increase in temperature due to adiabatic heating is 3°C for every 100 MPa increase in pressure.

Major Advantages of the Technology

1. It does not break covalent bonds; therefore, the development of flavours unacceptable to the product quality is prevented and the natural qualities of products are maintained.
2. It can be applied at room temperature thus reducing the amount of thermal energy needed for food products during conventional processing.
3. Since High pressure processing is isostatic (uniform throughout the food), the food is preserved evenly throughout without any particlcs escaping the treatment.
4. High pressure is not time-mass dependent i.e. it acts instantaneously thus reducing the processing time.
5. High pressure processing is independent of size and geometry of the food.
6. The process is environment friendly since it requires only electric energy and there are no waste products.

Applications in Marine Products

Sea foods are highly perishable and usually spoil faster than other muscle foods. They are more vulnerable to post-mortem changes when compared to meat or any other animal product. Fish is characterized by the presence of odourless compounds called Trimethylamine oxide (TMAO) which on spoilage is converted to trimethyl amine by bacterial enzymes, and is used as the assessment of quality. Generally volatile bases are produced in fish muscle by autolytic enzymes, putrefactive micro-organisms or by chemical reactions. High pressure processing can play a vital role in reducing the microbial load and thereby maintaining the quality of the product without bringing about any changes in the raw product.

HPP can be applied in a wide area of fish processing. HPP can be used to extend the shelf life of products. It can be used to eliminate pathogens like *E. coli, Salmonella* and *Listeria* and spoilage bacteria without affecting 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 used worldwide in shell fish processing for 100 % removal of meat from the shells and for reducing the microbial risks during raw seafood consumption. The application of high pressure processing in muscle foods is either for tenderization of the muscle or for extension of shelf life. This process inactivates vegetative microorganisms and reducing the bacterial contaminations and the pathogens (Ohshsima et al., 1993). High pressure can be used to modify functional properties of the food material while simultaneously enhancing safety of raw seafood's and retaining its sensory and nutritional qualities. High pressure promotes increased shelf life without affecting, chemical, microbiological, and sensory characteristics while inactivating pathogens inherent in the product. Since the processing is usually done at low or moderate temperatures, this does not affect the covalent bonds, but disrupts secondary and tertiary bonds and reduces the enzymatic activity and thereby minimize loss in flavor bearing components (Torres & Velazquez, 2005). High pressure treatment in combination with salting and smoking are reported to extend the shelf life of different types of products (Montero et al., 2007) and the combination of high pressure and short treatment was found effective in improving the quality of smoked salmon (Gudbjornsdottir et al., 2010). Applications for marination and impregnation of desired flavors and colors 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 helps in retaining the microstructure and reduce drip loss in fish products.

Seafood is a highly perishable commodity and technologies like high pressure processing are essential to increase the market value of some high value fishes. High pressure processing has a growing demand in the global market. A lot of studies are being done on HPP from the past decade. Further studies on the effects of this technology on the biochemical characteristics and microflora of shellfish are necessary. The effectiveness of high pressure on microbial and enzyme inactivation, while maintaining optimal product quality is a crucial factor for the commercialization of the technology. HP processing offers many advantages over conventional processing methods known to seafood. This is exemplified by the success of HP-processed oysters in USA by Motivatit Seafood, Goose Point Oysters and Joey Oysters. However, as HP processing becomes more widely available, initial capital costs may be reduced, making technology accessible to more producers. In addition, the commercialization of the technology for other foods may provide encouragement for seafood processors, by allaying apprehension regarding the use of this novel technology and demonstrating consumer acceptance of HP-processed products (Fig. 1.).

Pulsed light technology

Pulsed light (PL) is an emerging non-thermal technology for decontamination of food surfaces and food packages, consisting of short time high-peak pulses of broad-spectrum white light (Dunn et al., 1989). The term light is generally used to mean radiations having wavelength ranging from 180 to 1100 nm, which includes ultraviolet rays (UV 180–400 nm, roughly subdivided into UV-A, 315–400 nm; UV-B, 280–315 nm; UV-C, 180–280 nm); visible light (400–700 nm) and infrared rays (IR 700–1100 nm). (Palmieri and Cacace, 2005). Pulsed light is produced using technologies that multiply power manifold. It is used for the rapid inactivation of microorganisms on food surfaces, equipment, and food packaging materials (Dunn et al., 1995). The effect on microorganisms is mostly due to the photochemical action of the ultra violet part of the light spectrum that causes thymine dimerization in the DNA chain preventing replication and ultimately leading to cell death (Gomez-Lopez et al., 2007).

Pulsed light is a modified and claimed improved version of delivering UV-C to bodies. The classical UV-C treatment works in a continuous mode, called continuous-wave (CW) UV light. Inactivation of microorganisms with CW-UV systems is achieved by using low-pressure mercury lamps designed to produce energy at 254 nm (monochromatic light), called germicidal light (Bintsiset al., 2000). More recently, medium-pressure UV lamps have been used because of their much higher germicidal UV power per unit length. Medium-pressure UV lamps emit a polychromatic output, including germicidal wavelengths from 200 to 300 nm (Bolton & Linden, 2003). PL treatment of foods has been approved by the FDA (1996) under the code 21CFR179.41 (Fig. 2.).

Generation of Pulsed Light

Light can be emitted from different sources by different mechanisms, due to the spontaneous transition of some atoms from an excited state to a condition of lower energy. Light can be delivered either continuously or in the form of pulses. (Palmieri and Cacace, 2005). Pulsed light works with Xenon lamps that can produce several flashes per second. During the pulse treatment the spectrum produced is 20000 times brighter than sunlight at the surface of the earth (Dunn et al., 1995). Electromagnetic energy is accumulated in a capacitor during fractions of a second and then released in the form of light within a short time (nanoseconds to milliseconds), resulting in an amplification of power with a minimum of additional energy consumption. As the current passes through the gas chamber of the lamp unit, a short, intense burst of light is emitted. The light produced by the lamp includes broad-spectrum wavelengths from UV to near infrared. The wavelength distribution ranges from 100 to 1,100 nm.

Merits and Demerits

Merits

The inactivation of microbes by PL is very fast process and cause rapid disinfection in a very short period. It is a green technology as the consumption of energy is very less during its application. It has been proven as a safe technology for living being and their environment without producing harmful residuals, chemicals and toxic by-products in the PL treated foods. It does not affect the nutritional and sensory quality of the products. The concerns of ionized radicals and radioactive by-products in foods by consumers are removed in PL due to its nonionizing spectrum (Dunn et al.1995).

Demerits

PL application in meat industry has some constraints as the low penetration power and chances of lipid oxidation (Fine &Gervais, 2004). To get the desired outcome, the packaging materials showing high penetration of PL should be used while treating the packed food by this method. The limited control of food heating still remains the main concern in PL technology. Sample heating is perhaps the most important limiting factor of PL for practical applications (Gomez-Lopez et al., 2007).

Irradiation

Irradiation is the process of applying low levels of radiation to any food material to sterilize or extend its shelf life. It is a physical method that involves exposing the prepackaged or bulk foodstuffs to gamma rays, x-rays, or electrons. Foods is generally irradiated with gamma radiation from a radioisotope source, or with electrons or x-rays generated using an electron accelerator (Barbosa-Canovas et al., 1998). These rays have high penetration power and thus can treat foods for the purpose of preservation and quality improvement. During exposure of food the amount of ionizing radiation absorbed is termed 'radiation absorbed dose' (rad) and is measured in units of rads or Grays. A strictly regulated process of dosimetry is used to measure the exact dose of radiation absorbed by the food. One Gray is equal to one joule of energy absorption per kilogram of a material. Irradiation has been approved for the microbial disinfestations of various food products in the US (USFDA, 1998). A number of countries worldwide have irradiated products in the markets. Irradiation has the potential to enhance food safety for fresh foods that will be consumed raw and for raw foods that require further processing. Food irradiation mainly is done by the radioactive element cobalt-60 as the source of high energy gamma rays. Gamma rays are electromagnetic waves or photons emitted from the nucleus of an atom. These gamma rays have energy to dislodge electrons from food molecules, and to convert them into ions which are electrically charged. However, the rays do not have enough energy to dislodge the neutrons in the nuclei of these molecules and hence they are not capable of inducing radioactivity in the treated food. The radiation dose varies depending on the thickness moisture, and characteristics of the foods. External factors, such as temperature, the presence or absence of oxygen, and subsequent storage conditions, also influence the effectiveness of radiation (Doyle, 1990).

Applications of Irradiation

In general, irradiation of food does not significantly affect the protein, lipid, and carbohydrate quality. Minerals are stable to food irradiation. The overall chemical changes in food due to irradiation are relatively minor and hence there is little change in the nutritional quality. Irradiation of moist food under frozen condition and in the absence of oxygen significantly decreases the overall chemical yields by about 80%; so the cumulative effects of irradiating to a dose of 50 kGy at −30°C is essentially equivalent to a dose of 10 kGy at room or chilled temperature. A dose of 1-10 kGy has can control food-borne parasites responsible for diseases such as trichinosis, A minimum dose of 0.15 kGy can prevent development of insects in dried fish. Irradiation is considered as a phytosanitary measure often obligatory if certain agricultural commodities are to be exported . The unique feature of radiation decontamination is that it can be performed in packaged foods even when the food is in a frozen state (Fig. 3.). Table I gives details of irradiation processes for seafoods.

Table 1: Radiation processes of seafoods (*Source:* Venugopal, Protech 2013-Pg28)

Treatment and storage temperature	**Radiation process**	**Benefits**
-10° to -20°C Packaged, frozen, ready-to-export fish can be treated before shipment. Frozen storage	Radicidation (Radiation hygienization) Dose required: 4-6 kGy Elimination of non-spore forming pathogens such as *Salmonella, Vibrio, Listeria* etc.	Improvement of hygienic quality of frozen, materials for export such as frozen shrimp, cuttlefish, squid, finfish, fillets, and IQF items.
15° to 30°C Ambient storage	Radiation disinfestation Dose required < 1 kGy Elimination of eggs and larvae of insects.	Dry products free from spoilage due to insects, from dried fishery products including fish meal and feed for aquaculture. Inactivation of *Salmonella* spp. and other pathogens
-1°to +3°C (Post-irradiation storage: under ice).	Radurization (Radiation pasteurization for shelf life extension) Dose: 1-3 kGy Reduction of initial microbial content by 1 to 2 log cycles. Specific reduction of spoilage causing organisms.	Extends chilled shelf life of fresh marine and freshwater fishery products two to three times. Additional benefit includes reduction of non-spore forming pathogens

Pulsed electric field

Pulsed electric field processing is a non-thermal food preservation technique used mainly for inactivation of microbes. PEF technology involves the application of short pulses of high voltage to liquid or semi-solid foods placed between two electrodes. Most PEF studies have focused on PEF treatments effects on the microbial inactivation in milk, milk products, egg products, juice and other liquid foods. The pulsed electric field induces poration of cell membranes and thereby the cell membranes of microorganisms, plant or animal tissue are permeable. This process of electroporation is suitable for use in a broad range of food processes and bioprocesses using low levels of energy. PEF technology has many advantageous in comparison to heat treatments, because it kills microorganisms and at the same time maintains the original color, flavor, texture, and nutritional value of the unprocessed food (Fig. 4.).

Pulsed Electric Field Preservation (*Source:* i3 foods)

Pulsed electric field can be applied in fishes fresh and frozen fish dried, brined or marinated fish. Mass transport processes, such as moisture transport and removal, are improved by the electroporation of fish tissue, resulting in enhanced drying, brining and marinating of fish. The required field strength for cell disintegration of fish is 1,0 – 3,0 kV/cm and the energy delivery is 3 – 10 kJ/kg The applied pulsed electric field leads to cell disintegration in tissue, enhancing product quality and production processes. It also helps in inactivation of parasites such as nematodes. PEF processing enhances mass transport, processes during extraction, pressing, drying, brining and marinating processes.PEF technology speeds up drying of food products, minimizing processing times and energy consumption. The process can be applied to fruits, vegetables, potatoes and meat. Enhancement of extraction processes is also an advantage of electroporation. Extraction and pressing yields are increased, for example for fruit juice, vegetable oil and algae oil and protein. PEF technology speeds up freezing of food products, allowing a reduction of processing times and energy consumption. The cell disintegration increases the freezing rates. Cellular water flows easily out of the cell and ice nucleation outside the cell starts. As smaller ice molecules are formed, product quality of frozen food is improved. (www. pulsemaster).

Fig. 1.High Pressure Processing Facility at ICAR-CIFT

A Research model 2 litre capacity High Pressure machine from M/s Stansted Fluid Power Ltd, United Kingdom at Central Institute of Fisheries Technology, Cochin.

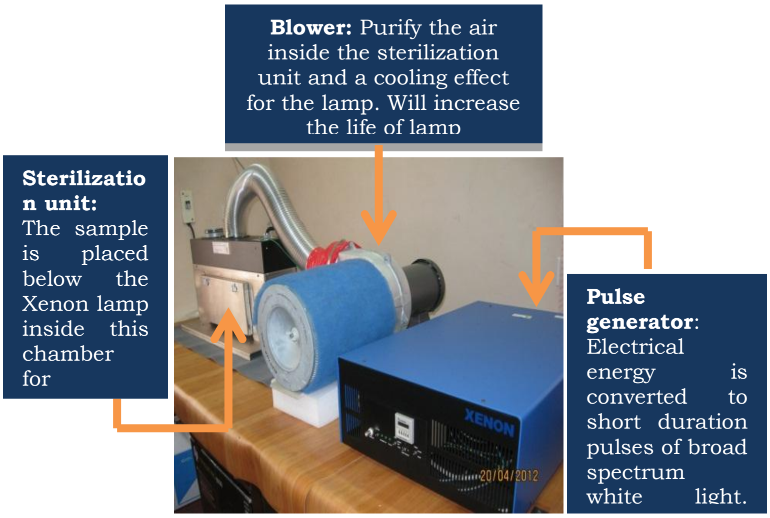

Fig.2 Pulse light equipment at CIFT

Fig.3 Applications of irradiation

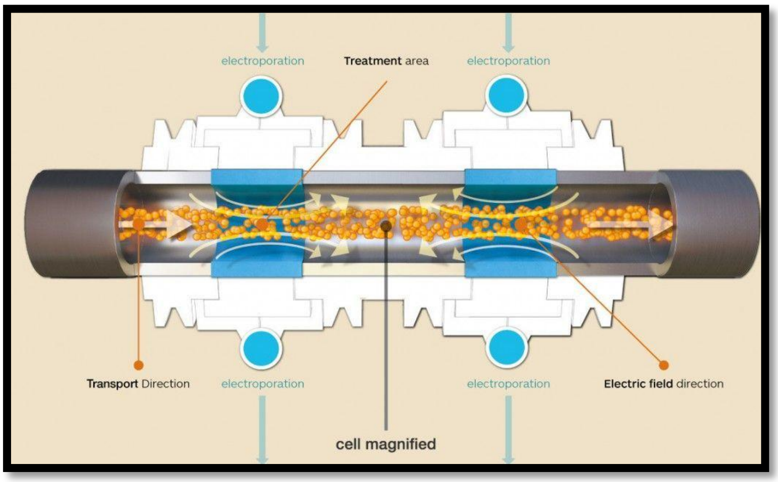

Fig.4 Pulsed electric field

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Chapter 15

Vacuum packaging & MAP

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There is ever increase in the demand for good quality food product with improved quality and shelf life. Over the years, packaging have brought out a revolution in the marketing and distribution of food products including fish. Among the food categories, seafood ranks 3rd with respect to consumption which explains the importance of fish. Fish is a vital source of food for people. It is the most important single source of high-quality protein, providing approximately 16% of the animal protein consumed by the world's population (Food and Agriculture Organisation (FAO), United Nations, 1997). By any measure, fishes are amoung the world's most important natural resources. Annual exploitation from wild populations exceeds 90 million tones, and total annual trade exceeds $ US 55 billion. Additionally, with over 25000 known species, the biodiversity and ecological roles of fish are being increasingly recognized in aquatic conservation, ecosystem management, restoration and aquatic environmental regulation.

Like any other food commodities, fish is one of the highly perishable items which undergoes spoilage if sufficient care is not taken. Various preservation methods have been in place to overcome the spoilage of fish. Chilling and refrigeration is the most preferred preservation method as it helps in preserving fresh like quality. Chilling or icing is reducing the temperature of fish so as to prolong the lag phase of bacteria and helps in reducing the spoilage rate. Fish being one of the most perishable foods, its freshness is rapidly lost even when stored under chilled conditions. Further, consumers demands to have fish in as fresh a state as possible so that the characteristics flavours are retained. Bulk transportation of fresh fish in ice has several limitations like limited extension of shelf life, unnecessary expenditure on freight due to ice, difficulty in handling and maintaining hygienic conditions due to leaching of ice melt water with leaching losses of soluble nutrients and flavouring compounds. Proper packaging will help in improving the keeping quality of fish. Packaging is an important aspect for improving the shelf life and marketability. Packaging enhances the consumer acceptability and hence saleability of the product. Traditionally, food packaging is meant for protection, communication, convenience and containment. The package is used to protect the product from the deteriorative effects of the external environmental conditionals like heat, light, presence or absence of moisture, pressure, microorganisms, and gaseous emissions and so on. Packaging is an integral part of the food processing and plays an important role in preventing or reducing the generation of waste in the supply of food. Packaging assists the preservation of the world's resources through the prevention of product spoilage and wastage, and by protecting products until they have performed their function. Basic requirements of a package are good marketing properties, reasonable price, technical feasibility, utility for food contact, low environmental stress, and suitability for recycling. Simply packing fish is suitable packaging material will enhance the shelf life of chilled and refrigerated fish to 7 to 15 days depending on fish species. However, in the normal packaging the spoilage process will be accelerated due to presence of O_2 in the normal air packing. Alteration in the package atmosphere will help in overcoming the problem of shelf life, which can be achieved by vacuum packaging or modified atmosphere packaging.

Vacuum Packaging

Important properties by which consumers judge fish and shell fish products are appearance, texture and flavour. Appearance, specifically colour, is an important quality attribute influencing the consumer's decision to purchase. In fresh red meat fishes, myoglobin can exist in one of three chemical forms. Deoxymyoglobin, which is purple, is rapidly oxygenated to cherry red oxymyoglobin on exposure to air. Over time, oxymyoglobin is oxidised to metmyoglobin which results in a brown discoloration associated with a lack of freshness. Low oxygen concentrations favour oxidation of oxymyoglobin to metmyoglobin. Therefore, in order to minimize metmyoglobin formation in fresh red meats, oxygen must be excluded from the packaging environment to below 0.05% or present at saturating levels. Lipid oxidation is another major quality deteriorative process in muscle foods resulting in a variety of breakdown products which produce undesirable off-odours and flavours. Hence O_2 may cause off-flavours (e.g. rancidity as a result of lipid oxidation), colour changes (e.g. discolouration of pigments such as carotenoids, oxidation), nutrient losses (e.g. oxidation of vitamin E, β-carotene, ascorbic acid) and accelerates microbial spoilage thereby causing significant reduction in the shelf life of foods. Therefore, control of oxygen levels in food package is important to limit the rate of such deteriorative and spoilage reactions in foods. Oxygen level in the package can be controlled by using the vacuum packaging technique in which, the air present in the pack is completely evacuated by applying vacuum and then package is sealed. Vacuum packaging, which is also referred as skin packaging involves removal of air inside the pack completely and maintaining food material under vacuum conditions, so that oxygen available for the growth of microbes and oxidation will be limited. This will help in doubling the shelf life of fish under chilled conditions. This technique is particularly useful in fatty fishes, where the development of undesirable odour due to the oxidation of fat is the major problem. Vacuum packaging for chilled and refrigerated fishes doubles the shelf life compared to normal air packaging. Application of this to frozen fishes is also commonly followed as it helps in reducing problem of freezer burn. This technique can be applied to fresh meat and fishes, processed meat and fishes, cheese, coffee, cut vegetables etc. One of the important aspect in the vacuum packaging is the use of packaging material with good barrier properties. Normally polyester-polyethylene or nylon-polyethylene laminates are used. Polyester and nylon provides good strength and acts as good barrier to oxygen. Polyethylene proves good heat sealing property and is resistant to water transmission. Typical vacuum packaging machine and vacuum packed fish is shown in Fig 1.

Fig 1. Vacuum packaging machine and Vacuum packed fish

Advantages of Vacuum packaging

- Reduces fat oxidation
- Reduces growth of aerobic microorganisms
- Reduces evaporation
- Reduces weight loss
- Reduces dryness of product

- Reduces freezer burn
- Reduces volume for bulk packs Eg. Tea powder, dry leaves etc
- Extends the shelf life
- Easy to use and maintain the equipment

Disadvantages of Vacuum packaging

- Cannot be used for crispy products and products with sharp edges
- Requires high barrier packaging material to maintain vacuum
- Creates anaerobic condition, which may trigger the growth and toxin production of *Clostridium botulinum* and the growth of *Listeria monocytogenes.* Additional barriers / hurdles are needed to control these microorganisms
- Capital intensive

Alternative to vacuum packaging, reduced oxygen level in the package can be achieved by using active packaging system like oxygen scavenger. Use of oxygen scavenger is very effective in reducing the oxygen level to <0.01% within 24 h, which helps in preserving the quality of food. This is not capital intensive and can be applied to any products including crispy and products with sharp edges.

Modified Atmosphere Packaging (MAP)

Marketing of modified atmosphere packaged (MAP) foods have increased, as food manufacturers have attempted to meet consumer demands for fresh, refrigerated foods with extended shelf-life. It is also used widely, as a supplement to ice or refrigeration to delay spoilage and extend the shelf life of fresh fishery products while maintaining a high-quality end product. A modified atmosphere can be defined as one that is created by altering the normal composition of air (78% nitrogen, 21% oxygen, 0.03% carbon dioxide and traces of noble gases) to provide an optimum atmosphere for increasing the storage length and quality of food/produce. Oxygen, CO_2, and N_2, are most often used in MAP. Other gases such as, nitrous and nitric oxides, sulphur dioxide, ethylene, chlorine, as well as ozone and propylene oxide have been suggested for a variety of products and investigated experimentally. However, due to safety, regulatory and cost considerations, they have not been applied commercially. These gases are combined in three ways for use in modified atmospheres: inert blanketing using N_2, semi-reactive blanketing using

$CO_2 : N_2$ or $O_2 : CO_2 : N_2$ or fully reactive blanketing using CO_2 or $CO_2 : O_2$. Typical MAP machine and gas composition analyser is given in Fig 2.

Development of modified atmosphere packaging

Kolbe was the first to investigate and discover the preservative effect of carbon dioxide on meat in 18th century and Coyne was the first to apply modified atmospheres to fishery products as early as 1930's. Modified atmosphere packaging (MAP) is the removal and/or replacement of the atmosphere surrounding the product before sealing in vapor-barrier materials. While technically different many forms of map are also case ready packaging, where meat is cut and packaged at a centralized location for transport to and display at a retail store. Most of the shelf life properties of meat are extended by use of map, but anoxic forms of MAP without carbon monoxide do not provide bloomed red meat color and MAP without oxygen may promote oxidation of lipids and pigments. Advances in plastic materials and equipment have propelled advances in MAP, but other technological and logistical considerations are needed for successful MAP systems for raw chilled fresh meat

Principle of MAP

The principle of MAP is the replacement of air in the package with a different fixed gas mixture. CO_2 is the most important gas used in MAP of fish, because of its bacteriostatic and fungistatic properties. It inhibits growth of many spoilage bacteria and the inhibition is increased with increased CO_2-concentration in the atmosphere and reduced temperature. CO_2 is highly soluble in water and fat, and the solubility increases greatly with decreased temperature. The solubility in water at 0 °C and 1 atmosphere is 3.38 g CO_2/kg water, however, at 20 °C the solubility is reduced to 1.73 g CO_2/kg water. Therefore, the effectiveness of the gas is always conditioned by the storage temperature with increased inhibition of bacterial growth as temperature is decreased. The solubility of CO_2 leads to dissolved CO_2 in the food product, according to the following equation:

$$CO_2\,(g) + H_2O\,(l) \longleftrightarrow HCO_3^- + H^+ \longleftrightarrow CO_3^{2-} + 2H^+$$

For pH values less than 8, typical of seafood, the concentration of carbonate ions may be neglected.

$$CO_2 + H_2O \quad H_2CO_3 \longleftrightarrow HCO_3^- \longleftrightarrow H^+$$

According to Henry's law, the concentration of CO_2 in the food is dependent on the water and fat content of the product, and on the partial pressure of CO_2 in the atmosphere. The growth inhibition of microorganisms in MA is determined by the concentration of dissolved CO_2 in the product. The preservation effect of MAP is due to the drop in surface pH in MA products because of the acidic effect of dissolved CO_2, but this could not entirely explain all of CO_2's bacteriostatic effect. The possibility of intracellular accumulation of CO_2 would upset the normal physiological equilibrium by slowing down enzymatic processes. Thus, the effect of CO_2 on bacterial growth is complex and four mechanisms of CO_2 on micro-organisms has been identified:

1. Alteration of cell membrane functions including effects on nutrient uptake and absorption
2. Direct inhibition of enzymes or decrease in the rate of enzyme reactions
3. Penetration of bacterial membranes, leading to intracellular pH changes
4. Direct changes in the physico-chemical properties of proteins.

Probably a combination of all these activities account for the bacteriostatic effect. A certain amount (depending on the foodstuff) of CO_2 has to dissolve into the product to inhibit bacterial growth. The ratio between the volume of gas and volume of food product (G/P ratio) should be usually 2 : 1 or 3 : 1 (gas : food product). This high G/P ratio is also necessary to prevent package collapse because of the CO_2 solubility in wet foods. The CO_2 solubility could also alter the food-water holding capacity and thus increase drip.

The major function of carbon dioxide in MAP is to inhibit growth of spoilage microbes. Carbon dioxide (CO_2) is soluble in both water and lipid it has a bacteriostatic and fungistatic properties. Carbon dioxide lowers the intra and extra cellular pH of tissue including that of microorganisms. It affects the membrane potential and influence the equilibrium of decarboxylating enzymes of microorganisms. CO_2 increases the lag phase and a slower rate of growth of microbes during logarithmic phase. This bacteriostatic effect is influenced by the concentration of CO_2, the partial pressure of CO_2, volume of headspace gas, the type of micro organism, the age and load of the initial bacterial population, the microbial growth phase, the growth medium used, the storage temperature, acidity, water activity, and the type of the product being packaged. Pathogens like *Clostridium perfringens* and *Clostridium botulinum* are not affected by the presence of carbon dioxide and their growth is encouraged by anaerobic conditions. In general, carbon dioxide is most effective in foods where the normal spoilage organisms consist of aerobic, gramnegative psychrotropicbacteria. The CO_2 is flushed into the modified atmosphere package by evacuating the air and flushing the appropriate gas mixture into the package prior to sealing. Another method to create a modified atmosphere for a product is either to generate the CO_2 and/or remove O_2 inside the package after packaging or to dissolve the CO_2 into the product prior to packaging. Both methods can give appropriate packages with smaller gas/product ratio to the package. The solubility of CO_2 decreases with increasing temperature, hence MAP products should be stored at lower temperatures to get the maximum antimicrobial effect. Also the temperature fluctuations will usually eliminate the beneficial effects of CO_2. The rate of absorption of CO_2 depends on the moisture and fat content of the product. If product absorbs excess CO_2, the total volume inside the package will be reduced, giving a vacuum package look known as “pack collapse”. Excess CO_2 absorption along with “pack collapse” results in the reduction of water holding capacity and further drip loss to the products.

The major function of oxygen is to avoid anaerobic condition which favours the growth and toxin production of *C botulinum* and growth of *L monocytogenes*. Oxygen in the MAP is also useful to maintain the muscle pigment myoglobin in its oxygenated form, oxymyoglobin. In fresh red meats, myoglobin can exist in one of three chemical forms. Deoxymyoglobin, which is purple, is rapidly oxygenated to cherry red oxymyoglobin on exposure to air. Over time, oxymyoglobin is oxidised to metmyoglobin which results in a brown discoloration associated with a lack of freshness. Low oxygen concentrations favour oxidation of oxymyoglobin to metmyoglobin. Therefore, in order to minimize metmyoglobin formation in fresh red meats, oxygen must be excluded from the packaging environment to below 0.05% or present at saturating levels. High oxygen levels within MAP also promote oxidation of muscle lipids over time with deleterious effect on fresh meat colour. O_2 in MA-packages of fresh fish will also inhibit reduction of TMAO to TMA.

Nitrogen (N_2) is an inert and tasteless gas, and is mostly used as a filler gas in MAP, either to reduce the proportions of the other gases or to maintain pack shape by preventing packaging collapse due to dissolution of CO_2 into the product. Nitrogenis used to prevent package collapse because of its low solubility in water and fat. Nitrogen is used to replace O_2 in packages to delay oxidative rancidity and to inhibit the growth of aerobic microorganisms. The exact combination to be sued depends on many factors such as the type of the product, packaging materials and storage temperature. The gas ratio normally used are 60% CO_2 and 40%

N_2, for fatty fishes and 40% CO_2, 30% O_2 and 30% N_2 for lean variety fishes. Shelf life of different fishes packed under vacuum and MAP at different storage conditions are given in Table 1.

Advantages of MAP

- The natural colour of the product is preserved
- The product retains its form and texture
- Reduces the growth of microogranisms
- Product retains its vitamins, taste and reduces fat oxidation
- The need to use preserving agents is reduced
- Helps in marketing products to distant locations
- Improved presentation –clear view of product
- Hygienic stackable pack, sealed and free from product drip
- Longer durability of perishable food / decrease of spoilage
- Extends the shelf life of fish in chilled / refrigerated storage by 2 – 3 times
- Helps in reducing post-harvest loss

Disadvantages of MAP

- Capital intensive due to high cost of machinery
- Cost of gases and packaging materials
- Additional cost of gas analyser to ensure adequate gas composition
- No control over the gas composition after packing
- Increase of pack volume which will adversely affect transportation cost and retail display space
- Benefits of MAP are lost once the pack is opened or leaks
- High concentration of CO_2 may favour anaerobiosis
- Strict maintenance of temperature has to be ensured to avoid the risks of *C botulinum* and *L monocytogenes.*

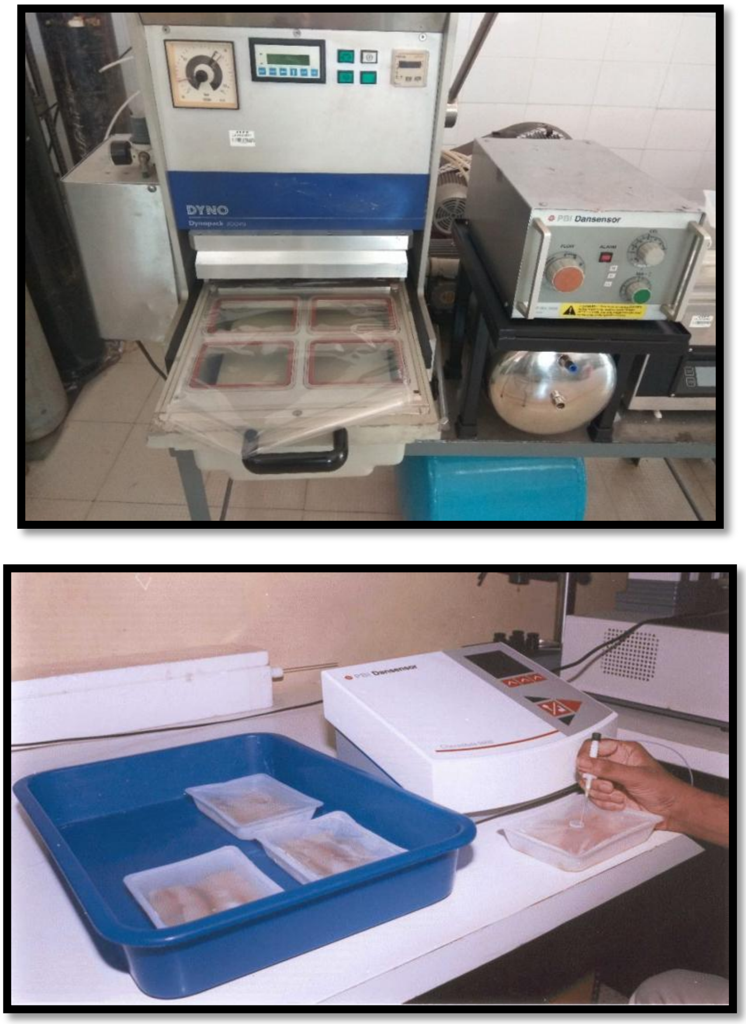

Fig 2. Modified Atmosphere packaging equipment and Gas composition analyser

Table 1. Shelf life of fishery products in air, vacuum and modified atmosphere packs

Type of fish	Storage temp (^0C)	Atmosphere $CO_2 : N_2 : O_2$	Shelf life (Days)
Catfish (ns) fillets	4	Air	13
	4	75 : 25 : 0	38–40
	4	Vacuum	20–24
Cod (*Gadus morhua*) fillets	1	Air	9
	1	60 : 40 : 0	12
Cod (*G. morhua*) fillets	2	40 : 60 : 0	11
	2	40 : 40 : 20	13
Cod (ns) fillets	4	Air	20–24
	4	75 : 25 : 0	55–60
	4	Vacuum	24–27
Cod (ns) fillets	0	40 : 30 : 30	12.5
	0	Vacuum	9
Cod (*G. morhua*) whole	2	100 : 0 : 0	10
	2	60 : 40 : 0	10
	2	40 : 60 : 0	9–10
	2	Vacuum	8–9
	2	Air	~7
Cod (*G. morhua*) whole/fillets	0	Air	12–13
	0	25 : 75 : 0	20
Cod (*G. morhua*) fillets	4	100 : 0 : 0	40–53
Cod, blue (*Arapercis colias*)	3	100 : 0 : 0	49
	3	Vacuum	14
	3	Air	14
Haddock (*Melanogrammus aeglefinus*) whole	0	40 : 30 : 30	10
	0	Air	8
Haddock (*M. aeglefinus*) fillets	0	60 : 20 : 20	14
	0	Air	10
Herring (*Clupea harengus*) whole and fillets	0	60 : 40 : 0	14
	0	Air	12
Salmon (ns) fillets	4	Air	24–27
	4	75 : 25 : 0	55–62
	4	Vacuum	34–38
Snapper (*Chrysophrys auratus*) fillets	-1	Air	9
	-1	40 : 60 : 0	9
	-1	100 : 0 : 0	18

Chapter 16

Seafood packaging

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Food packaging

Food packaging is an external means of preservation of food during storage, transportation and distribution and has to be provided at the production center. It forms an integral part of the production process and has an important function in the distribution of food. In today's consumer oriented market, a package is an extremely vital link between the manufacturer of the product and the ultimate user. There is great awareness among the consumers today regarding their right to obtain proper quality and correct quantity of the product at a fair price in an aesthetic and hygienic package. Hence the basic function of food packaging is to protect the product from physical damage and contaminants, to delay microbial spoilage, to allow greater handling and to improve the presentation.

Need for packaging of fish and fishery products

Fish is a highly perishable food item and should be handled at all times with great care, in such a way so as to inhibit the growth of microorganisms. Fish is having a unique biochemical composition and its quality deteriorates rapidly and the potential shelf life is reduced if they are not handled and stored properly. The quality and type of packaging materials and the methods of packaging and storage are, therefore, of great importance for preserving the quality of fish. Fish and fish products can generally be grouped into fresh fish, frozen fish, thermally processed fish, dried fish and other value added fishery products. Each category requires special requirements for packaging and storage and hence different packaging materials.

Fresh fish packaging

More than 20% of the fresh fish caught in many tropical areas is wasted due to poor handling and lack of proper packaging and transportation facilities. Fish after catch will remain fresh only for a limited period, 4-6 hours, depending on the environmental conditions and the intrinsic nature of the fish. The fish landing centers are far away from places where fish is processed or marketed and, therefore, they have to be transported over long distances. Fish must be cooled immediately after landing to prevent microbial deterioration. It is reported that the rate of spoilage doubles with every 5.5°C rise in temperature. Chilling by mixing fish with ice is the cheapest and most efficient method of preservation of fresh fish. The most effective way in which the temperature of wet fish is kept down at the required level is by mixing it with ice. Therefore, the design and material of the container used for transporting fish should have insulating properties to reduce, as much as possible, the rate of melting of ice. In addition, the other requirements of a suitable fresh fish package are to: reduce dehydration, reducefat oxidation, provide for less bacterial and chemical spoilage and be capable of being washed reasonably, free of bacteria, eliminate drip and prevent odour permeation.

Bulk fish packaging

Fish sold immediately in local markets may not need any special packaging, but a proper packaging to ensure better shelf life becomes essential when it has to be transported to distant localities.For bulk fresh fish packaging, following are the requirements:

- The container should be sturdy
- Shall be of light weight, hygienic and easy to clean
- Shall possess good insulation properties
- Should have good barrier properties

Double walled insulated moulded plastic containers, made of High density polyethylene (HDPE) or polypropylene (PP) with polyurethane insulation sandwiched between the inner and outer walls are suitable. They are durable, lighter in weight, and in normal use have a life span of over 5 years. These containers are hygienic and easily washable and provide good insulation. The other types of packages used for fresh fish transportation is the moulded container made from expanded polystyrene. Such boxes are very light in weight, provide very good insulating properties and can be cleaned easily by washing.

Retail packaging of fresh fish

The retail packaging of fresh fish in convenient forms is gaining popularity and the retail pack must be clean, crisp and clear and make the contents appear attractive to the consumer. The most popular form of package for fresh fish is a shallow tray of moulded pulp, foam polystyrene or clear polystyrene, which is over-wrapped with a plastic film which may be printed or over which a pressure sensitive label is applied. Generally food-grade Poly Vinyl Chloride (PVC) films are used as overwraps.

Packaging of frozen products

Raw frozen fishery products

Frozen raw fish and cooked shrimps constitute the major chunk of seafood products for export market. Frozen products are of two types in general – Block frozen and Individually Quick Frozen (IQF).

In case of Block frozen products, the fishery products are frozen with adequate glaze water and the frozen block is once again glazed in ice-cold water before final packing. The principal considerations in packaging requirement are adequate strength to withstand handling stress and strain and resistance to moisture. Fishes are frozen as blocks, packed in duplex board carton lined with low density polythene (LDPE) and such cartons are packed in a master carton made of 5 or 7 ply corrugated fiber board boxes.

Shrimps in various styles are generally processed in Individually Quick Frozen (IQF) form. The other major IQF products are cooked whole lobster, lobster tail, lobster meat, cuttle fish fillets, boiled clam meat and fish fillets from white lean fishes. The packaging requirements of IQF products vary considerably from those of block frozen products as they are in consumer packs. The risk of moisture loss or oxidative reaction leading to flavour changes etc. are moresince each product in an IQF pack is remaining as a discrete piece. Some of the essential characteristics desired out of a packaging material for IQF shrimp are:

- Low water vapour transmission rate (WVTR) to reduce the risk of dehydration.
- Low oxygen/gas permeability (OTR/GTR), thereby reducing the risk of oxidation and thus changes in odour and flavour, and retention of volatile flavours.
- Flexibility to fix the contours of the product.
- Resistance to puncture, brittleness and deterioration at low temperature.
- Ease of filling, packing and sealing.

Monofilm, co-extruded film or laminated pouches of different capacities varying from 500 g to 4 kg per pack are generally used. The unit pouches may be provided with unit/intermediate cartons or directly packed in master cartons. The unit / intermediate cartons are made of duplex or 3 ply corrugated fiberboard. The most functionally effective film has been identified as 10 microns Biaxially oriented Polypropylene (BOPP). Cartons made of 5 or 7 ply corrugated fiberboard having minimum compression strength of 500 kg can be safely used as master carton for IQF products.

Battered and breaded fishery products

Battered and breaded products are an important class of value added products having great demand in the export and internal markets. The battering and breading process increase the bulk of the product and a number of products can be prepared from fish minced meat, shrimp, squids, cuttle fish etc. Battered and Breaded products in convenience form include battered and breaded peeled shrimp, fantail (butterfly), shrimp round tail-on, squid rings, stuffed squid rings, stuffed squid, fish fillets, fish fingers, fish cutlets and fish patties. The changes taking place during frozen storage of the value added products are desiccation, discoloration, development of rancidity etc. Application of proper packaging prevents or retards these changes and enhances shelf life. Thermoformed containers are commonly used for the packaging since conventional packaging materials alone are not suitable for these products. Thermoformed containers provide mechanical protection to the products and as a result the products do not get damaged or broken during handling and transportation. Thermoformed trays produced from food grade materials are suitable for the packaging. Generally trays made of materials like PVC, HIPS(High Impact Polystyrene) and HDPE are unaffected by low temperature of frozen storage and provide protection to the contents.

Packaging of dried fishery products

A large chunk of fish catch is salted and dried for internal consumption. Dried fish is highly hygroscopic in nature and absorbs moisture when the climate is humid. When it comes in contact with air or oxygen, the deterioration due to oxidation is rapid. Dried fish is also prone to attack by insects. The most important requirements for a dried fish/product package are inertness, leak-proofness, impermeability to oxygen and moisture and less transparency. Resistance to mechanical abrasion and puncture is also required.

For bulk packaging

The packaging employed for internal distribution is baskets improvised with braided coconut leaves or palmsheaths. An overwrap with gunny fabric is given as reinforcement in the case of products meant for export and those which have to be transported over long distances. These packages are however prone to easy entry of insects, rodents and other pests. The product being highly sensitive to changes in relative humidity, the packaging has to be sufficiently water vapour proof.Among different packaging materials studied for bulk packaging of dried fish, high density polyethylene (HDPE) woven gusseted bags laminated with 100 gauge low density polythene (LDPE) are found quite suitable.

For consumer packs

The commonly used packaging materials for consumer packs of dry fish are low-density polythene or polypropylene. These materials are cheap, readily available and have good tearing and bursting strength. Disadvantages are high water vapour and gas transmission rate, proneness to puncture or damage from sharp spines and smell coming out. Shelf life is limited. The use of Polyester-Polyethylene laminated pouches for consumer packs is considered as a suitable alternative.

Packaging of thermally processed fishery products

Thermal processing is one of the most widely used methods for fish preservation which facilitates long-term stability for a wide range of seafood products. In thermal processing, food is preserved in hermeticallysealed containers, subjected to very high temperatures and pressure and the processed product is stored at ambient temperatures.

Cans

Cans are generally used for the packaging and processing of heat sterilized products. Today there are several choices available like standard tin plates, light weight tin plate, double reduced tin plate, tin free steel (TFS cans) and vacuum deposited aluminium on steel and polymer coated tin free steel cans. For fishery products they are coated inside to get desirable properties like acid resistance and sulphur resistance. But care has to be taken to avoid tainting of the lacquer. Metal cans are advantageous as packages because of superior strength, high speed manufacturing and easy filling and dosing. Disadvantages of metal cans are weight, difficulty in reclosing and disposal.

Retort pouches

Retort pouches are the flexible laminated packaging materials required for thermal processing of fishery products. The three or four layer retort pouches consist of an outer polyester layer, a middle aluminum layer and an inner cast polypropylene layer. Nylon is also added as an additional layer or is substituted for the aluminum layer to give additional strength in a four layer pouch. Aluminium foil is the barrier layer which gives the product a longer shelf life. Polypropylene has a high melting point of about 138°C and is used as the inner layer to provide critical seal integrity, flexibility, and strength. It also provides flavor locking properties, making it compatible for a wide range of products. The different layers are held together with adhesives which are usually modified polyolefins such as Ethylene Vinyl Acetate (EVA).

Packaging for other seafood products

Surimi

Surimi is mechanically deboned fish mince that has been washed, refined and mixed with cryoprotectants for frozen storage. It is generally frozen as rectangular blocks and is an intermediate product or raw material for processing several value added products like shrimp and crab analogues and a variety of other products. In order to prevent deterioration during storage like oxidative rancidity and desiccation, the packaging materials used have low water vapour permeability and low permeability to gases and odours. The packaging materials employed should be sufficiently strong and durable to withstand stress during handling, storage and distribution. Packaging employed for block frozen fish and shrimp are considered safe for surimi.

Fish sausage

Fish sausage is a product for which surimi is the base material, which is homogenised after mixing with several other ingredients. The homogenised mass is stuffed in synthetic casings like Ryphan (Rubber hydrochloride) or Kurehalon (Vinylidene chloride). The casing is closed using metal rings after which it is heated in water at 85-90°C and then slowly cooled. After drying the surface the sausage is wrapped in cellophane laminated with polythene. Fish sausage is kept at refrigerator temperatures for retail marketing but kept frozen for prolonged storage. Duplex cartons lined with a plastic film are ideal for short-term storage, for prolonged storage, packaging suggested for block frozen fish and shrimp is suitable.

Fish curry

Fish curry is a processed product presented in a ‘ready to serve’ style. It can be preserved both by freezing and by heat processing. For frozen stored curry, the common problems met with are discoloration, desiccation and rancidity. Thermoformed trays made of food grade polystyrene or polyvinyl chloride is an ideal packaging for frozen fish curry.For thermally processed fish curry, retortable flexible pouches are identified as the ideal choice of package as they offer advantage of low cost, boil-in-bag facility, ease of opening and reduced weight. The suitable flexible laminate is Polyester/Aluminium foil/Cast Polypropylene.

Fish pickles

Conventionally glass bottles are used as containers, which offer properties like inertness, non-toxicity, durability, non-permeability to gases, moisture etc. But they are heavy, prone to break, voluminous and expensive. New flexible packaging materials developed for fish pickle is based on polyester laminated with LDPE-HDPE co-extruded film or Nylon/Surlyn or LD/BA/Nylon/BA/Primacore. These are inert to the product, can be attractively fabricated as stand up packs and can be printed on the reverse side of the polyester film. For dry fish pickles the packaging material which offers safe storage of the product up to 14 months at ambient temperature has been identified as nylon/surlyn or LD/BA/nylon/BA/primacore.

Fish soup powder, Fish Protein/Hydrolysate powders

Such powdered products are hygroscopic and hence the selection of the package assumes great significance. Appropriate package developed for such products are 12 micron plain polyester laminated with LDPE-HDPE co-extruded film or 90-100 micron LD/BA/Nylon/BA/Primacore multilayer film which ensures a safe storage.

Accelerated freeze dried (AFD) products

These are practically devoid of moisture, its percentage generally being below 2. The products are very fragile and can easily undergo chemical reactions with air leading to oxidation, deterioration of colour, absorption of water etc. They are generally packed under an inert gas to exclude air and oxygen. Hence the main requirements in the packaging employed are low oxygen and water vapour transmission to protect the product from rancidity and absorption of moisture and sufficient mechanical strength to protect from shock. Paper/Aluminium foil/Polythene laminates or metallised Polyester-Polythene laminated pouches are recommended for accelerated freeze dried products.

Extruded products

The moisture content of extruded snack is very low, and any increase due to the hygroscopic nature of the product may lead to loss of crispness of the product. Moisture also accelerates other biochemical changes such as oxidative rancidity. Oxygen inside the package is replaced by an inert gas like nitrogen. Low water vapour and gas permeability of the package is, therefore, a very critical requirement. Also the packaging material must be physically strong enough to withstand the processes of vacuuming/gas flushing. Considering these facts, Metalized Polyester-Polyethylene laminated pouches are used for the packaging of extruded snacks.

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Chapter 17

Utilization of shellfish processing discards

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The commercial aquaculture for crustaceans in India has become a huge success due to the introduction of new species, the improved hatchery production of seeds, scientific management of culture practices and the availability of good quality feed and other input. Introduction of new species like Letopenaeus vennamei has resulted in increased yield and productivity. The farming of this species has already been established in coastal Andhra Pradesh, Karnataka and Tamil Nadu and gaining momentum in Kerala and other states.

Similarly, farmers in both coastal and land locked States have gone for large scale farming of Giant Freshwater Prawn (Macrobrachium rosenbergii) popularly called "Scampi" which is having high demand in both domestic and international markets. In order to meet the raw material requirement of large number of processing units established for export and also to meet the domestic demand. The state of Andhra Pradesh accounts for more than 50 per cent of the cultured Scampi production and also in terms of area under culture. During the year 2013-14 the estimated production of L. vannamei was 406018 tons whereas the black tiger export of cultured prawn from the country was to the tune of 41947 tons and that of scampi, it was 1401 tons (MPEDA 2008).

Industrial processing of prawn results in huge quantities of waste in the form of head and shell. Since the exported shrimp products are mainly of peeled items, the shell waste produced is quite high. The head and shell constitute nearly 60% by weight of the whole prawn depending on the species and size of the prawn. In India its availability is estimated to be 100,000 tonnes annually and it is the single largest fishery waste of the country. Crab shell and squilla are other important raw materials available from marine sector.

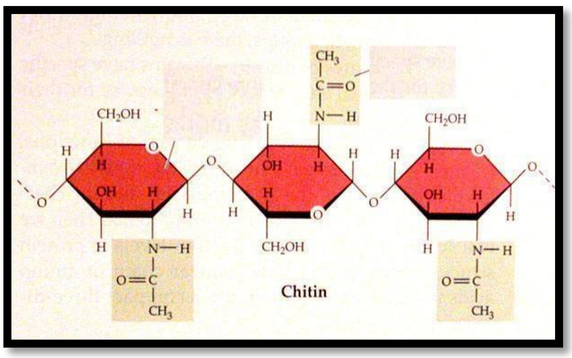
Proximate composition

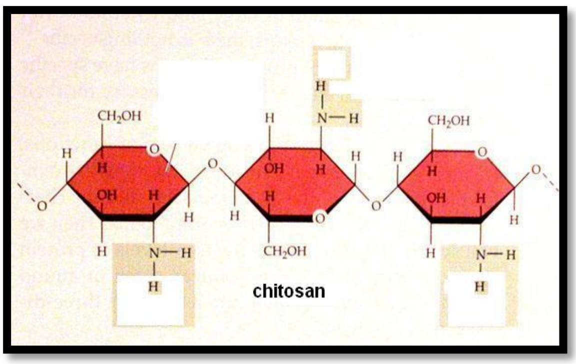
Characteristic	Prawn waste	Squilla	Crab shell
Moisture %	75-80	60-70	60-65
Ash (% dry weight basis)	30-35	33-37	45-50
Protein (% dry weight basis)	35-40	40-45	30-35
Chitin (% dry weight basis)	15-20	12-16	13-15
Fat (% dry weight basis)	3-5	2-3	1-1.5

The investigations carried out at the Central Institute of Fisheries Technology, Cochin, paved the way for production of valuable food and industrial products namely protein extract, chitin and its derivatives chitosan and glucosamine hydrochloride from the head and shell waste of prawns, crab and squilla.

Chitin (anhydro- N-acetyl- D-glucosamine (N-acetyl 2- amino 2- deoxy D-glucose) is the second most ubiquitous natural polysaccharide after cellulose on earth. It is estimated that chitin is produced annually almost as much as cellulose. Chitin is a white hard, inelastic, nitrogenous polysaccharide found in the exoskeleton as well as in the internal structure of invertebrates. The monomer units are linked by β (1-4) glycosidic bonds as in cellulose. It is insoluble in water and most organic solvents. It is the most important organic constituent of the exoskeleton of arthropods. The tough and resilient property of chitin is utilized by the living organism as skeletal support and body armor against attack by other marine animals.

The waste of these natural polymers is a major source of surface pollution in coastal areas. Chitin is considered as under utlised resource which has got high potential in new functional biomaterial in various fields. The most important economical source of this material is the shrimp processing industry. Apart from shrimp, the shells of lobster, crab, squilla and squid pens also provide chitin in large quantities. Deacetylation of chitin gives chitosan, a high molecular weight linear polymer of amino-D-glucose.





Production process for chitin and chitosan

Chitin is present in the shells of shrimp or crab or squilla as chitin protein complex along with minerals mainly calcium carbonate. The process for chitin production comprises demineralisation and deproteinisation to isolate chitin. In commercial production demineralisation is done by dilute hydrochloric acid and deproteinisation by dilute aqueous sodium hydroxide. The chitin thus isolated is deacetylated using con.aqueous caustic soda for production of chitosan.

Raw materials

The wet fresh head and body peelings of prawn collected from the peeling centers, crab shell from the processing plants and squilla caught along with prawns can be used either directly immediately on arrival at the plant or can be dried and stored and can be used when required as per the production programme. Shell can be collected from distant centers in the dry form in which case transportation is comparatively easy and economical. Care should be taken to see that the shell should not contain sand and extraneous matter to any significant level.

Selection of raw material

If production of shrimp protein extract is envisaged during the production of chitosan more care has to be taken in the selection of raw material. Only fresh prawn waste can be used for the extraction of protein. It should be iced and hygienically stored and transported. Commercial dry shell gives only very dark coloured protein paste. Moreover, cleaning of the shell is not practical as it normally contains objectionable foreign matters. But, if chitin/chitosan alone is the desired end product dry commercial shell can be used as the starting material.

Production process

The process involves two important stages. (1) Isolation of chitin from shell (2) Conversion of chitin to chitosan.

Isolation of chitin

Chitin is isolated from the shell by demineralisation followed by deproteinisation. If extraction of protein is envisaged for production of shrimp extract only hygienically collected fresh prawn shell has to be taken for processing. The fresh shell has to be treated first with 0.5% dilute aqueous caustic soda and the alkaline protein solution is drained out and kept separately for neutralization, concentration and drying. The residual shell is then deproteinised followed by demineralisation.

Demineralisation

Demineralisation is the process by which the minerals are removed from the shell. If recovery of the protein is not envisaged the wet or dried shells can be directly treated with dilute commercial hydrochloric acid at concentration around 1.25 N at room temperature. The demineraliser is an open cylindrical tank of size 2 m x 1.5 m made of S.S. or M.S. or brick masonry lined inside and outside with fiber glass having perforated false bottom made of S.S wire mesh with 3 mm mesh size and with sufficient reinforcement at the lower end of the cylindrical portion. The vessel is fitted with a propeller agitator of 60 rpm and 80 cm sweep driven by a 5 HP electric motor from the top for gentle agitation of the mass to facilitate the reaction and to avoid floating of the shell. The vessel is so installed that the acidic effluent can be drained by gravity to the fiber glass lined collection tank constructed in brick masonry by the side of the demineraliser. The demineraliser is to be housed in a well-ventilated place with suitable exhaust facility to remove the acid fumes as well as the carbon dioxide coming out during demineralisation of the shell. Demineralisation is an important step in the production of chitin and chitosan. The degree of demineralisation determines to a great extent the characteristics of chitosan.

Deproteinisation

The deproteinisation is the process by which the protein is removed from the chitin protein complex. The shell after demineralisation and washing free of acid is shifted to the deproteiniser where it is treated with 5% aqueous caustic soda at 70-80^{0}C with continuous stirring at an rpm of around 100 using propeller type stirrer for about 30 minutes in a false bottomed steam jacketed open cylindrical M.S. vessel having arrangements for heating either by steam or by thermic fluid heat exchanger. By 30 minutes the protein from the shell will dissolve in the alkali which can be drained off. The residue is washed well with water to make it free from alkali. This requires at least three washings in potable water with agitation. The product is wet chitin.

Deacetylation of chitin to chitosan

The wet chitin from the deproteiniser is transferred to the cemented collection tank and there to the centrifuge/hydraulic press/screw press for removal of water to the extent possible. The dewatered chitin cake is charged to the deacetylator where it is treated with 50% (w/w) aqueous caustic soda solution at 90-95^{0}C for 1.5 to 2 hours or longer till the deacetylation reaches the required level. After deacetylation, which is ascertained by checking the solubility in 1% acetic acid, the alkali is recovered for reuse. The residue washed twice with minimum quantity of water and collected for reuse making up the concentration. The alkaline chitosan mass is washed well either in the same vessel or after transferring to a storage tank and taking in small quantities to a S.S. washing vessel to remove residual alkali.

Dehydration

The alkali free chitin or chitosan from the washing vessel is collected in canvas bags and pressed under a screw press or hydraulic press or centrifuged to remove the adhering water as far as possible. The residue is wet chitin/chitosan with moisture content around 70%.

The wet alkali free chitin/chitosan cake is taken out, fluffed and spread in clean aluminium trays and dried in hot air drier at temperature 65-70^0 C. Alternatively it can also be sun dried by spreading in open cemented floor protected from dust and other contaminants to moisture content below 7%.

Pulverization

The dried chitin/chitosan is sorted manually to remove any foreign material before pulverizing. The pulverizing can be done in a swinging hammer type or a pin type pulveriser fitted with a balloon or cyclone collector to the desired particle size by suitably changing the screen. Sorting is an important step for getting high quality chitin. The foreign matter like match stick, feather, nylon pieces etc. which are normally present in the shell will be carried to the product even after demineralisation and deproteinisation. No mechanical separation is as effective as manual separation although it involves considerable labour.

Bagging and storage

The powdered chitin/chitosan can be bagged in polythene lined HDPE (high density polythene) woven sacks. Usually a bag of size 100 cm x 65 cm is used for this purpose which can hold 25 kg chitin of 1 mm size or 40 kg chitosan of 0.25 mm size produced from prawn waste or 30 kg chitin or 50 kg chitosan from crab shell. Such bags can withstand all transporting hazards.

Product quality

In commerce chitin and chitosan with the following characteristics are acceptable to the end users.

Characteristics	CHITIN	CHITOSAN
Moisture %	<10	<7
Ash %	<2	<1
Protein %	<2	nil
Colour	off white	off white
Particle size	10-20 mesh	60-80 mesh
Solubility in 1% acetic acid	nil	soluble
Insolubles in 1% acetic acid	N.A	<0.5
pH	7.0-7.5	8-9
Nitrogen %	6.5-6.8	7-7.5
Deacetylation %	N.A	>80
Viscosity (m pa s) in 1% acetic acid at 1% level at 28°C	N.A	<100

The process described above will give chitosan of medium viscosity from commercial dry prawn shell. For low, high and special grade chitosan for specified end use parameters like time, temperature, concentration of acid and alkali during demineralisation and deproteinisation and deacetylation are to be suitably modified in addition to raw material selection. Strict quality control measures are to be adopted for minimising batch to batch variation.

Glucosamine:

Hydrolysis of chitin with concentrated hydrochloric acid causes deacetylation and breakdown of the polymer releasing the monomer as glucosamine hydrochloride. Dry Chitin powder was hydrolyzed with concentrated Hydrochloric acid in a glass lined reactor equipped with reflux condenser in a thermostatically controlled digital water bath with occasional stirring. The temperature of the reaction mixture was slowly raised to the optimum level and maintained at that level for the completion of reaction until the solution no longer gives opalescence in dilution with water. During the process the liberated HCl gas was absorbed in water. The excess acid can be distilled off under vacuum after completion. The undissolved residue, was filtered after adding equal quantity of water. To this mixture 10% activated charcoal was added and the solution was warmed to 60o C for 30 minutes and filtered. If the filtrate still coloured repeat the treatment with little quantity of charcoal. This pale yellow solution was evaporated to dryness in a reduced pressure and mixture was washed with alcohol and dried under vacuum. Glucosamine hydrochloride is an approved nutraceutical product. It is prescribed as a remedy for osteo arthritis and approved by USFDA. It is found to have antiflamatory and antiulcerogenic properties.

Chitooligosaccharides (COS) applications:

Production of COS is of immense interest since these oligosaccharides are thought to have several interesting bioactivities. COS produced using endochitinase showed antibacterial activity against bacteria, that cause diarrhoeal and emetic syndromes in humans. Potential effects of COS reported were: as drugs against asthma, antibacterial agents, anti-fungal agents, ingredients in wound-dressings, reduce metastasis of tumors, increase bone-strength in osteoporosis, inhibit chitinases in *Plasmodium* parasites and thereby prevent malaria, immune modulators, and a lowering effect on serum glucose levels in diabetics.

Applications of Chitin, Chitosan and Glucosamine

Chitin and its derivatives, particularly chitosan (deacetylated chitin) find industrial application in various fields namely flocculation, paper making, textile printing and sizing, ion exchange chromatography, removal of metal ions from industrial effluents, manufacture of pharmaceuticals and cosmetics and as an additive in food industry. Several versatile applications of chitosan have been developed during the last three decades. There are about 200 current and potential applications of chitin and its derivatives in industry, biotechnology, food processing, pharmacy and medicine.

The application of chitosan for improvement of quality and shelf life of food products have been well documented. It can be directly incorporated into the food or can be used as coatings for food products or can be made as an integral part of the packaging materials. All these techniques are found to have beneficial effects on the food during processing and storage. Edible coatings can be used as a vehicle for incorporating functional ingredients such anit-oxidants, flavours and colors antimicrobial agents and nutraceutical into the food products whereby adding more value to the product. The applications of chitosan in the field of nanotechnology is being studied widely. It was observed that the antimicrobial properties of nano chitosan is far better when compared to natural chitosan. Nanochitosan in conjunction with metal ions have also been found to have applications in different fields.

Glucosamine hydrochloride and sulphate are marketed as food supplements for the treatment of osteoarthritis. Anti-ulcerative effect of glucosamine was recently reported. In the US glucosamine is one of the most common non-vitamin, non-mineral, dietary supplement used by adults. Since glucosamine is a precursor for glycosaminoglycans and glycosaminoglycans are a major component of joint cartilage, supplemental glucosamine may help to prevent cartilage degeneration and treat arthritis. Glucosamine and N-acetyl glucosamine help in building up connective tissue in joints (e.g. gycosamionoglycons (GAG), chondroitin and hyauronic acid). Glucosamine acts not only as a substrate for the synthesis of GAGs but also stimulates their synthesis and prevents degradation. Different combinations of glucosamine are now in use for treatment of arthritis and the annual global consumption of glucosamine exceeds 6000 tons.

Shrimp shell waste can be efficiently utilized by transforming it to value added by-products like chitin, chitosan, glucosamine and chitooligosaccharides that have wide and varied industrial applications.

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Chapter 18

Utilization of secondary raw material from fish processing industry

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Introduction

Fish and shellfish constitute an important component of global nutrition. Fish protein is an essential source of nutrients for many people, especially in developing countries. Health benefits of fish oil in preventing heart attack and other cardiovascular diseases are well appreciated. Mounting evidences suggest that the benefits of fish consumption are not limited to the well-known effects of fish oil alone. Fish is also a rich source of protein containing all essential amino acids, which is required for the body maintenance and muscular build-up. The protein content of most of the raw finfish meat is in the range of 17 to 22% (g per 100 g), while the cooked portions of some fish such as tuna may have as high as 30% protein. The amino acid score of fish protein compares well with that of whole egg protein, which is considered as a standard protein source. Fish is also rich in the non-protein amino acid - taurine, which has a unique role in neurotransmission. Apart from nutritional properties, fish proteins also possess a number of functional properties such as emulsifying, foaming, gel forming, water binding and fat binding properties, which are important in product formulations. These functional properties are mainly attributed to the major myofibrillar proteins, actin and myosin.

During the processing of fish generally only the fillets are retained while the bulk of product (up to 66%) is discarded. About 30% of the total fish weight remains as waste in the form of skins and bones during preparation of fish fillets. This waste is an excellent raw material for the preparation of high value products including protein foods. The utilization of fish wastes help to eliminate harmful environmental aspects and improve quality in fish processing. Skin and bone are sources of high collagen content. The average quantity of waste generated during fish and shellfish processing operations (based on average annual marine landing data) is indicated in Table 1.

Table 1: Waste generation in industrial fish processing in India

Products	Waste generated (%)
Shrimp products (PD, PUD, HL, etc.)	50
Fish fillets	70
Fish steaks	30
Whole and gutted fish	10
Cuttlefish rings	50
Cuttlefish whole	30
Cuttlefish fillets	50
Squid whole cleaned	20
Squid tubes	50
Squid rings	55

Source: Anon (2005)

At present, India is the second largest producer of fish in the world with second position in aquaculture production as well as in inland capture fisheries. The total fish production during 2013-14 (provisional) is registered at 9.58 mMT, with a contribution of 6.14 mMT from inland sector and 3.44 mMT from marine sector (Hand book on fisheries statistics, 2014). This indicates, a minimum of 4MT of fishery waste has been generated every year, even though it is scattered in the domestic and industrial sector.

An important waste reduction strategy for the industry is the recovery of marketable byproducts from fish wastes. Hydrolyzed fish wastes can be used for fish or pig meal as well as fertilizer components. The three most common methods for utilization of aquatic waste (either from aquaculture or wild stock) are the manufacture of fishmeal /oil, the production of silage and the use of waste in the manufacture of organic fertilizer . The utilization of by-products is an important cleaner production opportunity for the industry, as it can potentially generate additional revenue as well as reduce disposal costs for these materials. The transportation of fish residues and offal without the use of water is an important factor for the effective collection and utilization of these by-products. Some viable options for generating wealth from waste are detailed below.

Fish meal: Fish meal is highly concentrated nutritious feed supplement consisting of high quality protein, minerals, vitamins of B group and other vitamins and other unknown growth factors. Fishmeal is rich in essential amino acids. It is produced by cooking, pressing, drying and grinding the fish, by-catch fish, and miscellaneous fish. Fishmeal production also provides a major outlet to recycle trimmings from the food fish processing sector, which might otherwise be dumped at extra cost to the environment and the consumer. Spain, France, Germany, Ireland and the UK produce fishmeal primarily from trimmings. The composition of fishmeal differs considerably due to the variations in the raw material used and the processing methods and conditions. In India, oil sardine (*Sardinella longiceps*) is extensively used for the production of fish meal and oil. Most of the pelagic fishes mentioned earlier are rich in body oil. Hence both fish meal and fish body oil are produced in the same industry. Freshness of fish is very important in getting good quality fish meal. If the fish has lost its freshness, it will have high TVBN content and consequently, the meal produced from it will also contain high TVBN which is unacceptable to shrimp feed industry. In addition to oil sardines, fish dressing waste or cutting wastes (head and viscera) of surimi industry are also used in fish meal manufacture in India. In this case also, the quality parameters regarding freshness of waste have to be maintained. Generally, fish meal produced from fish processing waste, contain low percentage of proteins and high proportion of ash/minerals. Hence, it is not possible to produce Grade I fish meal using only wastes from fish processing industry.

The main objective in the production of fish meal is to reduce the moisture content of fresh fish (70-80%) to about less than 10% in the meal. Oil content in the fish meal should not be more than 10%. Hence, 80 to 90% of oil present in fish has to be removed during fish meal production. The most common methods employed for the manufacture of fish meal are dry rendering and dry rendering process. Dry rendering or dry reduction process is suitable for only lean or non-oil fish such as silver bellies, jew fish, sciaenids, ribbon fish, sole, anchoviella, carcasses of shark, fish offal and filleting waste. In this process, it is dried to moisture content of 10% and pulverized. If the quantity to be handled is sufficiently large a steam jacketed cooker dryer equipped with power devises for stirring is used. Being batch operation the process will have only limited capacity and labour cost is very high. Merit of this process is that the water-soluble materials are retained in the meal. Wet rendering or wet reduction process is normally applied to fatty fish or offal where simultaneous production of fish meal and fish body oil is envisaged. The process consists of grinding, cooking to soften the flesh and bones and to release the oil, pressing to expel the liquor and oil, fluffing the press cake drying, grinding and packing the meal, The press liquor is centrifuged to remove the suspended particles and to separate oil. The stick water is concentrated to retain protein and other valuable components. The press cake is fluffed and dried to a moisture level of 8%.

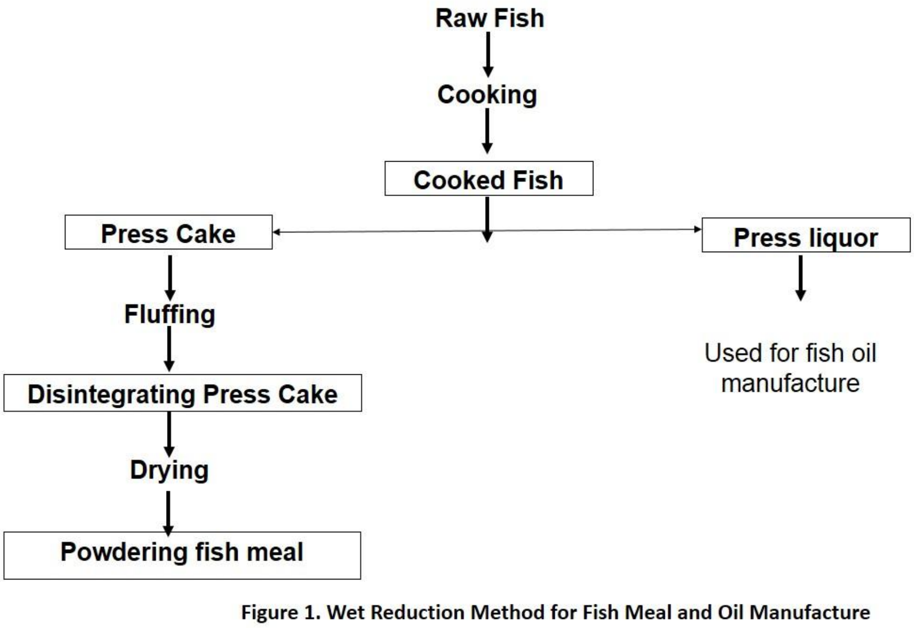

Figure 1. Wet Reduction Method for Fish Meal and Oil Manufacture

Drying is one of the key processes in fish meal production. The dryer used can affect many of the important attributes of fish meal quality. Raw material freshness is important if a producer wants to make premium quality fish meal. Enzymatic and bacteriologic activity in the fish can rapidly decrease the content and quality of the protein and oil. Protein decomposes into amines and ammonia, and both reduce the protein value and recovery of protein. The raw material freshness and drying methods are determining factors of fish meal quality.

BIS has brought out the specification for fish meal as livestock feed for facilitating proper quality control. The proximate composition of fish meal, in general, is protein, 50-60%; fat,5-10%; ash, 12-35% and moisture, 6-10% employed (Mathew, 2014). Around 15% of the global fish meal demand is met from fisheries resources alone. The projected (2030) annual growth rate in fishmeal use in aquaculture is 1.7%, where the current usage is at a tune of 3.9%. The recent development in captive breeding and rearing high value species such as cobia, grouper, pompano, Nile tilapia, lobster, Asean seabass etc. implies that there is a good scope for flourishing finfish and shellfish production through aquaculture in near future. This inturn highlights the bright future of fish meal industry in coming years, as most of these species demand high protein feeds for their optimum growth.

Fish protein hydrolysate: Hydrolysates find application as milk replacer and food flavouring. Enzymes like papain, ficin, trypsin, bromelein and pancreatin are used for hydrolysis. The process consists of chopping, mincing, cooking and cooling to the desired temperature, hydrolysis, sieving, pasteurizing the liquid, concentrating and drying (by vacuum or spray drying). The fish protein hydrolysate have desirable functional properties with potential applications as emulsifiers and binder agents. It can also be used in place of diary based and plant based protein hydrolysates (Binsi et al., 2016). The peptides formed by the hydrolysis of fish proteins are proven to have bioactive properties like antihypertensive, antithrombotic, immune modulatory and antioxidative properties. Also, they possess superior nutritional and functional properties. A variety of nutraceuticals from FPH are commercially produced and are available in international markets. Oyster peptide extract developed by ICAR-CIFT possess good antioxidant and anti-inflammatory activities. Similarly, hydrolysate made from squilla meat effectively reduced oil absorption in breaded and battered products, when incorporated in the batter mix.

Fish collagen/gelatin/collagen peptides: Collagen is the major structural protein in the connective tissue. Collagen extracted from fishes can be used in cosmetics, foods, biomedical applications etc. Gelatin is the partially hydrolysed form of collagen. Both collagen and gelatin are high molecular weight proteins of approximately 300 kDa, hence a considerable proportion is unavailable to human body for biological functions. Consequently, in recent years, much attention has been paid to the development of small molecular weight peptides from the native collagen with improved biological activities. This can be achieved by the process of hydrolysis in which the native collagen/gelatin molecules are cleaved to small fragments of less than 5 kDa. Currently, collagen peptides are being incorporated in a wide array of food products including protein bars, cereal bars, protein drinks, smoothies, yogurts, cold desserts, soups, cured meats etc. Nowadays, collagen/gelatin peptides have gained increasing attention as these peptides exhibit various biological activities such as antioxidant, anti-hypertensive, anti-human immunodeficiency virus, anti-proliferative, anticoagulant, calcium-binding, anti-obesity, anti-diabetic activities and postponement of age-related diseases. ICAR-Central Institute of Fisheries Technology (Cochin, India) has standardised a protocol for the extraction of collagen peptide from fish scale and bone. Further a nutritional mix based on collagen peptides was developed with a protein content of 78%. The product is mainly intended for middle aged and old people, ladies and sports-persons who needs a regular supply of collagen for healthy joints and bones. It may also be beneficial for patients suffering from osteoporosis and long-term- nursing home residents where there is a possibility of development of pressure ulcers.

Collagen peptide from fish scale and Nutritional mix formulated by CIFT

Surgical sutures from fresh water fish gut

Absorbable fine grade sutures are essential for microsurgeries and ophthalmic surgeries. CIFT has developed the method for the preparation of absorbable surgical sutures from fish gut. The production of sutures involves a low cost technology. Fish gut is separated and washed thoroughly to remove impurities and soluble proteins. The collagen fibres separated are twisted, cross-linked and bodied to give fine threads of collages. They are surface smoothened, cut to size and packed in isoporpanol. The packed sutures are sterilized to give absorbable surgical sutures. The sutures developed by this method are evaluated for tenacity, absorbability, freedom from abnormal tissue reaction etc.

Fish ensilage and foliar spray: When the animal farms are very near to landing centres it is worthwhile to go for silage production. Fish silage is made from whole fish or parts of the fish to which no other material has been added other than an acid and in which liquefaction of the fish is brought about by enzymes already present in the fish. The product is a stable liquid with a malty odour which has very good storage characteristics and contains all the water present in the original material. Fish silage is preserved against microbial spoilage mainly by the lowered pH, obtained by the added or in-situ produced acid. Specifically, the unionized acid molecules are able to cross the cytoplasmic membrane barrier of the microbial cell while protons (H+) and acid anions cannot. But once inside the cell, the acid mole can ionize and since the membrane traps the ions, the pH gradually comes down killing the cell. Thus it is the unionized acid molecules that are responsible for the preservative action rather than the total acid concentration. At equal concentrations, organic acids are weakly ionized in solution when compared to inorganic acids, thus contain greater amount of unionized (free acid) molecule making them more effective preservatives. In case of fermented silage, preservation occurs by several means. The presence of fermentable sugar is the beginning of the ensilation process prevents immediate deamination of amino acids by bacteria that would lead to ammonia production and foul smell. Later as the fermentation by lactic acid bacteria becomes dominant, spoilage bacteria are suppressed or killed by the increasing concentration of lactic acid, lowered pH and the production of several antibiotic substances called bacteriocins by the lactic acid bacteria. It is a simple process and it requires little capital equipment particularly if non-oily fish are used. The use of oily fish usually requires oil separation. This involves expensive equipment and is suited to a fairly large-scale operation. The silage may be suitable converted to foliar spray, as foliar feeding is an effective method for correcting soil deficiencies and overcoming the soils inability to transfer nutrients to the plant. The experiments conducted at ICAR-CIFT have shown that foliar feeding can be 8 to 10 times more effective than soil feeding and up to 90 percent of foliar fed nutrients. The application of foliar spray has been advocated in spices like cardamom, black pepper, tea etc and encouraging results have been reported. The quick absorption of the nutrients and precise dosage of foliar sprays has resulted in the success of precision farming of costly vegetables and flowering plants. The controlled nutritional supply through praying is an effective method which gives predicted resulted in most of the cases. The optimized supply of required micro and macro nutrients results in the maximum productivity of the available space and minimizes the wastage of costly inputs.

Enzymes: There is a great demand for enzymes with right combination of properties for a number of industrial applications. Enzymes from marine fisheries resources have wide biotechnological potential as they have some unique properties for industrial applications, e.g. in the detergent, food, pharmaceutical, leather and silk industries. Among the enzymes derived from various sources, marine enzymes have certain technological advantages. Some of the distinctive features of enzymes derived from fish include, the higher catalytic efficiency at lower reaction temperatures, and stability at wide range of pH and in the presence of surfactants or oxidizing agents. The higher catalytic activity at lower temperature is a unique property that further permits to process foods at low temperatures such as fruit juices, thereby protects heat-labile food components and reduces the energy cost. Similarly, the lower thermo-stability of marine enzymes would permit their complete inactivation by mild heat treatments, whereas the enzymes from microbial and plant resources often requires heating at above 90^{o}C for a minimum duration of 10 min for stopping the enzymatic reaction. World-wide the sales of industrial enzymes are growing at a fat rate. Presently, industrial enzymes are mostly derived from microorganisms and to a lesser extent from plant and bovine sources. Sofar, there is only very limited use of marine derived enzymes by industry. The reason may be the limited basic informations on these enzymes, the seasonal nature of raw material availability, the psychological inertia of the public towards fish offal, and to a greater extent, due to the lack of proper techniques for the recovery of enzymes from fish processing waste which comprises of a complex mixture of various biomolecules such as proteins, lipids, minerals, glyco-proteins etc. It is suggested that future research may be focused on the development efficient and cost-effective technologies for the recovery of various enzymes from fishery resources, so that some of the unique properties of marine enzymes may be exploited in various food applications, and thereby, obtain a share of lucrative industrial enzyme market to increase the profit for fish processing industry.

Fish calcium: In marine ecosystem, there is a large amount of calcium, mainly in the form of calcium carbonate and calcium phosphate, distributed as skeletal elements of teleosts, exoskeletal elements of molluscs or as coral deposits. In marine ecosystem, there is a large amount of calcium, mainly in the form of calcium carbonate and calcium phosphate, distributed as skeletal elements of teleosts, exoskeletal elements of molluscs or as coral deposits. The bone fraction, which comprises approximately 15-20% of the total body weight of fish has high calcium content. Calcium and phosphorus comprise about 2% (20 g/kg dry weight) of the whole fish. Generally, fatty fish have lower ash levels compared to lean species. The filleting wastes of tuna and other bigger fishes are very good sources for calcium when the quantity of calcium is concerned. Also, the bone structure differs between species since a large number of teleosts have acellular bone (bone without enclosed osteocytes). Cellular bones are confined to only a few fish groups, e.g. Salmonidae. The higher surface to volume ratio in acellular fish bone is likely to increase the calcium availability compared to cellular bone. The ash content is highest in lean fish species with acellular bones. Apart from that exoskeleton of mollusks and coral deposits are excellent source of calcium. However, the calcium from these deposits are mainly in the form of calcium carbonate. Central Institute of Fisheries Technology, Cochin has optimised the process to extract from fish bone which is mainly treated as processing discards during filleting operation of larger fishes, viz tuna, carps etc. The calcium powder was supplemented with vitamin D which is known to enhance absorption and bioavailability of calcium in the body. *In vivo* studies conducted at CIFT in albino rats have shown that fish calcium powder supplemented with vitamin D has improved the absorption and bioavailability.

Chondroitin Sulphate: Chondroitin sulfate (CS) is a major component of the extracellular matrix (ECM) of many connective tissues, including cartilage, bone, skin, ligaments and tendons. It is formed by repeating disaccharide units of glucuronic acid (GlcA) and N-acetylgalactosamine (GalNAc). The skeleton of shark and ray is therefore an attractive source of CS. This polymer is at the moment object of increasing attention in the engineering of biological tissues, especially in connection with the repair of bone, cartilaginous and cutaneous wounds. It is part of a large protein molecule (proteoglycan) that gives cartilage elasticity. Chondroitin sulphate is been used for the treatment of arthritis. Its high content in the aggrecan plays a major role in allowing cartilage to resist pressure stresses during various loading conditions. Chondroitin sulfatation profile has been described in cartilage CS is sold as over the counter dietary supplement in North America and is a prescription drug under the regulation of the European Medicine Agency (EMEA) in Europe. The extraction of CS includes the following steps: cartilage hydrolysis (with strong alkalis or using proteases), ethanolic precipitation of the hydrolysates and treatment of the redissolved precipitate (with ionic exchange resins or by means of dialysis) in order to eliminate remaining peptides and salts (Sumi et al., 2002).

Squalene: Squalene is a natural dehydrotriterpenic hydrocarbon ($C_{30}H_{50}$) with six double bonds, known as an intermediate in the biosynthesis of phytosterol or cholesterol in plants or animals. It is present in the liver oil of certain species of deep sea sharks mainly Centrophorus and Squalidae spp. In the case of deep-sea sharks, the liver is the main organ for lipids' storage, being in the same time an energy source and means for adjusting the buoyancy. The liver oil of these species contain high percentage of squalene (90%) which can be isolated and purified and can be used as a dietary supplement.In their case, the unsaponifiable matter represents 50–80% of the liver, the great majority thereof being squalene. Squalene has a melting point lower enough to allow the cooling composition to remain liquid, even at temperatures between −10°C and −60°C, unlike the ordinary oily topical drugs. Squalene is used as a bactericide, an intermediate in the manufacture of pharmaceuticals, organic colouring matter, rubber, chemicals, aromatics, in finishing natural and artificial silk and surface active agents. Nowadays it is extensively used as an additive in pharmaceutical preparations, cosmetics and health foods. Squalene is found to be a proficient chemo preventive agent against lung metastasis in mice bearing lung carcinoma. Squalene revives damaged body cells and aids to revitalize cell generation. Its chief attribute is the protection of cells from oxidation reactions. Squalene assists to clean, purify, and detoxify the blood from toxins, facilitating systemic circulation. It purifies the gastrointestinal tract and kidneys, causes better bowel movement and urination. Squalene was also used as an adjuvant in vaccines, stimulating the immune response and increasing the patient's response to vaccine. It is added to lipid emulsions as drug carrier in vaccine applications. Squlalene helps in regulating the female menstrual cycle and also improves irregular and abnormal cycles. Shark liver oil remains the richest natural source of squalene, eventhough it is widespread in animal and vegetal kingdom. ICAR-CIFT has standardised the protocol for extracting squalene from shark liver oil.

Hydroxyapatite (HAp): Hydroxyapatite is the major mineral component of bone tissue and teeth, with the chemical formula of $Ca_{10}(PO4)_6(OH)_2$. The composition Hap derives from biological sources differs from that of synthetic hydroxyapatite, due to the presence of several ionic substitutions in the lattice, such as CO_3, F, Mg^{2+} and Na^+. It is a member of the calcium phosphate group with 1.67 stoichiometric of Ca/P ratio. It is one of the few materials, classified as a bioactive biomaterial that supports bone in growth and osseointegration when used in orthopedic, dental and maxillofacial applications. Fish bone and scale is a rich source of hydroxyapatite. The hydroxyapatite content of fish skeleton may vary between 40-60%. Generally, very high heat treatment is used for extraction of HAp from bone and this temperature gives a higher strength to HAp structure. The high temperature also burns away any organic molecules such as collagen protein. Hydroxyapatite, found in fish is chemically similar to mineral components of bone and hard tissues in mammals. Approximately, 65-70% of the fish bone is composed of inorganic substances. Almost all these inorganic substances are hydroxyapatite composed of calcium, phosphorous, oxygen and hydrogen.

Pigments: Astaxanthin, fucaxanthin, melanin etc. from different fish resources are found to have a variety of bioactive properties. The filleting discards of salmonids and the shell wastes of crustaceans contain significant amounts of carotenoid pigments such as astaxanthin and canthaxanthin. Normally, wild caught shrimps will have more pigmentation compared to their cultured counterparts. For eg. level of astaxanthin in wild caught *P monodon* is reported as 55 mg /kg as compared to 18mg/kg for cultured variety. The carotenoid content in normal individual of *P monodon* is reported very high (78-80%) as compared to their blue varieties (7-8%). Total carotenoid content varies between species and body components. Highest carotenoid content was reported in the head of deep-sea shrimp (*A alcocki* 180-185 μg/g) and marine shrimp (*P stylifera* 150-155 μg/g) followed by *P monodon* (120-

135μg/g), *P vannamei* (120-130μg/g). High levels of carotenoids were also reported in carapace of *A alcocki* (115-120 μg/g), S *indica* (117-120.0 μg/g) and *P stylifera* (100-105μg/g). Relatively low levels of carotenoids were reported in shrimp *P indicus* and fresh water prawn *M. rosenbergii* and crabs. The protective role of carotenoids against the oxidative modification of LDL cholesterol could be explored by incorporating in health drinks. Carotenoids are also highly sought after as natural food colours. Cephalopod ink is another less-tapped reservoir of a range of bioactives having therapeutic and curative values. It is an intermixture of black pigment melanin, glycosaminoglycans, proteins, lipids, and various minerals. Cephalopod ink has been reported to have anti-radiation activity, antitumor activity, immunomodulatory activity, procoagulant function and so on.The pigment melanin can be used both as a natural colorant as well as antioxidant, in addition to a number of other therapeutic and prophylactic properties including anticancer, antihypertensive, Anti IDA etc.

Pearl Essence

Pearl essence is the suspension of crystalline guanine in a solvent,. It is the irridescent substance located in the epidermal layer of the scales of the pelagic fish. This is used for coating the objects to give them a lustrous effect. The scales are placed in 10-15% brined solution and the brine is later drained and scaled squeezed and compressed. Pearl essence is extracted by washing and scruibbving the quinine form the scales. Centrifugation is carried out for separating the pearl essence from wash liquid. For purification of quinine, the protein concentrate is digested with pepsin in acid at 25- 30 ^{0} C for 50 hours. Fat is removed with benzene or ether. Finally guanine is removed by centrigufation and suspended in water or in non aqueous liquid.

Fish glue

Fish glue is made from fish skins (the better quality flue) and of fish heads (the lesser quality flues). Skin can be salted for shorter period of storage but can be dried for longer period of storage. For extracting glue .for extracting glue from fish skin, the skins are initially cooled and the chloride is removed to less than 0.1% by washing. For 1-2 hours if fresh and 12 hours if they are stored) in cold running water in a roller mill. After the water treatment, the skins are placed in 0.2% NaOH or CaO, neutralized with 0.2% HCl, and again rinsed in running cold water. The skins now swollen are mixed with an equal weight of water and steam is added. Addition of 1.9 litre of glacial acetic acid during heating will a make the final glue a clearer product. First cooking is for eight hours and the glue layer is strained. Subsequent cooking will give a weaker glue.

Fish maws and Isinglass

The word isinglass is derived from the Dutch and German words which have the meaning sturgeon's air bladder or swimming bladders. Not all fish air bladder are suitable for isinglass production. The air bladder of deep water hake is the most suitable for production of isinglass. In India air bladders of eel and cat fishes are used for the production of isinglass.

The air bladders are separated from the fish, and temporarily preserved in salt during transport. On reaching the shore, they are split open, thoroughly washed and the outer membrane is removed by scraping and then air dried.

The cleaned, desalted, air dried and hardened swimming bladders (fish maws) are softened by immersing in chilled water for several hours. They are mechanically cut into small pieces and rolled or compressed between hollow iron rollers that are cooled by water and provided with a scraper for the removal of any adhering dried material. The rolling process converts the isinglass into thin strips or sheets of 1/8 to ¼ "; thickness. There are processes for the production of isinglass in powder form.

Isinglass dissolves readily in most dilute acids or alkalis, but is insoluble in alcohol. In hot water isinglass swells uniformly producing opalescent jelly with fibrous structure in contrast to gelatin. It is used as a clarifying agent for beverages like wine, beer, vinegar etc. by enmeshing the suspended impurities in the fibrous structure of the swollen isinglass.

India exports dried fish maws, which form the raw material for the production of isinglass and such other products. Process has been developed to produce the finished products from fish maws.

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Chapter 19

Nutraceuticals from Fish and Fish Wastes: Scopes and Innovations

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Bio-active compounds having health beneficial effect on human beings from terrestrial and marine sources are considered as "Nutraceuticals". Nutraceuticals from marine origin are proved to have wide range of therapeutic effects *viz.,* anti-obesity, immune enhancement, natural antioxidant, cardio protective, anti-diabetic, anti-inflammatory effects.These natural products do not have any side effects contradictory to many medicines available today, hence have attracted global market. Microencapsulation technique has been considered as one of the unique methods to encapsulate the bio-active compounds for target delivery. Importance and application of nutraceuticals from marine origin are highlighted.

Introduction

World over in the recent past, research in nutraceuticals has shown continuous growth and the progressive approach is aimed at identifying the potential nutraceutical compounds which are having health benefits in human beings. Awareness among the people is the prime reason for the growing demand for nutraceuticals.Today people are more aware about the nutrition and related health problems. Recently, researchers across the globe are exploring the possibilities to extract and isolate bio-active compounds from both terrestrial and marine sources.

Nutraceutical is a combination of two words, "nutrition" and "pharmaceutical," and the word nutraceutical was coined by Stephen L. DeFelice in 1989 (Wildman *et al.*, 2006). Nutraceuticals are food products of natural origin from both terrestrial and marine sources having healthcare importance. The word nutraceuticals comprise of variety of products derived from terrestrial and marine sources (isolated nutrients, dietary supplements, and genetically engineereddesigner foods, herbal products, processed foods, andBeverages). Recent report says that nutraceuticals provides a positive healthcare approach with tremendous therapeutic impacts on human body (Das *et al.*, 2012; Bagchi*et al.*, 2015). The nutraceutical industry has identified a wide range of phytochemicals described as phytoestrogens, terpenoids, limonoids, glucosinolates phytosterols, polyphenols, carotenoids, flavonoids, isoflavonoids, and anthocyanidins having therapeutic effects on human health as antioxidants, anti-inflammatory, antibacterial, anti-allergic, anti-fungal, chemopreventive, immunomodulatory etc., (Gupta and Prakash, 2014; Karwande and Borade, 2015).

Classification of Nutraceuticals

Based on the bio-functional properties of bioactive compounds from terrestrial and marine sources are classified in to following –

1. Dietary Supplements
2. Functional foods
3. Medicinal food

Dietary Supplements

According to the Dietary Supplement Health and Education Act (DSHEA), 1994 in USA, dietary supplements are defined as products comprised of "dietary constituents" and orally administered to supplement the nutritional requirement of diet. The "Dietary constituents" refers to bioactive components comprising of amino acids, vitamins, minerals, fibres, important metabolites, and certain enzymes. The dietary supplements also include extracts available in tablets, capsules, powders, liquids, and in any other dosage form (Radhika *et al.*, 2011).

Functional Food

Functional foods are foods derived from natural origin enriched in nutrients and are being fortified with essential nutrients (Jones, 2002). As per the Health Canada, functional food defines a regular food with an ingredient having specific therapeutic effect along with nutritional value (Wildman *et al.*, 2006). Whereas in Japan, functional foods are assessed on the basis of three important standards: (1) functional foods must be derived from natural sources and consumed in their native state instead of processed in different dosage forms like tablet, capsule, or powder; (2) consumed regularly as a part of daily diet; and (3) exert a dual role in prevention and management of disease and contribute in biological processes (Arai, 1996).

Medicinal food

Medical foods are foods that are specially formulated to be consumed internally under the supervision of a physician, which is intended for the dietary management of particular disease that has distinctive nutritional needs that cannot be met by normal diet alone. Dietary supplements and functional foods do not meet these criteria and are not classified as medical food (Radhika *et al.*, 2011).

Nutraceuticals from marine sources

Chitin and chitosan

Chitin, a cationic amino polysaccharide,is a natural biopolymer composed of *N*-acetyl-d-glucosamine with β (1 → 4) glycosidic linkages. The term chitosan is used when nitrogen content of chitin is more than 7% by weight or the degree of deacetylation is more than 60% (Peter *et al.*, 1986; Gagne and Simpson 1993). Chitosan is a biopolymer and it consists of d-glucosamine units obtained during the deacetylation of chitin by adopting hot alkali treatment. Chitin and chitosan can be obtained from the bio-waste generated from both terrestrial and marine sources. Chitin is abundant in the marine organisms like lobster, crab, krill, cuttlefish, shrimp, and prawn. The extraction of chitin form marine source comprises of thee-steps: deproteinization (DP), demineralization (DM), and decolorization (DC). Further, chitin has to undergo a de-acetylation process to obtain chitosan. Chitin is known for its unique properties like, biodegradability, nontoxicity, physiological inertness, antibacterial properties, hydrophilicity, gel-forming properties (Se-Kwon, 2010). In India, a few entrepreneurs are producing chitin and chitosan on a commercial scale under the technical guidance of the ICAR-Central Institute of Fisheries Technology, Cochin. In-line with chitin, chitosan also finds extensive application in multidimensional sectors, such as in food and nutrition, biotechnology, material science, drugs and pharmaceuticals, agriculture and environmental protection, dental and surgical appliances,removal of toxic heavy metals, wine clarification, industrial effluent treatment, etc. (Se-Kwon, 2010).

Glucosamine Hydrochloride

Generally, glucosamine is obtained from the crustacean waste (Xu and Wang, 2004; Tahami, 1994). Glucosamine is part of the structural polysaccharides such as chitosan and chitin, which is present in the exoskeletons of crustacean and other arthropods. Though, glucosamine was discovered long back, market for glucosamine has gained popular interest due toits health benefits. Dietary supplementation of glucosamine (glucosamine sulphate, glucosamine hydrochloride, or N-acetyl-glucosamine) is proven to promising biomolecule for the treatment of osteoarthritis, knee pain, and back pain (Houpt*et al.*, 1999; Luo *et al.*, 2005). It is also known for its unique properties like anti-cancer, anti-inflammatory and antibacterial effects (Nagaoka *et al.*, 2011).

Chondroitin sulphate

Chondroitin sulphate (CS) consists of repeated disaccharide units of glucuronic acid (GlcA) and *N*-acetylgalactosamine (GalNAc) linked by β-(1→3) glycosidic bonds and sulfated in different carbon positions (CS no-sulfated is CS-O). Shark cartilage is found to be a good source of chondroitin sulpahte. Chondroitin sulfate plays various roles in biological processes such as the function and elasticity of the articular cartilage, hemostasis, inflammation, cell development, cell adhesion, proliferation and differentiation by being an essential element of extracellular matrix of connective tissues (Schiraldi*et al.*, 2010).

Hyaluronic acid (HA)

HA can be obtained from the bio-waste like fish eyeball and it is also present in the cartilage matrix of fishes. HA finds several biomedical applications *viz.*viscosupplementation in osteoarthritis treatment, as aid in eye surgery and wound regeneration. Further, hyaluronic acid finds its applications in drug delivery, tissue engineering applications, gene delivery applications, targeted drug delivery, tumor treatment, environmental applications and sensors (Mathew *et al.*, 2017).

Collagen, gelatin and collagen peptides

Fish skin and scales which constitutes about 30% and 5% of the total seafood processing discards respectively are considered as the richest source for collagen and gelatin. Collagen derived from marine sources is finding wide applications in various sectors due to its biocompatibility, biodegradability, high cell adhesion properties and weak antigenicity (Yamada *et al.*, 2014). Another major application of collagen is to act as a source for extraction of collagen hydrolysates, peptides, gelatin and gelatin peptides. Collagen peptides are reported to have bioactive properties like antioxidant, antimicrobial, antihypertensive, metal chelating, tyrosinase inhibitory, immunomodulatory, neuroprotective, antifreeze, wound healing, cell-proliferation, activities (Zhuang *et al.*, 2009; Chi *et al.*, 2014).

Gelatin, the denatured form of collagen, by virtue of its surface active properties finds extensive applications in food, pharmaceutical and biomedical industries. Gelatin peptides are reported to have antihypertensive, antioxidant properties. The major difference between fish and mammalian gelatin lies in the iminoacid composition, viz, proline and hydroxyprolinecontents. (Mathew *et al.*, 2017).

Fish lipids

Across the globe the researchers have well documented the health beneficial effects of long chain omega-3 polyunsaturated fatty acids (PUFA) (Connor, 2000). The major omega-3 PUFA, such as eicosapentaenoic acid (EPA C20:5) and docosahexaenoic acid (DHA C22:6) are very much essential for human beings, and hence are considered as essential fatty acids. The intake of long chain omega-3 PUFA is promoted by many health organizations owing to the health benefits associated with it. An average intake of 0.2 g and 0.65g of EPA and DHA a day is recommended by the European Academy of Nutritional Sciences (EANS) and International Society for the Study of Fatty Acids and Lipids (ISSFAL) respectively (Dedeckere, *et al.*, 1998). Fish oil remains as an excellent and economical source of omega-3 PUFA. Having high contents of fat soluble vitamins and lipids, especially EPA, cod liver has been exploited as an omega-3 PUFA source for development of nutraceuticals (Mondello*et al.*, 2006). Dietary consumption of fish oil (omega-3 PUFA) in adequate quantities is reported to have health benefits in the treatment of cardiovascular diseases, cancer, hypertension, Alzheimer's disease, diabetes, arthritis, autoimmune disorders and to improve overall functioning of brain and retina (Cole *et al.*, 2009).

Squalene

Squalene, a naturally occurring triterpenoid compound, is an intermediate in cholesterol synthesis. It is widely present in nature, such as wheat germ, rice bran, shark liver and olive oils and among all the sources identified, shark liver oil is considered to be the richest source accounting for about 40% of its weight. Recently, the squalene has gained attention due to its diverse bioactivities such as antioxidant, anti-lipidemic, membrane stabilizing, cardioprotective, chemopreventive, anti-cancerous, antiaging properties etc (Passi*et al.*, 2002; Ko*et al.*, 2002). Further, it is also reported to protect human skin surface from oxidation (Kabuto *et al.*, 2013). Based on its diverse bio-active properties, squalene finds applications in field of biomedical, cosmetic, drug delivery systems and even in food industries.

Minerals

Marine organisms especially fish are considered as important source of minerals such as sodium, potassium, calcium, phosphorous and magnesium. Fish bone which is often discarded after the removal of protein is an excellent source of calcium and hydroxy apatite. Being rich in minerals, fish bone powder can be fortified into several food products. However, for fortification, the fish bone should be converted into an edible form by softening its structure by pre-treatment with hot water or hot acetic acid or superheated steam. Calcium powder processed from the backbone of tuna is a potential nutraceutical. It can be used to combat calcium deficiency in children. Fortification of calcium in foods helps consumers in meeting the calcium requirements and may reduce the risk of osteoporosis. Other than fish bone calcium, certain other minerals such as selenium, potassium, iodine, zinc, magnesium are more abundant in seafood than in meat. The higher intake of seafood diet will also ensure that adequate amount of iodine is obtained.

Nutraceutical industry in India: Current scenario and future trends

During the year 2015, global nutraceutical industry, valued at US$ 182.6 billion and is one of the fastest growing industries today and expected to grow at a Compound Annual Growth Rate (CAGR) of 7.3% from 2015 to 2021. As on today, the United States, Europe and Japan account for about 93% of the total global nutraceutical market and seems to have attained maturity in all three major regions. Hence, nutraceutical industries across the world are now showing their interest to emerging markets like India and China. Nutraceuticals industry in India is one of the rapid growing markets in the Asia-Pacific region. As per the record, the nutraceuticals industry in India is worth about US$ 2.2 billion and is expected to grow at 20% to US$ 6.1 billion by 2019-2020.

Innovative work done at Central Institute of Fisheries Technology, Cochin

By adopting grafting and micro-encapsulation technology, ICAR-Central Institute of Fisheries Technology, Cochin has developed some of the nutraceuticals products, such as thiamine and pyridoxine-loaded vanillic acid-grafted chitosan microspheres; sardine oil loaded vanillic acid grafted chitosan microparticles; microencapsulated squalene powder; vanillic acid and coumaric acid grafted chitosan derivatives; thiamine and pyridoxine loaded ferulic acid-grafted chitosan. These nutraceuticals products were shown to have health beneficial and immunomodulatory response in animal models.

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Chapter 20

Profiling of macro and micronutrients in seafood

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Nutrients are organic and inorganic complexes contained in the food and it is essential for all living organisms for their normal body development. Macronutrients are the key biopolymers such as proteins, carbohydrates and lipids, which are needed in hefty quantities to provide the bulk of the energy while micronutrients (vitamins and minerals) are required in minor levels in the body; however, are indispensable for proper growth and development of living organisms. Food that cannot provide the right blend of energy including high-quality protein, essential fats, and carbohydrates as well as vitamins and minerals definitely impair growth and development, increase the risk of death from common childhood illness, or result in life-long health consequences. Fish and fishery products form a substantial part of human diet, both of poor and wealthy. Seafood is an excellent resource for proteins, vitamins, trace elements and polyunsaturated fat (omega-3 fatty acids). Profiling of nutrients is very much essential due to *the ever-increasing awareness about healthy food which finds more acceptance towards the consumption of fish and fish products owing to its special nutritional qualities.*

The knowledge of fish composition is essential for its maximum utilization. The percentage composition of the four major constituents of fish viz. water, protein, lipid and ash (minerals) is referred to as proximate composition (it may be noted that the term does not indicate any degree of inaccuracy in the analysis). These four components account for about 96-98% of total tissue constituents in most cases. The range of values for these constituents in the edible portion of common fish species from Indian coastal waters are given below:

Constituent	**Percentage**
Water	65-90 %
Protein	10-22 %
Fat	1-20 %
Mineral	0.5-5 %

Water

Water is important for all living organisms. It acts as medium of transport for nutrients, metabolites etc. It is required for normal functioning of biological molecules like proteins. The percentage of water is good indicator of its relative contents of energy, proteins and lipids. The lower the percentage of water would be greater the lipids and protein contents and higher the energy density of the fish. However, these values vary considerably within and between species, size, sexual condition, feeding season and physical activity.

Protein

In addition to the routine functions of protein, fish proteins are considered as superior to plant and animal protein in biological value and protein efficiency ratio due to its easily digestible and absorbable form of proteins. Fish protein comprises of all the ten essential amino acids in desirable quantity for human consumption and it accounts 30% higher than from plant origin. The highly digestible fish protein can be incorporated into protein supplement for human consumption. Presence of essential amino acids in required proportion like lysine, histidine, methionine and cysteine with high bio availability and minerals makes fish highly nutritious. Non-protein amino acid taurine is found to be rich in free amino acid pool which is beneficial in regulating heart function. Fish proteins lessen the risk of microalbuminuria. It also improves blood lipid profile of obese children. Fish protein powder can be used to formulate infant foods, soups and protein containing beverages to enhance their protein content and nutritive value. Fish protein hydrolysate prepared from low value fishes contains important bioactive peptide fraction like gastrin, calcitonin gene related peptides (CGRP) and some growth promoting peptides which play a key role in our metabolic path ways. Fish protein hydrolysate suppresses both hypertension and atherogenesis. Collagen found in skeleton, fins, skin and air bladder (source of pure collagen) of fish is a good source of amino acids required for the synthesis of extra cellular matrix protein of connective tissue. Its supplementation is also beneficial in the normal functioning of fragile bone joints.

Lpids

Quantity wise it is 3rd major component in the fish muscle. Major component of fish lipids includes phospholipids and triglycerides. Wide variation is occurs in the quantity of triglycerides. It is considered as stored form of energy and stored mainly in the form of depot fat in the liver as well as in the muscle tissue. Phospholipid in the fish lipid mainly found in the cell membrane and plays a vital role in the functioning of the cells. It accounts 0.5 to 1% of the total lipid component. Fish fat is considered as unique, beneficial, healthy fat due to its high degree of unsaturation in their fatty acids composition. Fish and other marine life are rich sources of ω-3 Fatty acids [EPA & DHA], especially the low value fishes such as sardine, mackerel, anchovies etc. EPA and DHA are essential for the development of brain and heart tissue. EPA and DHA play a major role in modulating lipid and prostaglandin metabolism, required for proper functioning of vascular system in growing children. They also influence kidney function by modulating retention of water and removal of excess sodium, which plays a major role in a child's behavior. DHA enhances memory power and is critical to normal eye and vision development in the early and later stages of life of a human being.

Minerals

Minerals are inorganic substances required by the living organisms to accomplish many of their biological functions. Fish and shellfish are valuable sources of Ca & P, and trace elements, Fe, Cu, Se, Zn. Fish is also good source of magnesium, sodium, potassium, chlorine and iodine. Calcium powder from fish bones and back bone of tuna can be used to combat calcium deficiency in diet, particularly of children. Salt water fish have high content of iodine essential for brain and thyroid function. Sodium content in fish is relatively low, making it suitable for low sodium diets. Tuna is a rich source of macro minerals like Mg, which contributes to hardness of bone and acts as cofactor for certain enzymes important in nerve and muscle function. Tuna is also an important source of essential antioxidant trace element Se that provides protection against heavy metal poisonings and a variety of carcinogens. Crustaceans and shellfish are richest source of Cu essential for normal blood formation, maintenance of blood vessels, tendons and bones and health of central nervous system.

Carbohydrates

It is not nutritionally important component in the fish muscle. The major carbohydrate present in fish is glycogen and it is stored mainly in liver. Unlike fish and crustaceans, molluscs have high glycogen content in the range of 1-7%. It plays a significant bearing in post martom rigor changes in the fish flesh.

Vitamins

Vitamins are low molecular weight substances performing important roles in regulating the bodily functions. Fatty fishes are rich in fat soluble vitamins (A, D & E). Fish is also relatively good source of water soluble vitamins of B group. Fish meat, liver, eggs, milt and skin are good sources of B vitamins, thiamine, riboflavin, pyridoxine, folic acid, biotin and cyanocobalamin. Regular consumption of fish helps in preventing anemia especially pernicious anemia. Fatty or semi fatty fishes are excellent sources of fat soluble vitamins, vitamin A- essential for normal vision, vitamin D-plays an important role in calcium and phosphorous metabolism; vitamin K- an anti-hemorrhage factor; vitamin E-a potent antioxidant involved in counteraction of free radical mediated oxidative damage to the cell membranes. Large quantity of vitamin A, D and E (500-3000 IU) are present in liver and body oils of shark and tuna.

Laboratory protocols for the analyses of biochemical constituents

Preparation of sample

Wash the fish with clean water to remove sand/mud debris, if any and cut the fish into small pieces after removing the fins, scales, bones etc. and homogenize well in a blender. Grind the pieces as smoothly as possible for obtaining a uniform mixed sample. Keep the material in an air-tight container, at low temperature, to prevent the loss of moisture during subsequent handling. This material can be used for most of the biochemical analysis.

Determination of Moisture Content

The water content of many fresh foods, including fish ranges from 60 to 95%. The water content of dried food stuffs are kept very low in order to extend shelf life. The most common methods for water analysis are the following:

- Oven drying (98-100°C)
- Vacuum oven drying (60-70°C)
- Infrared analysis
- Room temperature drying/vacuum desiccator
- Karl Fischer Method etc.

In the above mentioned methods oven drying is most easy and commonly used for determining moisture content

Oven drying

Apparatus

- Petridishes
- Weighing balance
- Hot air oven

- Desiccator

Procedure

Weigh2-10g of homogenized material in a flat bottomed metallic plate/or a clean dried petridish pre-dried at 98°C for 60 min. Dry the sample by heating for a period ranging from 2 to 3 h. to overnight in an hot air oven at 100+1°C. Weigh the sample periodically until it reaches a constant weight (+ 2mg). The percent moisture content can be calculated from the difference between the initial sample weight (W_1) and the final sample weight after drying (W_D)

$$\% \text{ Moisture} = \frac{W_1 - W_D}{W_1} \times 100$$

During oven drying, at high temperature, volatile components (flavour components) can be lost by evaporation along with moisture. Care is needed to avoid rehydration of dried material from moist air. Samples should be covered (preferably in desiccators) and weighed as soon as possible after drying and cooling.

Determination of Crude Protein (Kjeldahl Method) – AOAC Method

The most universally accepted method for determining total nitrogen or crude Protein in fish is the so called Micro Kjeldahl method. First, the food to be analysed is treated with concentrated sulphuric acid at high temperature, in presence of a catalyst, digestion mixture (a mixture of $CuSO_4$ and K_2SO_4 in the ratio 1:8). Digest over a burner till solution turns colourless. $CuSO_4$ acts a catalyst and K_2SO_4 elevates the boiling point of H_2SO_4 from 324°C to 400°C. $HgCl_2$ or SeO_2 can also be used as a catalyst.

The protein content in the food is calculated by estimating the nitrogen content and multiplying with a factor calculated based on the nitrogen content of the food. This is referred to as crude protein content because the non-protein nitrogen (NPN) is not excluded from the total nitrogen. The true protein content can be calculated by subtracting the NPN from the crude protein nitrogen before multiplying with the factor.

Principle

The nitrogenous compounds in the sample are converted in ammonium sulfate on treating with concentrated sulfuric acid. Upon distillation with excess alkali, the ammonia is liberated which is absorbed in 2% boric acid and is estimated by titration with standard N/50 sulfuric acid.

Apparatus

- Kjeldahl digestion flask
- Kjeldahl distillation apparatus
- Standard flasks
- Conical flasks
- Pipettes

Reagents

- *Con. Sulfuric acid* (AR).
- *Digestion mixture*: Mix copper sulphate ($CuSO_4.5H_2O$) and potassium sulphate (K_2SO_4) in the ratio 1:8 and powder finely.
- *40% Sodium hydroxide*: Dissolve 40 g sodium hydroxide crystals in 100 mL distilled water and cool.
- *2% Boric acid solution*: Dissolve 20 g boric acid in 500 mL hot distilled water, cool and make up to 1 liter.
- *N/50 Sulfuric acid*: Standardized
- *Tashiro's indicator*: Stock solution: (a) 0.2 % alcoholic methyl red; (b) 0.2% alcoholic methylene blue. Mix 100 mL (a) with 50 mL (b)
- Working solution: Mix 1 vol. stock, 1 vol. Alcohol and 2 vol. Water.

Procedure

Weigh 1 to 2g of homogenized wet sample (or 0.2 to 0.5g of the well minced/powdered dry sample) into a Kjeldhal flask (digestion flask) of 100mL capacity. Add a few glass beads and a pinch of digestion mixture ($CuSO_4$ and K_2SO_4) and 10mL of AR sulphuric acid. Digestover a burner till solution turns colourless. $CuSO_4$actas catalyst and K_2SO_4 elevates the boiling point of sulphuric acid from 324°C to 400°C.

To the digested and cooled solution in the digestion flask add distilled water in small quantities with shaking and cooling till the addition of water does not generate heat. Transfer quantitatively into a 100mL standard flask and make up the volume. Transfer with a pipette 5mL of the made up solution to the reaction chamber of the micro-Kjeldal distillation apparatus. Rinse down with distilled water. Add two drops of phenolphthalein indicator and 40% sodium hydroxide till the indicator changes to pink. Distill for four minutes and absorb the ammonia liberated in 2% boric acid (10mL) containing a drop of Tashiro's indicator and determine the amount of ammonia by titrating with $\frac{N}{50}$ sulphuric acid.

$$\% \text{ of crude protein} = \frac{\frac{14}{50} \times \text{Vol}\frac{N}{50} \times H_2SO_4 \times 100 \times 100 \times 6.25}{5 \times \text{weight of sample} \times 1000} \quad \text{OR}$$

$$\frac{\text{N} \times 14 \times 6.25}{\text{wt. of sample}}$$

Where: N is % nitrogen

- The main source of error is the presence of non-protein nitrogen compounds associated with some foods. High concentration of peptides, amino acids, nucleic acids or urea will give false positive results.
- Kjeldahl analysis can be used to determine nitrogen levels in a wide variety of agricultural materials ranging from fertilizer to feeds.

Determination of Crude fat (Soxhlet method)

Fat from dried sample is extracted repeatedly using petroleum spirit as solvent at high temperature. The fat soluble in the hot petroleum ether, except phospholipid, is extracted from the sample and quantified.

Principle

Fat soluble in organic solvents can be extracted from moisture free samples by using solvents like petroleum ether, ethyl ether etc. The solvent is evaporated and fat is estimated gravimetrically.

Apparatus

- Soxhlet extraction apparatus
- Thimble
- Flat bottom flask
- Water Condenser
- Desiccator

Reagent

- Diethyl ether or Petroleum spirit (60-80°C)

Procedure

Weigh, accurately 5 –10 g (W1) of dried sample in to a thimble and keep a cotton plug on top of it. Place the thimble in a soxhlet apparatus and add 1½ volumes of ether (approximately 200mL) in to a pre-weighed flat bottom flask (w_2) and distill for 16 h. (Cool the apparatus and filter the solvent in to a pre-weighed conical flask (W_2). Rinse the flask of the apparatus with small quantities of ether and then add washings to the above flask). Remove ether by evaporation and dry the flask with fat at 80 –100°C, cool in a desiccator and weigh (W3).

Calculations

$$\text{Fat content (g/100\%)} = \frac{(W3-W2) \times 100}{W1} = X$$

$$\text{Fat content (g/100\%)} = \frac{\text{Weight of fat} \times 100}{\text{Weight of sample}} = \text{'X'}$$

Where W1- weight of dry matter taken for extraction; W2 – weight of flat bottom flask and W3 – weight of flask with fat

Conversion of dry weight to wet weight basis

$$\text{Wetweight} = \frac{\text{'X'} \times (100\text{-Moisture})}{100}$$

Estimation of Ash content

Principle

Ash is the residue obtained after incineration of the dry material at high temperature and appears as grey- white colured powder.

Apparatus

- Crucible
- Muffle furnace
- Desiccator

Procedure

Heat a platinum or silica crucible to 600°C in a muffle furnace for one hour, cool in a desiccator and weigh (W1). Weigh accurately 2 g of the dried sample (w_2) in to a crucible and heat at low flame by keeping on a clay triangle to char the organic matter. Keep the charred material inside the previously set (600°C) muffle furnace and heat for 6-8 h to get white or greyish white ash. Cool the crucible in a desiccator and weigh (W3). Heat the crucible again for further 30 min to confirm completion of ashing, cool and weigh.

Calculation

$$\% \text{ Ash content (g/100g)} = \frac{(W3 - W1) \times 100}{(W2 - W1)}$$

Where;

W1 – weight of crucible and
W2- weight of dry matter with crucible taken for ashing
W3 – weight of crucible with ash

The minerals like sodium, potassium and calcium are estimated using Flame Photometer after dissolving the ash in dilute hydrochloric acid (6N). The reading is compared against standard solutions of the respective minerals.

Determination of carbohydrates

Principle

Carbohydrate is determined by the furfural colorimetric method after treatment with concentrate sulphuric acid. The intensity of the pink colour is measured at 520 nm.

Reagents

- Concentrated sulphuric acid AR
- 10% Trichloroacetic acid (TCA)
- Weigh 10g. of pure TCA dissolved in water and diluted to 100 mL.

- Silver sulphate
- Standard glucose solution
- Prepare a series of glucose standard for preparing the calibration curve

Procedure

Carbohydrate was determined by the furfural colorimetric method after treatment with con. H_2SO_4. About 30-50 mg of material was weighed out into a 20 mL centrifuge tube and heated in a boiling water bath for 30 minutes with 4 mL of 10% TCA and about 30 mg of Ag_2SO_4. After centrifuging, the clear supernatant and the subsequent washings of the residue with the TCA solution were transferred to a 25 mL graduated flask and made upto the volume. 2 mL aliquots were taken in duplicate and carefully layered over 6 mL of concentrated H_2SO_4 taken in a boiling tube. The tubes were quickly agitated to mix the contents thoroughly and then heated for 6.5 minutes in a vigorously boiling water bath. After rapid cooling to room temperature (~28°C) the optical density was measured at 520 nm. Blanks were run with each batch of analysis. Glucose was used to obtain the standard curve (Heath and Barnes, 1970).

Determination of Amino Acid Composition

Principle

Protein is hydrolysed to their constituent amino acids by 6N hydrochloric acid. The amino acids are separated in a HPLC equipped with an ion exchange column. Two buffers (pH 3.2 and pH 10.0) are used to elute the amino acids from the column and the individual amino acids are estimated by their fluorescence intensity, imparted on to the individual amino acids by reaction with o-phthalaldehyde in the presence of sodium hypochlorite solution, using a fluorescence detector.

Apparatus and facilities

- HPLC equipped with ion exchange column and fluorescence detector
- Rotary vacuum flash evaporator
- Fusing instruments
- Nitrogen gas

Reagents

a) 6N Hydrochloric acid

b) HPLC buffers -

Buffer A: Dissolve 13.31 g tri sodium citrate in 70 mL ethanol; add 12.8 mL citric acid (monohydrate), 3.74g. NaCl and 4 mL Brij; adjust pH to 3.2 and finally make up to 1L with distilled water.

Buffer B: Dissolve117.6 g Tri sodium citrate and 24.8g boric acid in 500 mL distilled water; add 45 mL 4N NaOH, adjust pH to 10 and make up to 2 L with distilled water.

c) O-pthalaldehyde(OPA) buffer – Dissolve 40.7g sodium carbonate, 13.57g boric acid and 18.8g potassium sulphate in distilled water and make up to 1 L with water.

d) O-phthalaldehyde (OPA) reagent : Dissolve 80 mg OPA, 1.4 mL ethanol, 0.2 mL 2-mercaptoethanol and brij 0.15 mL in distilled water and make up to 200 mL in OPA Buffer

e) Sodium hypochlorite solution**:** 0.2 mLsodium hypochlorite diluted to 200 mL in OPA buffer.

Preparation of sample

Weigh about 100 mg of finely homogenized fish mince in to a borosil test tube. Add 10 mL of 6N HCl in to the test tube. Seal the tubes after filling nitrogen and digest the contents of the tube by keeping at 110°C for 24 hours in an oven. Cool the test tubes and filter the contents using Whatman No.1 filter paper. Rinse the tubes with distilled water and filter. Evaporate filtrate in a vacuum flash evaporator. Add deionised water in to the tubes and continue evaporation until the contents are acid free. Generally, three washings with 50 mL water are required. Dissolve the amino acids in buffer A and inject in to HPLC.

HPLC Analysis

The separation and quantification of amino acids is carried out using an HPLC with an ion exchange column. Filter samples using 0.45μm syringe filter and inject appropriate quantities in to the HPLC system as per the specifications of the injector. The eluted amino acids are derivatized post column with O-phthaldehyde (for fluorescence detector).

Instrument details

- Equipment
- Model Hitachi L-2130 Elite La Chrom
- HPLC equipped with
- Auto sampler L-2200

- FL detector L-2485
- Wave length
- Ex: 340 nm
- Em: 450 nm
- Column Oven L-2350
- Column Shodex
- CX Pak
- P-421S and
- Two channel peristaltic pump

Calculation

$$\frac{\text{Conc. of Std AA } (\mu \text{ mol}) \times \text{Area of sample AA}}{\text{Area of Std AA}} = \text{Conc. of sample AA as } \mu \text{ mol}$$

$$\frac{\text{Conc. of sample AA} \times \text{Mol. Wt of AA} \times 1000 \times 100 \times 16 \times \text{Vol. made up}}{10 \times 1000 \times 1000 \times \text{wt. of sample} \times \% \text{ of } N_2} = AAg/16gN_2$$

Spectrophotometric Determination of Tryptophan

Tryptophan being labile to the conditions of hydrolysis described for other amino acids, it is estimated separately by spectrophotometer after alkali hydrolysis of the protein.

Principle

The 5-hydroxy furfural resulting from sucrose under acidic conditions of reaction forms pale green coloured condensation product with thioglycolic acid, which reacts with tryptophan in the hydrolysed protein giving a pink coloured complex. The colour intensity of the solution is measured at 500 nm.

Reagents

- **Sodium hydroxide**: 5% solution
- **Hydrochloric acid - 6 N solution**: Dilute A.R. concentrate Hydrochloric acid in the ratio 1:1 using ditilled water
- **Sucrose**: 2.5 % solution

- **Thioglycolic acid**: (80% solution) - 0.6 mL diluted to 100 mL (V/V) distilled water;
- **Sulphuric acid**: 50 % solution, v/v
- **Tryptophan standard**: Stock- 1 mg per mL solution in 0.1 N HCl;
- **Working standard**: 1 mL stock in 100 mL of 0.1N HCl to get 10 µg/mL solution

Procedure

Sample preparation

Weigh about 300 mg of finely homogenized fish mince in to a test tube. Add 10 mL of 5% NaOH in to the test tube. Seal the tube after filling with nitrogen gas and digest the contents of the tube by keeping at 110°C for 24 hours in an air oven. Neutralise the contents after hydrolysis to pH 7.0 using 6N HCl. Total volume is made to 100 mL and filter through Whatman No.1 filter paper

Estimation

Add 0.1 mL 2.5 % sucrose and 0.1 mL 0.6% thioglycolic acid successively in to a test tube containing 4 mL of 50% H_2SO_4. Keep the tubes in a water-bath at 45-50°C for 5 min. and cool. Aliquots (0.1 – 0.8mL) of sample was added to the test tube and mixed. Make the volume of the test tube to 5 mL with 0.1N HCl and leave aside for 5 min. Measure the colour intensity at 500 nm. For standards, add tryptophan standard solution in to a series of test tubes instead of sample and perform experiment as above. Calculate the concentration using a standard graph or by regression.

Calculation

$$\frac{\text{µg of trypt obtained by regression x vol. made x 100 x 16}}{\text{Vol. for colour development x sample wt. x 1000 x 1000x } N_2\%} = \text{g/16g } N_2$$

Determination of Fatty Acid Profile by Gas Chromatograph

Fat Extraction

The wet fish/shellfish muscle is homogenized with 2:1 mixture of chloroform and methanol. The chloroform-methanol mixture extracts the total lipid from the tissue in to a single phase of solvent. Disturbing the equilibrium between chloroform and methanol separates the chloroform soluble fat.

Apparatus

- High speed stirrer or mortar and pestle
- Buckner flask & Buckner funnel
- Filter paper
- Vacuum flash evaporator
- Water bath

Reagents

- Chloroform (Excelar grade)
- Methanol (AR grade)
- Chloroform- methanol mixture: (2:1)
- Anhydrous sodium sulphate

Procedure

Extract about 25 – 50 g (depending on the fat content) meat with 15 volumes of chloroform - methanol mixture for two minutes in the case of high speed stirrer or five minutes in the case of mortar and pestle (few grams of acid washed sand can be added at the time of grinding in mortar). The extraction and filtration is carried out in three steps. Filter the extract using a Buckner funnel with Whatman No.1 filter paper, applying little vacuum. Take the combined extract in to a separating funnel, add 20% of the volume water, mix well and allow to separate overnight. Collect lower layer and filter through sodium sulphate. Concentrate lipid to a known volume, say 10 ml, by evaporating the solvent in a vacuum flash evaporator and keep under nitrogen pending analysis. Take 1 mL of aliquot in a pre-weighed test tube and evaporated it off. The test tube is cooled in a desiccator and weighed.

Calculation

$$\text{Fat content (g/100g meat)}: \frac{W_2 \times V_1 \times 100}{V_2 \times W_1}$$

Where: V_1 : total volume of extract

V_2 : Volume of extract taken for drying

W_2: weight of dried lipid

W_1: weight of sample for fat extraction

Reagents

- 150% *Potassium hydroxide* – 3g Potassium hydroxide in 2 ml D/W
- *Petroleum ether*
- Std***: FAME*** mix (Fatty Acid Methyl Ester mix)
- *Methanol*
- *Boron trifluride-Methanol* **(BF_3–Methanol)**
- *Sodium chloride (saturated* solution)

Saponification and separation of non-saponifiable matter

Take appropriate volume of lipid (containing minimum 250 mg fat) evaporate solvent, add 30 mL methanol and 1.5 mL 150% KOH. Reflux for 30 min. in a boiling water bath under N_2. Cool slightly, transfer the solution into a separating funnel, add 20 mL D/W. Extract 3 times with 20 mL of Petroleum ether. Keep aqueous layer for fatty acid estimation. Pool extract (Non saponifiable matter) wash N.S. matter with D/W to make it alkali free (check washings with phenolphthalein). Note volume of NSM. Dry over Na_2SO_4. Keep aside for further analysis (cholesterol).

Extraction of fatty acids

Acidify the aqueous layer with Con. HCl. Check with pH paper. Extract 3 times with petroleum ether. Combine extract, wash with D/W 3 times. Filter through anhydrous Na_2SO_4. Flash evaporate to remove the solvent.

Preparation of fatty acid methyl ester

Add 6 mL BF_3-Methanol into the above flask containing fatty acids. Reflux in a boiling water bath for 6 min. Cool, add 6 mL.saturatedNaCl, transfer to a separating funnel. Extract 3 times with Petroleum ether, filter through Na_2SO_4, evaporate and make upto 1 mL in PE for GC analysis. The complete analysis should be done under N_2.

Fatty Acid Methyl Ester – Direct Method

To 100 mg of fat/oil, add 5 mL of 0.5 N Methanolic NaOH (1 g NaOH in 50 mL Methanol). Reflux for 5 min in a boiling water bath under N_2. Add 6mL BF_3-Methanol, boil for 5 more minutes. Cool and add 6 mL Sat. sodium chloride, extract thrice with Petroleum ether, pool extract and wash with water. Filter through Na_2SO_4, evaporate and make upto 1 mL in Petroleum ether for Gas chromatographic analysis.

Gas Chromatographic Analysis

The Gas chromatograph programme for analysis of fatty acid is as follows:

Programme of GC; *Injector 265°C;*

Flame Ionisation Detector (FID) at 275°C; Capillary column (Elite -225) (30m, 0.25mm i.d, 0.25 µm);

Carrier gas, *Nitrogen* at 0.6 mL / min ; Temperature programme – 110°C for 4 min; temperature is programmed to raise at 2.7°C/ min to 240°C and maintained at that temperature for 5 min; *Split flow* 20 mL.

Sample 1 µl injection; Samples are identified by retention time by comparing with respective standards using Chromcard software; Area of each component is obtained from the computer-generated data and concentration calculated using the software by external standard method.

Calculation

$$\text{mg/g of sample} = \frac{\text{Area of sample x Con. Std x total vol. of extract x final vol. made up (FAME)}}{\text{Area of std. x vol. of lipid extract taken for FAME x wt. of sample}}$$

DETERMINATION OF FAT SOLUBLE VITAMINS

Principle

High performance liquid chromatography (HPLC) is now used regularly for the analysis of fat soluble vitamins in a wide range of foods. It offers many advantages over traditional methods of analysis in particular with regard to speed, sensitivity and selectivity. An extraction step prior to chromatographic determination is required for cleanup and concentration of vitamins.

Reagents

Chloroform :methanol 2:1; BHA or BHT; KOH -150%- 3 g KOH in 2 ml water; Methanol; Petroleum Ether; Water with 1% TFA; Acetonitrile with 1% TFA

Alpha tocopherol (vit E), cholcalciferol (vit D), retinol(vit A), vitamin K - Stock solution of 1ppm is prepared in hexane and stored in brown bottles at 20C. Working standard solutions were made by appropriate dilutions.

Procedure

Sample preparation

Grind fish tissue (20g) with anhydrous sodium sulphate and extract oil using 2:1 chloroform : methanol after adding BHA or BHT as antioxidants (Folch's method). To about 2g oil in a RB flask, add 25 ml alcohol, & 1.5 ml of 150% KOH. Reflux in a water bath for 30 min. Transfer the contents in to a 250 ml separating funnel after cooling; wash the flask with 50 ml petroleum ether and add to the separating funnel; shake the content of the separating funnel thoroughly and allow to separate. Extract the aqueous layer twice more and the pool solvent layer. Wash the solvent layer with two 20 ml portions of water to make it alkali free. Concentrate non-saponifiable matter in the ether fraction using a flash evaporator at 30 – 40°C to a definite volume. NSM is filtered through 0.45µ syringe filter and stored under refrigeration.

Chromatographic analysis

The HPLC consisting of a quaternary gradient pump, programmable variable wave length UV detector is used for the analysis.

Column: C18 RP 5µ 250 x 4 mm Atlantis (Waters Corporation) or related

The mobile phase - water with 1% TFA (A) and acetonitrile with 1% TFA (B) at 1 ml per min. The programme made in the HPLC is as follows.

Time (min)	Mobile phase B	Mobile phase A
0	50	50
5	80	20
6	100	0
10	100	0
20	100	0

The fat soluble vitamins elute from the column in the order vitA, vit D, vit E and vit K.

The wavelength used for eluting different vitamins is as follows. 265nm for vitamin D3, 325 for vitamin A, 291nm for vitamin E and 250 for vitamin K.

Calculation

The vitamin content in the unknown sample is determined from the linear graph drawn for the standard.

MINERAL PROFILING

The ash estimated under 'Experiment 4' of Biochemical analysis is dissolved in 100 ml 6N HCl quantitatively. The solution is appropriately diluted and aspirated in to the AAS for quantification.

The following steps are to be followed.

1. The AAS is switched on.
2. Three sets of concentrations are aspirated and the calibration line is drawn.
3. The cell tubes are washed with water
4. The sample is placed and aspirated and the reading is noted. The calculation is made based on the reading and dilution.

Calculation: The concentration of metal is detected in mg/l or PPM.

Metal mg/100g = (Conc. of metal in PPM x volume made) / weight of sample

Chapter 21

Microencapsulation for food fortification

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Micronutrient deficiency

Micronutrient deficiencies are the cause for widespread health problems, especially in developing countries. The deficiencies in vitamin A, iron, and iodine have been identified as the greatest concern, as they affect over one third of the world's population (WHO, 1995). In addition, these micronutrients interact with each other, i.e., synergistic effects between iodine deficiency disorder (IDD) and iron deficiency anemia (IDA), or between vitamin A deficiency (VAD) and IDA to deepen their negative impacts (Lonnerdal, 2004; Lynch, 1997; Zimmermann et al., 2004). Deficiencies typically coexist in children in developing countries (Zimmermann et al., 2000).

70% of people in India do not consume enough micronutrients such as vitamins and minerals. About 70% of pre-school children suffer from anaemia caused by iron deficiency and 57% of preschool children have sub–clinical Vitamin A deficiency. Neural Tube Defects (NTDs) are the most common congenital malformation with an incidence that varies between 0.5-8/1000 births. It is estimated that 50-70% of these birth defects are preventable. One of the major causes is deficiency of folic acid. Thus, micronutrient deficiency also known as "hidden hunger", is a serious health risk. Unfortunately, those who are economically disadvantaged do not have access to safe and nutritious food. Others either do not consume a balanced diet or lack variety in the diet because of which they do not get adequate micronutrients. Often, there is considerable loss of nutrients during the processing of food.

Addressing micronutrient deficiencies

Micronutrient deficiencies can be addressed in three ways namely by making changes in the diet, through supplementation, and by means of fortification of food with selected nutrients. While dietary modification is desirable, it is a long-range solution and may require changes in food preparation practices and social customs. Supplementation is an effective and rapid approach, but it requires appropriate medical infrastructure/administration and thus it is costly. Food fortification is a cost-effective intervention that does not require any conscious action by the consumer, and needs no changes in the dietary habits of the target populations. Moreover, it is readily adapted into existing food production and distribution systems.

Food fortification has been extensively used for many years as a cost-effective strategy for combating micronutrient deficiencies. It is the addition of key vitamins and minerals such as iron, iodine, zinc, Vitamin A & D to staple foods such as rice, milk and salt to improve their nutritional content. Fortification strategy is the best long-term approach and the cheapest way to initiate and maintain the desired micronutrient levels in the diet.

Advantages of fortification

1. Since staple foods that are commonly consumed are enriched with nutrients, this is a splendid method to improve the health of a population with lesser effort.

2. Fortification is a safer way of ensuring better nutrition among people. Since fortification is done as per guidelines in accordance with approved standards, an overdose never occurs.

3. It is not necessary for people to make changes in their routine food habits.

4. It is a socio-culturally acceptable way to deliver nutrients to people.

5. Food characteristics are not altered by fortification.

6. Implementation of fortification programs can be swiftly done . The positive impact on nutritional status is quickly evident too.

7. If the existing technology and delivery platforms are taken advantage of, fortification can be very cost-effective.

8. It has a high benefit-to-cost ratio. The Copenhagen Consensus estimates that every rupee spent on fortification results in a benefit of Rs nine.

Fortification programs worldwide

Many fortification programs have been implemented worldwide, including universal iodization of salt and enrichment of B vitamins in wheat flour. 70% of the world's population consumes iodized salt now significantly reducing the incidence of iodine deficiency disorders (IDD) over the past three decades (United Nations, 2008). The introduction of folic acid into cereal-grain products in over 40 countries has resulted in dramatically increased folate status and significant reduction in the risk of neural tube defects in newborns (Buttriss, 2005).

Globally, 87 countries have legislation to mandate fortification of at least one industrially milled cereal grain. In addition, ten countries fortify more than half of their industrially milled wheat or maize flour through voluntary efforts. These include Afghanistan, Democratic Republic of Congo, Gambia, Lesotho, Namibia, Qatar, Swaziland, the United Arab Emirates, Lesotho and Namibia.

Fortification efforts in India

In October 2016, the Food Safety Standards Authority of India published draft standards for food fortification. The draft for wheat flour fortification is in line with global fortification recommendations for iron, vitamin B12, and folic acid. In Haryana, fortifying flour for the mid-day meal, infant child development, and public distribution systems is expected to have a significant health impact. In 2000, Darjeeling in West Bengal was the first place to fortify wheat flour. About 7.6% of the industrially milled wheat flour in India is fortified presently. Fortified rice is available through social safety net programs in the states of Odisha and Karnataka. Rajasthan has taken the lead in fortified oil and fortified milk, which are being sold across the entire state. Flour fortification is supported by the government of India and several state governments. Active involvement of international agencies, national health and nutrition research institutions, and flour milling professionals have contributed toward wheat flour fortification. Most fortified flour in India is distributed in the government's welfare system.

Fortification criteria

All successful fortification programs have some common features, i.e., they are effective in reducing the prevalence of specific micronutrient deficiencies, they are economically viable, and the fortified products enjoy consumer acceptance. To meet these criteria, several technical factors need to be considered, including selection of food vehicles and fortificant forms, determination of fortification levels and quality assurance and quality control of the fortified food products. Among these, food vehicle selection determines whether food fortification programs are effective as an ideal carrier guarantees that the micronutrients reach the largest number of people.

Selection of food vehicle for fortification

Varieties of food or food ingredients have been considered for fortification, including cereal and grain products, milk and dairy products, fats and oils, infant formula and weaning foods, condiments such as salt, sugar, and monosodium glutamate (MSG), as well as a range of processed foods (Lofti et al., 1996). It is generally accepted that staple foods, such as salt, sugar, wheat flour, and rice, are good carriers for fortification, since they are regularly consumed by all of the target population at a fairly constant rate, and are relatively inexpensive so that all segments of the target population could afford them. The global salt iodization is an example of effective programs that improve human nutrition, mainly due to the attributes of the food vehicle – salt. It is universally consumed and is open to a simple fortification technique, which makes the program affordable. In ICAR-Central Institute of Fisheries Technology, fish soup powder was used for fortification. Interestingly, fish is probably the most affordable source to provide almost 40 essential nutrients. Fish soup powder incorporating the nutritional goodness of fish and fortified with iron and calcium by taking into account WHO-recommended RDA values has been developed at ICAR-Central Institute of Fisheries Technology, Kochi. Integrated Child Development Scheme(ICDS), Jowai, West Jaintia District Hills District, Meghalaya and Health Department, Jowai, Child Development Project Officer, Thadlaskein Block, Jowai, and ICAR-CIFT Scientists chalked out a one month program of distributing fortified fish soup to adolescent girls selected to improve their hemoglobin levels and health status. Fifty adolescent girls,age ranging from 11-16 whose blood hemoglobin levels were 9 or below, were recruited for the study. The intervention was closely monitored by ICDS officials which ensured 100% compliance. Blood hemoglobin analysis post intervention showed that all the adolescent girls recorded a statistically significant rise.

Selection of fortificants

Selection of appropriate forms of fortificants is vital. Some vitamins and minerals could be simply added into selected food carriers in powder form, which involves solid-solid blending or solid-liquid mixing. These methods are straightforward and low in cost, but usually ineffective in protecting the micronutrients within the fortified foods. Moreover, the incorporation of these minor ingredients often causes undesirable sensory changes in the fortified foods, such as off-flavours or colors caused either by the additives themselves or the interactions between the additives and the food vehicles. Ignoring sensory effects and physical/chemical properties leads to major concerns regarding product stability and consumer acceptance that may jeopardize the success of a fortification program. Microencapsulation of nutrients can be effective in delivering fortificants into fortified foods.

Challenges confronted during fortification

A major challenge for food fortification programs is the development of stable forms of micronutrients that overcome the instability of vitamins and the reactivity of minerals. For instance, vitamin A is sensitive to almost all environmental factors, including light, heat, oxygen, and chemical interactions. The difficulty with iron is in finding an appropriate chemical form which is adequately absorbed and yet does not alter the appearance or taste of the food vehicle (Mannar & Gallego, 2002). In addition, the presence of reactive iron compounds significantly affects the stability of other vitamins added in the same food matrix. It is important to prevent interactions between added micronutrients and the food system, and subsequently ensure stability, bioavailability, and sensory properties of the fortified food through production, distribution, retail, and food preparation.

Microencapsulation of nutrients

The best approach for delivering two or more micronutrients simultaneously in a stable and bioavailable form without interaction and degradation, is to microencapsulate them in an inert, but digestible matrix separated from other food components and other added micronutrients. Nutrients are added as concentrated, encapsulated premixes with modified physical and chemical properties, favourable for adding into selected food carriers without greatly reducing their bioavailability. Microencapsulation can also improve the sensory properties of the fortified foods by hiding the undesirable colours and tastes from the fortificants and by preventing the interactions between the fortificants and the food carrier. The microencapsulation-based technology allows the fortificants to be delivered in appropriate forms that resemble the physical characteristics of the selected food vehicles, in terms of shape, size, colour, and appearance. Microencapsulation-based approach allows for multiple micronutrient fortification of a wide variety of staple foods with particle sizes ranging from several hundred microns to several millimeters. To prevent particle segregation, which may result in potential under- or over-dosing, micronutrients must be added in forms that either stick to the food particles, or in agglomerated premixes that match the particle size, and if possible, the particle density of the food. Successful food fortification processes require that the added micronutrients are evenly distributed and are unnoticeable to the consumer. Thus the complete delivery system must match the food in colour and appearance, and must not alter the food flavour.

Microencapsulation is defined as the application of thin polymeric coating to individual core materials (tiny particles or droplets of liquids and dispersions) that have an arbitrary particle size range from 5-5000 micron (Rawdwick and Burgess 2002). It enables conversion of liquids to solids, which alter colloidal and surface properties, provides protection and controls the release characteristics of different coated materials (Deepak et al. 2013). Encapsulation involves the entrapment of an active compound within another polymeric substance . Microencapsulation finds applications in many areas such as pharmaceutical, nutraceuticals and cosmetic industries (Sanguansri et al., 2013). A large number of core materials like live cells, adhesives, flavors, agrochemicals, enzymes, pharmaceuticals antioxidants, color, pigments, probiotics, aminoacids, essential oils, herb extracts, flavours, sweetners etc., can be encapsulated. The important benefits associated with the encapsulation of bioactive compounds are as follows:

1. For better handling of the bioactive components.
2. The bioactive components which are sensitive to moisture light and oxygen can be protected by microencapsulation.
3. Protection of active components from factors that can cause oxidation and hence a prolonged shelf life.
4. The compounds, which are volatile in nature and vaporize at room temperature, can be prevented by microencapsulation.
5. The microencapsulation process can also help to mask undesirable odours and flavours in the final product.
6. For the controlled release of active components, especially in the case of drug delivery systems.

Structure of a microcapsule

The size of the microcapsule ranges from 5-300 micron in diameter. It has a continuous core region surrounded by a continuous shell called wall material. The wall material may consist of one or more materials. Microcapsules are categorized according to their morphology as mononuclear, polynuclear and matrix. The mononuclear microcapsules contain the wall material layer around the core, polynuclear microcapsules will be having number of cores enclosed within the wall material. In matrix type, there is a homogenous distribution of the core in the wall material. Since the wall material has an important role to play in many aspects such as encapsulation efficiency, stability as well as the protection of the core compound, a proper selection of the wall material is an important task. Composition of the wall material determines the functional properties of the microcapsule and how it may be used to improve the performance of a particular ingredient.

The wall material selection depends on number of factors such as solubility, molecular weight, glass transition temperature, diffusibility, film forming and emulsifying properties etc. Moreover, the main role of wall material is to protect the core material from oxidation and allow controlled release. Apart from this, the cost of wall material also has to be taken into account because the total process should be economical.

An ideal coating material exhibits the following characteristics:

- Good rheological properties at high concentration during encapsulation.
- Ability to disperse or emulsify the active material and stabilize the emulsion produced.
- Non-reactivity with the material to be encapsulated during processing and storage.
- Ability to seal and hold the active material within its structure during processing or storage.
- Ability to release the solvent used during encapsulation under desolventization conditions.
- Ability to provide protection to the material against oxygen, heat, light, humidity.
- Solubility in solvents acceptable in the food industry (e.g., water, ethanol).
- Chemical non-reactivity with the active core materials.
- Inexpensive, food-grade status.

Commonly used Wall materials or coating materials

- Carbohydrates-Modified starches, Hydrolysed starches (maltodextrins) Starch, chitosan, corn syrup solids, dextran, cyclodextrins, sucrose, Gum Arabic, Modified starch, Agar, Alginates, carrageenan, pectin,
- Cellulose- Carboxymethyl cellulose,methyl cellulose, ethylcellulose, celluloseacetate- phthalate, celluloseacetate butylate-phthalate
- Gum -Gum acacia, agar, sodium alginate, carrageenan

- Fats and waxes- Hydrogenated vegetable oils, Bees wax, paraffin, diacylglyerols, oils, fats

Proteins- Gelatins (types A and B), Sodium caseinates, Whey protein isolate, albumins, peptides, skimmed milk powder

Fortification of foods through Microencapsulation

Conventional way of incorporating the nutrients often alters the physical, chemical and functional properties of the fortified food. Microencapsulation for food fortification is very useful techniques as it delivers staple forms of micronutrient in a bioavaiable form. This technology overcomes the instability of vitamins and reactivity of minerals in the processed products. It maintains the active ingredients in a stable environment, separated from other food components and thereby preventing undesirable changes in fortified foods. This technology can be a best approach for delivering two or more micronutrients simultaneously in a stable and bio-available form.

Microencapsulation Technologies

1. Spray drying

One of the most commonly used microencapsulation technology is spray drying which finds wide range of applications in food and pharmaceutical industries. It is a very economical, flexible, efficient, easy to scale-up technology which produces good quality powder with low water activities that can be easily stored and transported (Ashady, 1993). The process of spray drying involves the dissolution of wall material and core material resulting in the formation of an emulsion, followed by proper homogenization, pumping of the emulsion, atomization of the emulsion and the subsequent dehydration of the atomized droplets to yield microcapsule. The size of microcapsules formed will depend on the concentration of solids content in the dispersion content and accordingly can vary from smaller to larger particles. Apart from this, the viscosity of the emulsion, feed rpm, inlet and outlet temperatures also have an influence on the particle size as well as the oxidative stability of the particles.

2. Freeze drying

Freeze drying is widely accepted as one of the best methods for production of superior quality dried products (Calvo et al., 2011). Though spray drying is the most widely accepted technology for encapsulation, a lower oxidative stability of spray dried products has also been reported. Because of the low temperature employed in freeze drying process and removal of about 97-98% moisture content and oxygen, this technology is often reported to produce good quality products than spray drying (Minemoto, Adachi, and Matsuno, 2001). The process of freeze drying involves three processes, freezing at a lower temperature of −90 and −40 °C, followed by primary and secondary drying under low pressure. But one limitation of this technology is that it is an expensive process requiring high energy consumption and higher processing time. Moreover, certain researchers have reported spray drying as a better process than freeze drying for fish oil encapsulation (Chen et al., 2013). Taking into consideration the limitations of both freeze drying and spray drying, it can be concluded that the freeze drying can be employed to encapsulate products that are highly sensitive to heat.

3. Coacervation

Coacervation, also known as phase separation is the separation of two liquid phases in a colloidal solution. The phase which is rich in polymer is known as the coacervate phase and that is devoid of polymer is known as equilibrium solution. There are two kinds of coacervation, simple and complex. In case of simple coacervation, there will be only one polymer whereas in complex coacervation, the interaction between oppositely charged polymers is made use of (Ke-Gang et al., 2005). The biopolymers that are being widely employed in the complex coacervation process are gelatin or whey protein and oppositely charged gum arabic, sodium polyphosphate or carboxy methyl cellulose. This method produces microcapsules that are having better and controlled release activities along with heat resistant properties (Jun-xia et al., 2011). The microcapsules thus produced are collected by centrifugation or filtration and further dried by either spray or fluidized bed drying. The size of microcapsules produced depends on a number of factors such as temperature, stirring speed, viscosity and pH (Carvalho et al., 2015). One limitation with this technology is that the coacervates produced are stable over a narrow range of pH and ionic strength.

4. Extrusion

Extrusion process involves mixing of the molten wall material with the core material which is then allowed to pass through a nozzle under high pressure to produce microcapsules of higher density and less porosity (Serfert, Drusch, & Schwarz, 2009). The extrusion microencapsulation includes 3 processes such as centrifugal extrusion (coextrusion), melt injection and melt-extrusion. Centrifugal extrusion, also known as co-extrusion is another extrusion technology that is commonly used for microencapsulation that can produce microcapsules in the size range of is 500–1000μm. Since the particle size of the extruded powder is more, it can impact the mouth feel. Melt injection process involves dispersion of the core material in a matrix containing starch, anti-oxidants, sugars, emulsifiers and water at about 130°C, extruded thorough a die or filter into a bath filled with organic solvent such as isopropanol which solidifies the sugar matrix. The microcapsules thus formed are collected by filtration or centrifugation (Valentinotti, Armanet, and Porret, 2006). The melt-extrusion process and melt-injection is almost similar, where melt-injection is a vertical screw less process with surface-washed particles, while the melt extrusion is a horizontal screw process with particles that are not surface-washed.

5. Insitu polymerization

In situ polymerization is commonly used for the preparation of microcapsules and functional fibers. The process doesn't include any reactants in the core material and polymerization occurs in the continuous phase itself. By adjusting pH and temperature, the wall material precipitates and distributes evenly over the surfaces of core material. Particles produced by this technology are found to have better encapsulation efficiency, good chemical, thermal and storage stability and controlled release.

6. Liposome entrapment

Liposomes are microscopic, spherical lipid bilayers that can enclose a number of aqueous compartments. The most commonly used encapsulating agents in this method are phospholipids and they are bio compatible and bio degradable substances (Kim &Baianu, 1991). The formation of a lipid bilayer is mainly attributed to the amphiphilic nature of phospholipids. These liposomes can be used to encapsulate omega-3 fatty acids by dissolving them in phospholipid before addition of water. This mixture of phospholipid, omega-3 oil and water is then sonicated to form encapsulated products and oil encapsulated in liposomes is said to have better oxidative stability (Kubo, Sekine, & Saito, 2003). But the limitation of this technology is its high cost and low stability.

7. Fluidized bed drying

This method is restricted mainly to the encapsulation of solid core materials where a coating is applied on the powder particles (Rumpler & Jacob, 1998). Hence this method cannot be used for the direct encapsulation of fish oil, instead it can be considered as a secondary method to provide an additional coating on the already microencapsulated fish oil for better oxidative stability and physicochemical properties. In one of the patented technology for double encapsulation of fish oil, corn starch was used for coating the already spray dried powder (Skelbaek and Andersen., 1994). In another method, molten hydrogenated palm wax (30% w/w) was used to coat over the already spray dried fish oil powder (Ponginebbi and Publisi, 2008).

Advantages and Disadvantages of Some Encapsulation Methods:

Encapsulation Method	Principle	Advantages	Disadvantages
Spray drying	Dispersion of the core material in a entrapment material, followed by atomization and spraying of the mixture in a hot air desiccant into a chamber	a) Low process cost; b)Wide choice of coating material; c)Good encapsulation efficiency; d) Good stability of the finished product; e)Possibility of large-scale production in continuous mode	a) Can degraded highly temperature sensitive compounds; b) Control of the particle size is difficult; c) Yields for small batches are moderate
Spray cooling/chilling	The same of as the spray drying differing only that the air desiccant is cold	Temperature-sensitive compounds can be encapsulated	a) Difficult control of the particle size; b) Moderate yields for small batches; c) special handling and storage conditions can be required
Simple extrusion	Forcing a core material in a molten wall material mass through a die (laboratory scale) or a series of dies of a desired cross section into a bath of desiccant liquid. The coating material hardens on contacting liquids, entrapping the active substances	a) The material is totally surrounded by the wall material; b) Any residual core is washed from the outside; c) It is a relatively low-temperature entrapping method	a) The capsule must be separated from the liquid bath and dried; b) It is difficult to obtain capsules in extremely viscous carrier material melts
Centrifugal extrusion	Similar as simple extrusion differing that the core material and coating material form a unified jet flow only at the end through a nozzle with a coaxial opening (coextrusion) by centrifugal force	The same of simple extrusion	The same of simple extrusion
Coacervation	The entrapment is due to the deposition of a liquid coating material around the core material by electrostatic attraction	Can be used to encapsulate heat-sensitive ingredients due to done at room temperature	a) Toxic chemical agents are used; b)The complex coacervates are highly unstable; c) There are residual solvents and coacervating agents on

			the capsules surfaces; d) spheres low size range; e)expensive and complex method
Liposome entrapment	Phospholipids are dispersed in an aqueous phase spontaneously formation a liposome. A core material is entrapment into a liposome	a) Either aqueous or lipid soluble material can be encapsulated; b) suitable to high water activity applications; c) efficient controlled delivery	Mainly used on a laboratory scale
Fluidized bed coating	This technique relies upon by nozzle spraying the coating material into a fluidized bed of core material in a hot environment	a) Low cost process; b) It allows specific capsule size distribution and low porosities into the product	Degradation of highly temperature- sensitive compounds
Lyophilizaton/ Freeze drying **Inclusion complexation**	The entrapment occurs by lyophilization of an emulsion solution containing a core material and a coating material Particular apolar molecules are entrapped through a hydrophobic interaction inside the β-Cyclodextrin cavity replacing water molecules	Thermosensitive substances that are unstable in aqueous solutions may be efficiently encapsulated by this technique Very efficient to protect unstable and high added value apolar compounds such as flavors	a) Long processing time; b) expensive process costs; c) expensive storage and transport of the capsules a) Encapsulation restricted to apolar compounds with a suitable molecular dimensions; b) β cyclodextrin price is expensive; c)frequently undesirable release of the formed complex

Further reading

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Chapter 22

Technological interventions in fishery engineering

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Fisheries comprise a major economic activity within complex interactions between human beings and water - 'the first among equals' of the natural resources (Ahmed, 1992). Fisheries data assembled by the Food and Agriculture Organization (FAO) suggest that global marine fisheries catches increased to 86 million tonnes in 1996, then slightly declined.In the past three decades, employment in fisheries and aquaculture has grown at a higher rate than the growth of world population. The fishery engineering is evolving as an important domain in view of depleting stocks on both pre and post-harvest scenarios. It will also aid in fish processing technologies, optimizing energy and water use in seafood industries, mitigating climate change related issues and reducing carbon foot print. It is important toexplore novel ways to obtain, quantify, and integrate industry responses to declining fishing stocks and increasing management regulations into fishery- and ecosystem-based management advice. The technological interventions help to reduce the wastage of fishes, which is otherwise a highly perishable commodity by preservation technologies and converting it into value added products with higher shelf life. Use of appropriate technologies along the fish value chain will help in producing better quality products and fetch more markets and higher price.

Major areas of technological interventions in the field of fishery engineering cover design and development of fish processing equipment and machineries, energy efficient and eco-friendly solar fish dryers, fuel efficient fishing vessels and fiberglass canoes, indigenous electronic instruments for application in harvest and post-harvest technology of fish, quality improvement of Indian fishing fleet and energy and water optimization techniques for fish processing industries. Focused areas includedevelopment of cost effective solar dryers with LPG, biomass, Infra-Red or electrical back-up heating systems, fish de-scaling machines, Fish freshness sensor etc.

Technologies for fish processing and value addition

Post-harvesting processing of fishes are important to reduce the wastage, increase shelf-life, add more value to the products and ensure higher returns. The major engineering interventions for fish post-harvest operations, processing and value addition are given below:

1.1 Solar dryers: Out of total catch 30-40 % of fish is dried or processed for export and local consumption. Sun drying (open air drying) is the traditional method employed in most parts of the state to dry fishery products. It denotes the exposure of a commodity to direct solar radiation and the convective power of the natural wind. This form of energy is free, renewable and abundant in any part of the world especially in tropical countries. Also it offers a cheap method of drying but often results in inferior quality of product due to its dependence of weather conditions and vulnerability to the attack of dust, dirts, rains, insects, pests, and microorganisms. Solar drying is an alternative which offers numerous advantages over the traditional method and environmentally friendly and economically viable in the developing countries. In solar drying, a structure, often of very simple construction, is used to enhance the effect of the solar radiation. Compared to the sun drying, solar dryers can generate higher air temperatures and consequential lower relative humidity, which are conducive to improved drying rates and lower final moisture content of the final products. However, there exist some problems associated with solar drying i.e. reliability of solar radiation during rainy period or cloudy days and its unavailability during night time. To overcome this limitation, an auxiliary heat source and forced convection system are recommended for assuring reliability and better control, respectively.

In a hybrid solar drying system, drying can be continued during off-sunshine hours by utilizing back up heat source and stored heat energy of daytime sunshine. In this way, drying becomes continuous process and the product is saved from possible deterioration by microbial infestation. These types of Hybrid solar dryers find useful applications in developing countries where the conventional energy sources are either scarce or expensive and the heat generating capacity of the solar system alone is not sufficient. Further, to assist the drying process (forced convection) in a hybrid dryer, a small blower is attached in between solar collector and drying chamber or inside the drying chamber which is powered by solar PV panels installed on drying chamber. Moreover, power from PV panels can be used for street lighting purpose. In addition, if the proposed setup is not used for drying purpose (kept idle), then the same can be used to draw hot water for domestic use. Therefore, in a single set up it is envisaged to have multiple utilities i.e. drying of fish, hot water and electricity generation.

Design of solar dryer varies from simple direct dryers to more complex hybrid designs. Hybrid model solar dryers are having LPG, biogas, biomass or electricity as alternate back up heating source for continuous hygienic drying of fish even under unfavourable weather conditions. ICAR-CIFT has developed different models and capacities of solar dryers for hygienic drying of fish. The capacity of these hybrid solar dryers varies from 6 to 110 m^2 of tray spreading area for drying of various quantities of fish varying from 10 kg to 500 kg.

The labour requirement is considerably reduced compared to open sun drying in beaches / coir mats because of the elimination of cleaning process due to sand and dust contamination. Re-handling process like spreading, sorting and storing because of non-drying or partial drying due to unfavourable weather conditions and spoilage due to rain is also not required. The drying time is reduced considerably with improved product quality. Improved shelf life and value addition of the product fetches higher income for the fisher folk. The eco-friendly solar drying system reduces fuel consumption and can have a significant impact in energy conservation.

ICAR-CIFT design includes small capacity dryers like solar tent dryers, natural convection dryers *etc.* which will be useful to dry fish hygienically during sunny days. Solar tunnel dryers, solar fish dryers with alternate electrical back up (SDE-10, SDE-20 and SDE-50) and solar fish dryers with fire wood or biomass alternate back up heating system (SDF-20, SDF-50) *etc.* can be efficiently used to dry fish using renewable solar energy which is abundantly and freely available. The details of solar dryers with different backup systems are given below:

(a) Solar Dryer with LPG back-up: ICAR-CIFT designed and developed a novel system for drying of fish using solar energy supported by environment friendly LPG back up (Fig.1). In this dryer during sunny days fish will be dried using solar energy and when solar radiation is not sufficient during cloudy/ rainy days, LPG back up heating system will be automatically actuated to supplement the heat requirement. In the solar fish drier with LPG back up heating system, water is heated with the help of solar vacuum tube collectors installed on the roof of the dryer and circulated through heat exchangers provided in the PUF insulated stainless steel drying chamber loaded with fish. Thus continuous drying is possible in this system without spoilage of the highly perishable commodity to obtain a good quality dried product.

This dryer is ideal for drying of fish, fruits, vegetables, spices and agro products without changing its colour and flavour. It helps to dry the products faster than open drying in the sun, by keeping the physico-chemical qualities like colour, taste and aroma of the dried food intact and with higher conservation of nutritional value. Programmable logical Controller (PLC) system can be incorporated for automatic control of temperature, humidity and drying time. Solar drying reduces fuel consumption and can have a significant impact in energy conservation.

(b) Solar dryer with Electrical back-up: Effective solar drying can be achieved by harnessing solar energy by specially designed solar air heating panels and proper circulation of the hot air across the SS trays loaded with fish (Fig.2). Food grade stainless steel is used for the fabrication of chamber and perforated trays which enable drying of fish in a hygienic manner. Since the drying chamber is closed, there is less chance of material spoilage by external factors. An alternate electrical back-up heating system under controlled temperature conditions enables the drying to continue even under unfavourable weather conditions like rain, cloud, non-sunny days and in night hours, so that the bacterial spoilage due to partial drying will not occur. Improved shelf life and value addition of the product fetches higher income for the fisher folk. The eco-friendly solar drying system reduces fuel consumption and can have a significant impact in energy conservation.

(c) Solar-Biomass Hybrid dryer: A dryer working completely on renewable energy was designed and developed for eco- friendly operation. Solar Biomass Hybrid Dryer consists of well insulated and efficient solar air-heating panels, drying chamber, SS mesh trays, photo-voltaic cells, fans and biomass heating system (Fig.3). Hot air is generated by virtue of solar energy inside the heating panels and passed into the drying chamber. Continuous flow of hot air is maintained with the help of Photo Voltaic cells and fans to enable drying process. During cloudy days when sufficient solar energy is not available to maintain required temperature within the dryer, an alternate biomass heating system is manually actuated. Thus a fully green technology for fish drying is achieved by this.

Fig.1. CIFT Solar-LPG Dryer

Fig.2. CIFT Solar Electrical Dryer

Fig.2. CIFT Solar Electrical Dried fish

Fig.3. CIFT Solar Biomass dryer

(d) Solar Tunnel dryer: Solar tunnel dryer utilizes solar energy as the only source of heat for drying of the products. Heat absorbing area of 8 m^2 is made of polycarbonate sheet (Fig.4) . Products to be dried are placed on nylon trays of dimension 0.8X0.4 m. The dimensions of the whole drying unit is 2.21X2.10X0.60 m. The capacity of the dryer is 5 kg. Drying takes place by convection of hot air within the drying chamber. Apart from fishes, this dryer is also suitable for other agricultural products like fruits, vegetables and spices.

(e) Solar Cabinet dryer with electrical back-up: This offers a green technology supplemented by electrical back up in case of lacunae in solar radiation. The dryer consists of four drying chambers with nine trays in each chamber (Fig.5). The trays made of food grade stainless steel are stacked one over the other with spacing of 10 cm. The perforated trays accomplish a through flow drying pattern within the dryer which enhances drying rates. Solar flat plate collectors with an area of 7 m^2 transmit solar energy to the air flowing through the collector which is then directed to the drying chamber. The capacity of the dryer is 40 kg. Electrical back up comes into role once the desired temperature is not attained for the drying process, particularly during rainy or cloudy days.

1.2 Fish Descaling Machines

(a) Fish descaling machine with variable drum speed: Fish de-scaling machine is designed and fabricated for removing the scales of fishes easily. This equipment can remove scales from almost all types/sizes/ species of fishes ranging from marine to freshwater species like Sardine, Tilapia to Rohu. The machine is made of SS 304 and has 10 kg capacity. It contains a 1.5 HP induction motor and a Variable Frequency Drive (VFD) to vary the speed of the drum depending on the variety of the fish loaded. The drum is made of perforated SS 304 sheet fitted in a strong SS Frame. Water inlet facility is provided in the drum for easy removal of the scales from the drum so that area of contact to the surface will be more for removal of scales. The water outlet is also provided to remove scales and water from the machine. An Electronic RPM meter was attached with the de-scaling machine which directly displays the RPM of the drum. Speed of the drum is a factor influencing the efficiency. The machine takes only 3-5 minutes to clean 10 kg fish depending on the size.

Fig. 4. CIFT Solar –Tunnel Dryer

Fig.5. CIFT Solar-Cabinet Dryer with Electrical back-up

Fig. .6 Fish de-scaling machine with variable drum speed

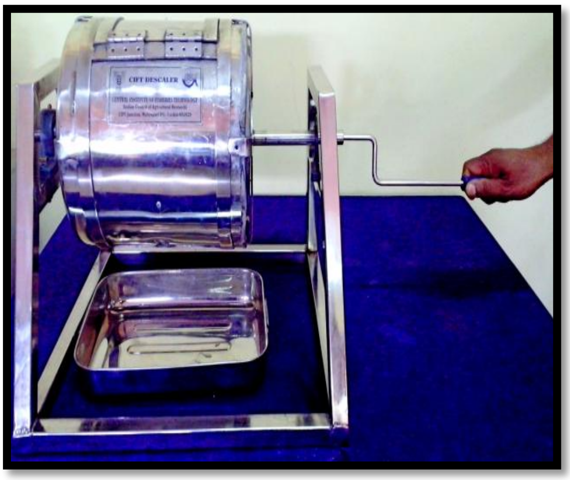

Fig.7 Fish de-scaling machine hand operated

(b) Fish de-scaling machine with fixed drum speed- table top: Fish de-scaling machine is designed and fabricated for removing the scales of fishes easily. This equipment can remove scales from almost all types/sizes/ species of fishes ranging from marine to freshwater species like Sardine, Tilapia to Rohu. This machine is made of SS 304 and has 5 kg capacity. It contains a 0.5 HP AC motor with proper belt reduction mechanism to achieve required drum speed of 20-30 rpm. Body is fabricated in dismantling type one-inch square SS tube with a suitable covering in the electrical parts. The drum is made of perforated SS sheet fitted in a strong SS Frame having suitable projections to remove the scale and provided with a leak proof door with suitable lock.

(c) Fish de-scaling machine hand operated: Fish de-scaling machine is designed and fabricated for removing the scales of fishes easily. This equipment can remove scales from almost all types/sizes/ species of fishes ranging from marine to freshwater species like Sardine, Tilapia to Rohu (Fig.7). This machine is made of SS 304 and has 5 kg capacity. Body is fabricated in dismantling type 1 inch square SS tube. The drum of 255.5 mm diameter and 270 mm length is made of perforated SS sheet fitted in a strong SS Frame having suitable projections to remove the scale and provided with a leak proof door with suitable lock. A pedal is fitted in the side to rotate the drum manually.

1.3 **Fish meat bone separator:** A Fish Meat Bone Separator with variable frequency drive (VFD) to separate pin bones from freshwater fishes was designed and developed. This can be used at a range of 5-100 rpm. With a unique belt tighten system developed; the new machine can be easily adapted to any species and need not be customised for specimen during design stage. In existing imported models, only two speeds are possible which restricts the yield efficiency in a single span operation and also limits easy switching of the system for utilising specimen other than for which the yield has been originally customised. The meat yield of this machine was about 60% against 35% in imported models. Capacity of the machine is 100kg/hour.

1.4 Modern Hygienic Mobile fish vending kiosk: Most of the fisher folk across India sell fish in an open basket without any hygienic practices. The fish is kept in an open bag or container, it loses its freshness.They use ice purchased at high cost for temporary preservation and at the end of the day, if the fish is not sold, they give it at a low rate to customers with little or no profit. More over fish gets contaminated under unhygienic handling practices. The fish vending persons, especially women folk find it difficult to carry the fishes as head load and subsequently sell it in the local markets or consumer doorsteps. In this context, the ICAR-CIFT have designed and developed a mobile fish vending kiosk for selling fish in the closed chilled chamber under hygienic conditions at consumer doorstep.

The major advantages of the new Kiosk are as follows:

- The mobile kiosk was designed considering the maximum weight that a man pulls on rickshaw.
- The mobile unit is mounted on frame with wheels at the bottom. The kiosk can carry 100kg fish with 20kg under chilled storage display in glass chamber and remaining in insulated ice box (developed by CIFT).
- The main components of the kiosk are fish storage & display chilled glass chamber, hand operated descaling machine and fish dressing deck with wash basin, water tank, cutting tool, waste collection chamber and working space.
- The vending unit has been fabricated mainly using stainless steel (SS 304 Food Grade) and frame and supports are made with MS and GI sheets.
- The kiosk main part *i.e* chilling unit & display for fish storage which was envisaged to power by solar energy through solar PV cells,however presently powered by AC current.
- The stored fish is covered with transparent glass cover through which consumer can see the fishes and select according to their choice of purchase.
- Kiosk is attached with hand operated descaling machine for removal of scales. The fishes coming out of descaler is free of scales, dirt or slime.
- It also reduces human drudgery and avoids cross contamination, consumes lesser time. Fish dressing deck with wash basin also designed conveniently to prepare fresh clean fish under hygienic conditions.

Chilling of fish using electricity/PV cells or by adding large quantity of iceadds to cost to the selling price. Since this technology has well insulated storage space for fish with provisions for refrigeration, it reduces the ice melting rate and its cost, thereby reducing the selling price. The unit also extends the keeping quality of fish for 4- 5 days and increases marginal benefit to fish vendors. It also helps change the practice of unhygienic handling and marketing of fish.

1.5 **Electronics and Instrumentation:**

ICAR-CIFT identified the vast scope of electronics and instrumentation for fisheries technological investigations and started research and development activities. This resulted in a series of instruments for systematic monitoring, analysis and assessment of the marine environment including the performance of the machineries used for harvesting the resources and post-harvest technology. Basic technologies developed in ICAR-CIFT include more than five dozens of electronic instruments with fully indigenous technology and more than 50 sensors with novel features and designs. The notable achievement is the development of indigenous sensors, which are rugged to withstand hostile marine environment and enable us to monitor field data from remote areas. The total instrumentation is built up around these sensors, with required electronics, new signal processors and other peripherals for solid-state data storing, compatibility to PC, wireless transmission to distant points *etc*.

Some of the instruments, which has got great attention and acceptance are as follows: environmental data acquisition system, freezer temperature monitor, salinity temperature depth meter, hydro meteorological data acquisition system, warp load meter, solar radiation monitor and integrator, ship borne data acquisition system, water level recorder, ocean current meter, remote operated soil moisture meter, water activity meter, rheometer and micro algae concentration monitor. Since the instruments are designed to be compatible with computer and solid-state memory module, the information can be stored for long duration and retrieved at our convenience.

A few areas where research is possible by integrating electronics with fisheries engineering are given below:

· *Expert System/Mobile Application in fisheries- for tracking the catches, control over-fishing and monitor the presence of invasive species*

· Development of electronic/mechanical equipment for finding out sea depth, volume/quantity of catch, pollution levels, water currents etc.

· *GIS Supported Strategic Framework with DSS for Climate Smart Fish Value Chain*

· Mapping of fishing trends/catches in local/regional scale and monitoring of invasive predator species, fish stocks etc. using RS and GIS

· Sensor based fish capturing technology

Researches have also been undertakento develop electronic based fish freshness indicator using image analysis techniques, digital programmable control units for fish dryers and descaling machines, etc.

By effective use of efficient and appropriate engineering technologies which are cost-effective, adaptable and environment friendly, the fishermen community as well as seafood industry can reduce the harvest and post-harvest expenses and losses, add more value to the products, ensure better fish value chain dynamics and thereby obtain more income. The use of green and clean technologies also ensures less carbon and water foot prints.

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Chapter 23

Novel drying techniques in fish processing and preservation

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Drying

Drying is the most ancient and pre-eminent physical methods of food preservation. Normally the term 'drying' implies the removal of water by evaporation It is aimed at lowering the moisture content of foodstuff and predominately used for foods which are considered 'highly perishable'. Water is essential for the activity of all living organisms its removal will slow down, or stop, microbiological or autolytic activity thereby act as a preservation technique. Dried foods offer multiple benefits which include extended product shelf-life, reduced packaging requirements, lower storage space, lesser handling and transportation costs, throughout the year availability and finally diversified product for the consumers.

Fish drying

Drying has evolved as a traditional method of preserving fish, the action of the sun and wind is used to effect evaporative drying. In recent times, the controlled artificial dehydration of fish has been developed in some industrialised countries so that fish drying can be carried out regardless of weather conditions. In any process of drying, the removal of water requires an input of thermal energy. At normal temperatures, fish muscle can be considered to be a gel; it remains a gel until a considerable quantity of water has been removed. During drying, considerable shrinkage takes place, as well as other irreversible changes, and dried fish will not reconstitute to their original condition.

During air drying, water is removed from the surface of the fish and water moves from the deeper layers to the surface. Drying takes place in two distinct phases. In the first phase, whilst the surface of the fish is wet, the rate of drying depends on the condition (velocity, relative humidity etc.) of the air around the fish. If the surrounding air conditions remain constant, the rate of drying will remain constant; this phase is called the 'constant rate period'. Once all the surface moisture has been carried away, the second phase of drying begins and this depends on the rate at which moisture can be brought to the surface of the fish. As the concentration of moisture in the fish falls, the rate of movement of moisture to the surface is reduced and the drying rate becomes slower; this phase is called the 'falling rate period'.

Novel drying techniques

Conventional drying technologies have now been used on commercial scale for drying numerous food products. Conventional drying process relies on conductive and convective form of heat transfer but these methods end up in poor quality product and higher contamination. This leads to the development of dryers that have the capacity for more efficient and reliable drying process In recent years, there have been many advances in technology associated with the industrial drying of food including pre-treatments, techniques, equipment and quality. Recent research has revealed that novel drying approaches such as microwave- or ultrasound-assisted drying, high electric field drying, heat pump drying and refractance window drying can be now taken to improve the efficiency and efficacy of drying process with high quality product and minimum energy requirement.

Microwave-Assisted Drying

Microwave radiation is part of the electromagnetic spectrum with wavelengths ranging from 1 mm to 1 m. For food applications, the common frequencies used are 915 and 2450 MHz. Microwaves are non-ionizing in nature, and the concept of application of microwave energy is considered as a fourth-generation technology. There is an increase in interest in microwave-assisted dehydration. Unlike conventional drying techniques, in microwave heating energy is delivered directly to the material through molecular interactions with the electromagnetic field. This principle of dielectric heating involves two basic mechanisms: dipolar rotation and ionic interaction/ionic conduction, and relies heavily on the product’s dielectric permittivity and loss factor. Major process parameters are time–power level combinations used. Among the crucial product parameters is the moisture content of the product and its dielectric properties. Microwave-assisted drying of various food materials has shown excellent results. For example, up to 25–90 % reduction in drying time, up to 400–800 % increase in drying rate and 32–71 % reduction in energy consumption as compared to conventional drying techniques, superior product quality, even better than freeze dried foods, lesser floor-space requirements and better overall process control (Wang *et al.*, 2014).

High Electric Field Drying

In high electric field (HEF) or electrohydrodynamic (EHD) drying, an alternating current (AC) or direct current (DC) at high intensity and normal frequency (around 60 Hz) is used for moisture removal during drying. Potential difference generated between the electrodes showed direct effects with sample drying rate. The exothermic interaction of the electric field within the dielectric food material results in rapid evaporation. The heating effect is caused as a result of the secondary flow induced by the electric field. This is termed as 'corona wind' or 'ionic wind'. In short, the method creates forced convection using ionic injection, followed by subsequent acceleration between electrodes. Parameters such as electrode size, electric field strength and inter-electrode spacing are major deciders of efficiency of the drying process. High electric field drying is a convective drying technique that can effectively remove product moisture whilst retaining heat-sensitive components including ascorbic acid. As a non-thermal drying technique, high electric field drying shows lower risk to browning. High electric field drying offers high energy efficiency, reduction in drying time and lower power requirements compared to conventional drying techniques. Superior dried product quality attributes of shrimps in comparison with oven drying (Bai and Sun, 2011) further support the hypothesis that high electric field is a promising method for drying of seafoods. Similar conclusions were drawn from studies conducted on scallop muscle (Bai *et al.*,2012) and Spanish mackerel (Bai *et al.*,2011).

Infrared Drying

Infrared radiation is part of the electromagnetic spectrum, ranging between 0.75 and 1,000 lm in wavelength. As a food processing technique, it offers several advantages including high heat transfer capacity, better process control and uniform heating. Infrared energy incident on the food material creates charges in electronic, vibrational and rotational states at atomic and molecular levels, without heating the surrounding air. The uniqueness of the process is that infrared drying results in uniform temperature distribution require less start-up time and less residence time.

Heat Pump Drying

Unlike other drying systems that require new technology and capital investments, heat pump dryers can be developed with little modification of existing refrigeration systems. Hence, most commonly used heat pump units are closed-loop systems that work on the thermodynamic principle of vapour compression cycle. Heat pump dryers have the capability to convert the latent heat of vapour condensation into sensible heat of an air stream passing through the condenser. The basic components of the heat pump drying system encompass an expansion valve, two heat exchangers (evaporator and condenser), and a compressor and a dryer attachment. The evaporator functions as dehumidifier and the condenser as heater. More recently, chemical and hybrid (microwave, infrared and radiofrequency) heat pump sources have been developed, to improve process efficiency. Drying temperature and air humidity in heat pump drying systems can be kept under control. This has allowed heat pump dryers to be employed for both agricultural, pharmaceutical products and also suitable for highly heat-sensitive commodities. Shi *et al.* (2008) suggested that heat pump drying is the best method to produce intermediate moisture foods, particularly for applications in fish processing. Fadhel *et al.* (2011) have reviewed the recent advances in technologies for solar-assisted CHP dryers for agricultural produce, highlighting the uniqueness of utilizing renewable energy sources for drying.

Ultrasonic Vacuum Drying

Ultrasound treatment is widely used as a pre-treatment technique to accelerate drying. Applying ultrasound interrupts the continuity of the membranes, and thus increases the mass transfer rate between the cell and its extracellular surroundings. Ultrasound treatment is connected to drying during the process and as a preliminary treatment positively affects the drying process in terms of improving the quality of the dried products and reducing the energy consumed during drying. Ultrasound can be applied to improve the convective heat transfer co-efficient or to increase mass transfer for different products and processes. Combining vacuum drying with ultrasound treatment can be considered as perfect drying techniques to increase drying efficiency and to reduce drying time. In this method, the advantages of both processes were used to shorten the drying period.

Conclusion

Novel drying techniques/methods listed above for fish processing and preservation can be considered as better option due to its lower drying time and higher quality product. However, the development of new dry food items using novel techniques introduces different challenges, namely the consumer perception, the approval of the novel technology and the retention of the physical, sensorial and nutritional quality of foods. The potential of novel technologies for drying and food preservation has gained increased industrial interest and has the potential to replace, at least partly, the traditional entrenched preservation methods, as the industry seeks to become more environmentally and economically sustainable.

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Chapter 24

Preprocessing of fish and solar fish drying

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Pre-processing of fish

Fish is a highly perishable food which requires proper handling and preservation to increase its self life and retain its quality and nutritional aspects. Therefore, fish pre-processing and preservation are become a very important part of commercial fisheries. Preservation means keeping the fish after landing in a condition of wholesome and fit for human consumption for a particular period. This preservation should cover the entire period from the time of capture of fish to its sale at retailer's counter. The main aim of processing and preservation of fish is to prevent fish from deterioration. Methods which are commonly used to preserve fish and fishery products include the control of temperature using ice, refrigeration or freezing and control of water activity by drying, salting, smoking or freeze-drying *etc* (FAO, 2011). Fish has to be pre-processed in such a manner that it remains fresh for a long time with a minimum loss of flavour, colour, taste, odour, nutritive value and digestibility. Fish processing can be subdivided into fish handling which is the preliminary processing of raw fish and the manufacture of fish products.

Handling:

Fish handling and preservation can be carried out on board of the fishing vessel or on land. In general, some methods for handling and preservation of fish are needed in order to maintain the raw fish quality after catching. Lowering the fish temperature using ice is a popular method for fresh fish preservation. When fishes are captured or harvested for commercial purposes, some pre-processing practices are required to deliver the fish to the next part of marketing chain in a fresh and undamaged condition. Pre-processing means preparation of raw fishes by de-shelling, de-heading, gutting *etc.* to use as raw materials for finished products or for distribution for further processing or cooking. The first pre-processing stage for whole fish includes bleeding, gutting, icing and freezing. Some fish species can be bled and gutted on board, but this work can take much time and some fish species are only primarily washed and put into boxes or tubs with ice and stored in hold of the vessel.

Fish starts to spoil as soon as they have been captured. Concern for quality of fish should begin on board the vessel. The first consideration should be to bring the fish alive and good condition. Fish should only come in contact with clean surfaces. The deck and storage boxes should be free of fish residues, dirt and slime with the use of clean water. Fish should be handled with care. Kicking, trampling the fish will increase the rate of spoilage. Also fish should be chilled as quickly as possible to 0^0C. It is essential to keep the ice and fish together in a covered box. Fish and ice should be packed in alternate layers. Chilled Sea Water (CSW) that includes ice and seawater is used to chill the raw fish. Chilled water (CW) is also often used for chilling the fish and it does not affect the fish. Different types of ice can be used for chilling fish like liquid ice, flake-ice, tube ice and block ice. Among the various types liquid ice has the highest cooling rate and the ground block ice is the slowest. A common way to chill the fish is to arrange it with ice in a fish box.

Today, keeping fish alive for consumption is a common fish handling practice in world wide. In this practice, fish are conditioned in a container with clean water, while the damaged, sick and dead fish are removed. Then fish are starved and if possible water temperature is lowered in order to reduce metabolic rates and make fish less active. Low metabolic rates decrease the fouling of the water with ammonia, nitrite and carbon dioxide that are toxic to fish and impair their ability to extract oxygen from water. A large number of fish species are usually kept alive in a holding basin, floating cages, wells and fish ponds.

Fish handling operations in on board after capture are as follows:

1. Transferring catch from fishing gears to fishing boats
2. Holding catch before handling
3. Sorting/Grading
4. Bleeding/Degutting/ Washing
5. Chilling
6. Chilled storage and unloading *etc*.

These operations can be carried out in several ways. The number of operations and the order in which they are performed depend on the fish species and the gear used, vessel size, duration in which the catch is to be marketed.

Fish are processed both on shipboard and in land-based plants. Fishing vessels deliver their catches to land-based plants or other vessels.

1. Receiving and inspection: Fish is normally inspected to determine the quality of fish.

2. Washing: Fish that have been packed in ice are usually washed in some manner to remove surface slime (high microbial contamination) and other contaminations.

3. Sorting or grading: Fish are usually graded physically according to size, species, sex, area of catch or type of gear used. An experienced person can determine the quality of as-received fish by sensory evaluation (touch, sight and odor). A visual inspection is normally adequate for rating, grading or generally to determine whether the fish is acceptable or not. Grading based on size and geometry is probably more important in processing plants. Machines are made to handle fish over a certain size range in order to maximize the yield.

4. Scaling: It is desirable to remove the scales from fish. The usual scaler is a rotating drum made of screening (1/2 inch). Scales are removed as fish rub against each other and the wire drum while rotating. The loose scales are flushed through the screens by jets of water directed into the machine.

5. Cutting and eviscerating: Fish are prepared for market or processing in many different manners. Always the viscera are removed and the belly wall is thoroughly cleaned or slimed to increase the shelf life or holding time. Depending on the specific density of the fish some or all of the other nonedible portions are removed. Butchering is done by hand or machine. The basic procedure is to remove the head, slit the belly and remove the viscera and lastly remove the fins and tail.

Processing of fish:

Various traditional methods of fish preservation are carried out in world wide. These include air drying and smoking by the use of heat in the smoking kilns, salting, or brining involving the use of common salt (sodium chloride), sun drying through exposure to direct sunlight, solar drying where fish is dried in an enclosure which traps sunlight energy. These preservation techniques increase the shelf-life of fish, maintain the quality of the fish in terms of its nutrient, flavor, texture, and appearance, provide ease of handling and further processing of the fish, and reduce post catch losses thereby ensuring continuous availability of cheap animal protein to the people all year round.

Salting:

As part of a smoking or drying process, salting has been used for thousands of years to preserve marine products. Salting has no adverse effect on the value of fish protein. When fish is placed in a brine solution, salt penetrates inside the fish and water is extracted from the tissues by osmosis. Higher salt concentration in fish extends its storage life. Several methods of salting are commonly used: dry salting, brine salting and pickle salting. Dry salting is the simplest method and is used primarily for fish with high water content. Granular salt is rubbed onto the outer and inner surfaces of the fish. The wet salting methods (brine and pickle) are recommended for fatty fishes. In brine salting, the entire fish is immersed in an aqueous salt solution. An 80 -100 per cent saturated brine solution (270-360 g of salt per litre of water) is preferred. Some of the factors involved in salting of fish which play an important role are purity of salt, quantity of salt used, method of salting and weather conditions *etc*. During salting process small fishes are directly salted without being cleaned. In the medium and large sized fish the head and viscera are removed and longitudinal cuts are made with the help of knives in the fleshy area of the body. Then the fish is washed and filled with salt for uniform penetration through flesh. Large fishes are cut into convenient sized pieces.

Drying of fish:

Drying is the most widely used method of food preservation and is an integral part of food processing. Fish can be stored for long time only by drying. Sun drying of fish is the most widespread method of fish drying in India because of solar irradiance being very high throughout the year. In rural areas, fish is preserved by sun drying. As sun drying technique needs no energy during day time, it is more beneficial to the small scale farmers who can't afford the electricity or other fuel for drying. Even though the cost of sun drying is low, there are significant losses due to spoilage, contamination by dust, and insect infestation. All these disadvantages can be eliminated by using a solar dryer.

The advancement of sun drying is solar drying systems in which products are dried in a closed system in which inside temperature is higher. The development of solar driers has significantly improved the traditional preservation of fish by sun drying. Solar dryers have a number of advantages over traditional drying methods. The driers provide hygienic conditions for fish drying and it exclude rain, insects, animals, and dirt and can produce higher temperatures to reduce the possibility of mold or bacteria spoilage. Solar fish dryers are simple and inexpensive and can eliminate much of the spoilage that occurs with traditional drying methods. It could be constructed by simple technology from inexpensive and readily available materials. It can also be easily operated with effective and efficient performance (Hii *et al*., 2012).

The objective of a solar dryer is to provide sufficient amount of heat *i.e.* more than ambient heat under given humidity. It increases the vapour pressure of the moisture confined within the product and decreases the relative humidity of the drying air so that the moisture carrying capacity of the air can be increased. Air is drawn through the dryer by natural convection or sometimes by a fan. It is heated as it passes through the collector and then partially cooled as it catches moisture from the material. The material is heated both by the air and sometimes directly by the sun. Warm air can hold more moisture than cold air to maintain relative humidity, so the amount of moisture removed depends on the temperature to which it is heated in the collector as well as the absolute humidity of the air when it entered the collector. The moisture absorption capacity of air is affected by its initial humidity and by the temperature to which it is subsequently heated.

Solar dryers can be categorized into two classes on the basis of the mode of air flow through the dryer, *i.e.* natural convection or forced convection. Dryers that employ forced convection require a source of motive power, usually electricity, to drive the fan that provides the air flow. Solar dryers can also be classified primarily according to their heating modes and the manner in which the solar heat is utilised. In broad terms, they can be classified into two major groups, namely: active solar energy drying system (most of which are often termed hybrid solar dryer) and passive solar energy drying system (conventionally termed natural-circulation solar drying system). The performance of solar dryers is significantly dependent on the weather conditions. Both the heat required for removing the moisture as well as the electricity necessary for driving the fans are generated in the most cases by solar energy only.

Different types of CIFT dryers

ICAR-Central Institute of Fisheries Technology (CIFT), Cochin, has developed low cost, energy efficient and eco-friendly dryers like Solar tray dryer, Solar cabinet dryer, Solar tunnel dryer *etc.* based on solar energy for quality drying of fishes. Apart from fishes, this dryer is also suitable for drying other agricultural products like fruits, vegetables, spices and condiments. All of these dryers are provided with alternative heating source in order to continue the drying process during off sunshine hours especially during night time, cloudy and rainy days.

Solar tray dryer

Solar tray dryer consists of solar air collector, drying chamber with trays and exhaust. The capacity of the dryer is 20 kg. The total heat absorbing area of solar collector is $10m^2$ and drying chamber tray area is $5.4m^2$. The trays are made of food grade steel (SS 304) and are stacked one over the other with spacing of 10 cm. In this dryer, supplemental heating is provided by electrical coils placed in the drying chamber.

Solar cabinet dryer

Solar cabinet dryer consists of four drying chambers with nine trays in each chamber. The capacity of the dryer is 40 kg. The total tray area is $20m^2$. The trays are made of food grade steel (SS 304) which is stacked one over the other with spacing of 10 cm. The perforated trays accomplish a through flow drying pattern within the dryer which enhances drying rates. Solar flat plate collectors with an area of $7m^2$, transmit solar energy to the air flowing through the collector which is then directed to the drying chamber. Electrical back up starts automatically whenever the desired temperature is not attained in the drying chamber, particularly during rainy and cloudy days.

Solar tunnel dryer

Solar tunnel dryer utilizes solar energy as the only source of heat for drying of fish and fishery products. The capacity of the dryer is 5 kg. Total heat absorbing area is 8 m^2, and is made up of polycarbonate sheet. Products to be dried are placed on nylon trays of dimension 0.8 × 0.4 m. The dimension of the drying unit is 2.21 × 2.10 × 0.60 m, and drying takes place by convection of hot air within the drying chamber.

Solar dryers used for drying can be proved to be most useful device from energy conservation point of view. It not only save energy but also save lot of time, occupying less area, improves quality of the product, makes the process more efficient and protects environment also.

Further reading

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Chapter 25

Microbiological aspects of fish and fishery products

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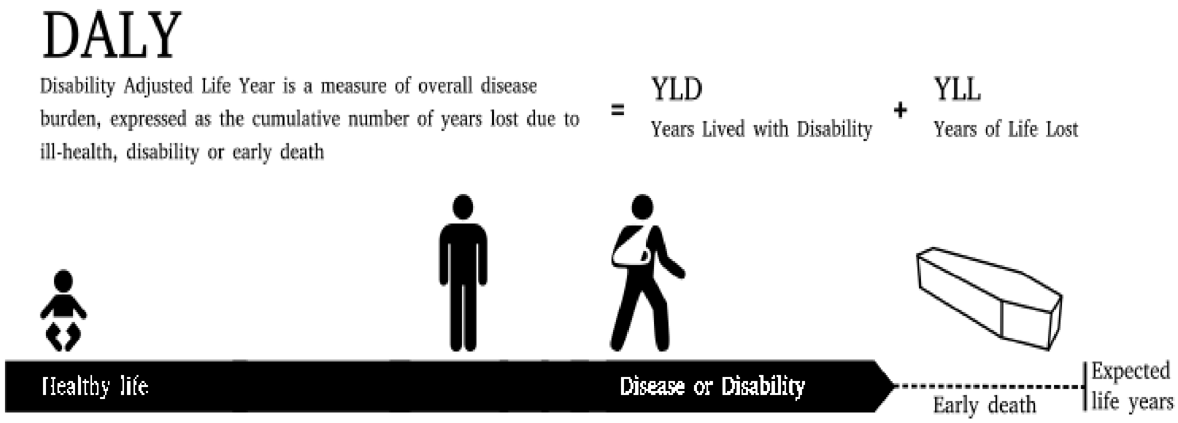
The planet earth harbors a total population of 7,530,687,482 (as on 7th September 2017 at 1345hrs) in which Asia and Africa share 4,486,207,286 and 1,252,251,830, respectively. In majority of the countries in Asia and Africa surveillance programs for detection and source tracking of human health hazard bacteria in foods is scant and in some cases do not exist. Hence, the task is much more complicated especially catering to needs of food, nutritional security and microbial safety of foods of more than 5,738,459,116 or 76.2 % of the total population of the world. The continued occurrence of foodborne illness is not evidence of the failure of our food safety system. In fact, many of our prevention and control efforts have been and continue to be highly effective. In advanced countries like US where food supply is one of the safest in the world, however, significant food borne illness continues do occur. Despite great strides in the area of microbiological food safety, much remains to be done.

Food-borne disease outbreaks are defined as the occurrence of 2 or more cases of a similar illness resulting from ingestion of a common food or observed number of cases of a particular disease exceeds the expected number. These can be confirmed (when at least one causal agent is identified) or suspected (based on clinical and epidemiological information). Although most cases are sporadic, these diseases draw attention to themselves due to outbreaks, thorough investigation of which can help in identifying control measures.Annual burden of foodborne diseases in the WHO South- East Asia Region includes more than: • 150 million illness • 175 000 deaths • 12 million DALYs Source: FERG Report 2010

The disability-adjusted life year (DALY) is a measure of overall disease burden, expressed as the number of years lost due to ill-health, disability or early death. It was developed in the 1990s as a way of comparing the overall health and life expectancy of different countries. The DALY is becoming increasingly common in the field of public health and health impact assessment (HIA). It "extends the concept of potential years of life lost due to premature death...to include equivalent years of 'healthy' life lost by virtue of being in states of poor health or disability." In so doing, mortality and morbidity are combined into a single, common metric.



"Despite significant success at improving the safety of the food supply, current science on which safety is based does not sufficiently protect consumers from emerging issues inherent to a complex food supply. The evolving characteristics of food, technology, pathogens and consumers make it unlikely the marketplace will be entirely free of dangerous organisms at all times for all consumers". This is the conclusion drawn in the report, Emerging Microbiological Food Safety Issues: Implications for Control in the 21st Century released at IFT's International Food Safety and Quality Conference and Expo in Atlanta one and half decades back. This holds good for fish and fishery products too.

The report, drew upon experts specializing in food borne pathogens and microbial evolution, food borne illness, food production and processing, testing methods and regulatory measures, reveals that diligent adherence to current methods that create and monitor the food supply cannot eliminate the risk of food borne illness. The report also offered the recommendations for providing the greatest possible reduction in food safety risks.

Among its seven important issues addressed were:

- Procedures from farm to table to significantly reduce illness due to mishandling,
- Processes to recognize and respond to outbreaks and to reduce their scope.

- Poor habits that make consumers more susceptible to foodborne illness,
- Education and training recommendations necessary for reducing pathogenic influence at every step
- From production to consumption (pond to plate/farm to fork)
- Recommendations to enhance monitoring, data generation, and risk assessment. And
- The current state and future potential of rapidly evolving illness-causing pathogens and other key issues.

In this premise let us examine the fish and fishery products scenario in four parts that include Human health hazard pathogens in fish and fishery products (Part I); Emerging Pathogens in Fish and Fishery Products: Public Safety Issues and Control Measures (Part II), Beneficial Microbes Associated with Aquatic Environment (Part III) and Fish and fishery products safety goals (Part IV).

Part I: HUMAN HEALTH HAZARD PATHOGENS IN FISH AND FISHERY PRODUCTS

Fish are of great concern for export earnings because of their higher nutritive value such as high protein content, with little or no carbohydrate and fat value. But their high water activity, neutral pH, and presence of autolytic enzymes makes fish, shellfish and their products highly perishable in nature. Among different types of spoilage, microbial spoilage due to bacteria and their toxins ranks first which results in loss of about one-third of the world's food production. Microbial spoilage is mainly due to the rapid microbial growth of microorganisms naturally present in fish or from contamination, which can occasionally result in either economic or health-related problems. Generally, fish muscle is sterile at the time of slaughtering/catch, but becomes quickly contaminated by surface and intestinal bacteria, and from equipment and humans during handling and processing.

Food borne pathogens are microorganisms which causes infections from mild illness like gastroenteritis to a range of life threatening cases including death, up on food consumption. *Salmonella* spp., *Listeria* spp., *Shigella* spp., *E. coli, Staphylococcus aureus*, *vibrio* species and *Clostridium botulinum* are the major food borne pathogens associated with fish and fishery products. Fecal *coliforms* and fecal *streptococci* in fish and fishery products are indicator organisms for fecal contamination, whereas, the presence of *staphylococcus* and *coliforms* reflects the poor hygienic handling practices. The presence all pathogenic microflora makes fish and its products unsafe for consumption.

I.1. *Salmonella*

Salmonella is a genus of rod-shaped (bacillus) Gram-negative bacteria of Enterobacteriaceae family which named after the American Bacteriologist D. E. Salmon. They are motile due to peritrichous flagella. The two species of *Salmonella* are *Salmonella enterica* and *Salmonella bongori*. *Salmonella enetrica* is the type species and is further divided into six subspecies that include over 2,500 serotypes. All groups of *Salmonella* other than *Salmonella typhi* and *S. paratyphi* which causes typhoid are called as Non Typhoidal Salmonella (NTS). NTS usually causes food borne diseases like diarrhea, vomiting, fever, indigestion, enteritis etc. They are generally considered as zero tolerant organisms which means their presence should be nil in food. Compared with other Gram-negative rods, *Salmonella* are relatively resistant to various environmental factors. *Salmonella* grow at temperatures between 8°C and 45°C, at water activities above 0.94 and in pH range of 4-8. The bacterium is heat sensitive and will not survive at high temperature. But they have relatively high resistance towards drying, salting, smoking and even to freezing. *Salmonella* contamination to food is mainly through polluted waters, pets and through feeds used in aquaculture systems etc.

I.2. *Vibrio species*

In contrast to most other foodborne pathogens, *Vibrio spp.* have the aquatic habitat as their natural niche. As a result, *vibrios* are most commonly associated with fish and fishery products, as natural contaminants. *Vibrios* are associated with live fish and fishery products as they form part of the indigenous microflora of the environment at the time of fish and fishery products capture or harvest. *Vibrio spp.* are Gram-negative, facultative anaerobic motile curved rods with a single polar flagellum. Among the members of the genus, 12 species have so far been reported to be pathogenic to humans, where eight of these may be associated with foodborne infections of the gastrointestinal tract. Most of these foodborne infections are caused by *V. parahaemolyticus* and *V. cholerae,* and to a lesser extent by *V. vulnificus* and by *V. mimicus*.

I.3. *Vibrio cholera*

Among the Vibrios, *V. cholerae* is of most concern because of its ability to cause cholera.Cholera is an acute intestinal infection. Its incubation period ranges from a few hours to five days, usually two to three days.Cholera is transmitted through ingestion of food or water contaminated with the bacterium, especially via faeces or vomitus of infected persons, directly or indirectly. *V. cholerae* is a mesophilic organism that grows in the temperature range of 10 to 43°C, with an optimum growth at 37°C. The pH optimum for growth is 7.6 although it can grow in the pH range of 5.0 to 9.6. *V. cholerae* can grow in the salt range of 0.1 to 4.0% NaCl, while optimum is 0.5% NaCl.Of the more than 200 *V. cholerae* serogroups that exist, only O1 and O139 are associated with the epidemiological features and clinical syndrome of cholera. However, organisms of *V. cholerae* serogroups other than O1 and O139 (non-O1 non-O139 serogroups) have been associated with sporadic cases of foodborne outbreaks of gastroenteritis, but have not spread in epidemic form. The most important virulence factor associated with V. cholerae O1 and O139 serogroups is the cholera toxin. Non-O1 non-O139 serogroups are generally nontoxigenic.

I.4. *Vibrio parahaemolyticus*

Among the potentially pathogenic *vibrios* occurring naturally on fish and shellfish, *V. parahaemolyticus* is the most widespread. *V. parahaemolyticus* is a slightly halophilic bacterium. The optimum growth NaCl concentrations range from 2 to 4% and poor growth is exhibited in media below 0.5% NaCl. The bacterium is inactivated rapidly in distilled water and growth at levels of 10% NaCl is inhibited. The organism grows at a temperature range between 5 and 43°C, with optimum growth at 37°C. The optimum pH range for growth is 7.8 to 8.6, although it can grow in the pH range of 4.8 to 11. The illness caused by *V. parahaemolyticus* food poisoning is a gastroenteritis characterized by watery diarrhea and abdominal cramps in most cases, with nausea, vomiting, fever and headache. The incubation period is usually between 12 and 24 hours and the disease usually resolves in three days. The infection is typically acquired through consumption of contaminated fish and fishery products. These could be raw or inadequately cooked, or that have been cross-contaminated by improper handling.

I.5. *Vibrio vulnificus*

V. vulnificus is an opportunistic pathogen that can cause wound infections and a rapidly progressing septicemia with few gastrointestinal signs.*V. vulnificus* is very similar to *V. parahaemolyticus* in cultural characteristics and sensitivity to processing procedures. It differs principally in salt requirement and tolerance, growing in media containing between 0.1 and 5% NaCl. Same as *V. parahaemolyticus,* the organism grows optimally at 37°C although it can grow at a temperature range between 8 and 43°C. The pH range for growth of *V. vulnificus* is 5 to 10, with an optimum at 7.8. The incubation period is from seven hours to several days

I.6. *Vibrio mimicus*

Vibrio mimicus are facultative anaerobes and possess a single polar flagellum for movements, and are oxidase-positive. *V. mimicus* are found in aquatic ecosystem, including seawater, freshwater, and brackish water, where it has been found both as a free-living bacterium and in association with zooplankton, crustaceans, filter-feeding mollusks, turtle eggs. *Vibrio mimicus* are responsible for gastroenteritis and are closely related phylogenetically to *Vibrio cholerae*. The ingestion of raw or uncooked fish and fishery products containing *Vibrio mimicus* can cause gastroenteritis and diarrhea.

I.7. *Shigella species*

Shigella is a genus of Gram-negative, facultative anaerobic, non-sporeforming, non-motile, rod-shaped bacteria genetically closely related to E. coli. The genus is named after Kiyoshi Shiga, who first discovered it in 1897.There are four different species of *Shigella* like *Shigella sonnei* (the most common species in the United States), *Shigella flexneri, Shigella boydii***,** *Shigella dysenteriae.* Most who are infected with *Shigella* develop diarrhea, fever, and stomach cramps starting a day or two after they are exposed to the bacteria. Shigellosis usually resolves in 5 to 7 days. Some people who are infected may have no symptoms at all, but may still pass the *Shigella* bacteria to others. *Shigella* is implicated as one of the pathogenic causes of reactive arthritis worldwide.

I.8. *Listeria monocytogenes*

Listeria monocytogenes is the species of pathogenic bacteria that causes the infection listeriosis. It is a Gram-positive, facultative anaerobic rod shaped bacterium, capable of surviving in the presence or absence of oxygen which named after Joseph Lister. It is catalase-positive and oxidase-*negative, and expresses a beta hemolysin, which causes destruction of red blood cells. This* bacterium exhibits characteristic tumbling motility when viewed with light microscopy. Although *L. monocytogenes* is actively motile by means of peritrichous flagella at room temperature (20−25 °C), the organism does not synthesize flagella at body temperatures (37 °C). *Listeria monocytogenes* has been associated with foods such as raw milkand milk products, raw vegetables, fermented raw-meat sausages, raw and cooked poultry, raw meats (of all types), and raw and smoked fish. Most bacteria can survive near freezing temperatures, but cannot absorb nutrients, grow or replicate. *L. monocytogenes* ability to grow at temperatures as low as 0 °C permits exponential multiplication in refrigerated foods. At refrigeration temperature, such as 4 °C, the amount of ferric iron can affect the growth of *L. monocytogenes*.

I.9. ***Escherichia coli***

E. coli is a Gram-negative, facultative anaerobic, rod-shaped, coliform bacterium of the genus *Escherichia* that is commonly found in the lower intestine of warm-blooded organisms (endotherms). Most *E. coli* strains are harmless, but some serotypes can cause serious food poisoning in their hosts, and are occasionally responsible for product recalls due to food contamination.It has been generally recognized as a sanitary indicator organism for faecal contamination of water and fish and fishery products in tropics**.** *E. coli* is often nonpathogenic, although different strains may cause diseases in gastrointestinal, urinary, or central nervous systems.At least five biotypesare currently known to induce intestinal infection: enterotoxigenic *E. coli* (ETEC), enteroaggregative *E. coli* (EAggEC), enteropathogenic *E. Coli* (EPEC), enterohemorrhagic *E. coli* (EHEC), and enteroinvasive E. coli (EIEC).

I.10. ***Staphylococcus aureus***

Staphylococcus aureus is a mesophilic, Gram-positive bacterium associated with warm-blooded animals. They are non-moving small round shaped or non-motile cocci that occur in microscopic clusters resembling grapes. It is a common member of the skin and nasal microflora of humans. Many strains of *S. aureus* may produce enterotoxins which upon ingestion causes a sudden reaction in terms of cramps, abdominal pain and vomiting. Several different enterotoxins may be produced and they have, based on antigenic properties been divided into sero-types A to J. Enterotoxin A is assumed to be the most commonly involved in food-poisoning outbreaks, however, recently type C has become prevalent *S. aureus* can be detected sporadically on raw fish but is clearly more typical of fish and fishery products that have been heat treated and manually handled, such as crustacean products. Emergence of antibiotic-resistant strains of *S. aureus* such as methicillin-resistant *S. aureus* (MRSA) is a worldwide problem in clinical medicine

I.11. ***Clostridium species***

Clostridium s a genus of Gram-positive bacteria, which includes several significant human pathogens, including the causative agent of botulism and an important cause of diarrhea in man. Botulism results from the ingestion of food containing botulinum toxin produced during the growth of this organism which can even cause the death of organism at microgram level. They are obligate anaerobes capable of producing endospores. *Clostridium botulinum* and *C. perfringens* are the two common food borne pathogens of this group and often associated with the consumption of uncooked, undercooked, smoked, fermented fishes and even with the vacuum packed fish and fishery products.

I.12. Yeast and Mold (Fungi)

Fungus consists of mainly two types like yeasts (cellular fungi) and molds (filamentous fungi). Several foodborne molds and possibly yeast may be hazardous to human or animal health because of their ability to produce toxic metabolites known as mycotoxins. Most of the mycotoxins are heat stable compounds which even cannot destroyed by cooking. Their growth temperature range is very broad (10°C to 35°C), so also their moisture and pH requirements. This usually enables them to invade and virtually grow in or on many food items. Usually they will not see in fresh raw fish since the moisture content is too high. But fishery products like dry fishes, pickles and even fermented fish can be contaminated with fungal spores.

Principal symptoms of bacteria & potential food contamination are shown below.

PRINCIPAL SYMPTOMS OF BACTERIA & POTENTIAL FOOD CONTAMINATION (h: hours, d; days, wks: weeks)					
Organisms responsible for the food borne illness	Common Name of Illness	**Onset Time After Ingesting**	**Signs & Symptoms**	**Duration**	**Food Sources**
Bacillus cereus	*B. cereus* food poisoning	10-16 h	Abdominal cramps, watery diarrhea, nausea	24-48 h	Meats, stews, gravies, vanilla sauce
Campylobacter jejuni	Campylobacteriosis	2-5 d	Diarrhea, cramps, fever, and vomiting; diarrhea may be	2-10 d	Raw and undercooked poultry, unpasteurized

			bloody		milk, contaminated water
Clostridium botulinum	Botulism	12-72 h	Vomiting, diarrhea, blurred vision, double vision, difficulty in swallowing, muscle weakness. Can result in respiratory failure and death	Variable	Improperly canned foods, especially home-canned vegetables, fermented fish, baked potatoes in aluminum foil
Clostridium perfringens	Perfringens food poisoning	8–16 h	Intense abdominal cramps, watery diarrhea	24h	Meats, poultry, gravy, dried or precooked foods, time and/or temperature-abused foods
Cryptosporidium	Intestinal cryptosporidiosis	2-10 d	Diarrhea (usually watery), stomach cramps, upset stomach, slight fever	May be remitting and relapsing over weeks to months	Uncooked food or food contaminated by an ill food handler after cooking, contaminated drinking water
Cyclospora cayetanensis	Cyclosporiasis	1-14 d, usually at least 1 wk	Diarrhea (usually watery), loss of appetite, substantial loss of weight, stomach cramps, nausea, vomiting, fatigue	May be remitting and relapsing over weeks to months	Various types of fresh produce

E. coli (Escherichia coli) producing toxin	*E. coli* infection (common cause of "travelers' diarrhea")	1-3 d	Watery diarrhea, abdominal cramps, some vomiting	3-7 or more d	Water or food contaminated with human feces
E. coli O157:H7	Hemorrhagic colitis or *E. coli* O157:H7 infection	1-8 d	Severe (often bloody) diarrhea, abdominal pain and vomiting. Usually, little or no fever is present. More common in children 4 years or younger. Can lead to kidney failure.	5-10 d	Undercooked beef (especially hamburger), unpasteurized milk and juice, raw fruits and vegetables (e.g. sprouts), and contaminated water
Hepatitis A	Hepatitis	28 d average (15-50 d)	Diarrhea, dark urine, jaundice, and flu-like symptoms, i.e., fever, headache, nausea, and abdominal pain	Variable, 2 wks-3 months	Raw produce, contaminated drinking water, uncooked foods and cooked foods that are not reheated after contact with an infected food handler; shellfish from contaminated waters
Listeria monocytogenes	Listeriosis	9-48 h for gastro-intestinal symptoms, 2-6 weeks for	Fever, muscle aches, and nausea or diarrhea. Pregnant women may have mild flu-like illness, and infection can lead to	Variable	Unpasteurized milk, soft cheeses made with unpasteurized milk, ready-to-eat deli meats

		invasive disease	premature delivery or stillbirth. The elderly or immunocompromised patients may develop bacteremia or meningitis.		
Noroviruses	Variously called viral gastroenteritis, winter diarrhea, acute non-bacterial gastroenteritis, food poisoning, and food infection	12-48 h	Nausea, vomiting, abdominal cramping, diarrhea, fever, headache. Diarrhea is more prevalent in adults, vomiting more common in children.	12-60 h	Raw produce, contaminated drinking water, uncooked foods and cooked foods that are not reheated after contact with an infected food handler; shellfish from contaminated waters
Salmonella	Salmonellosis	6-48 h	Diarrhea, fever, abdominal cramps, vomiting	4-7 d	Eggs, poultry, meat, unpasteurized milk or juice, cheese, contaminated raw fruits and vegetables
Shigella	Shigellosis or Bacillary dysentery	4-7 d	Abdominal cramps, fever, and diarrhea. Stools may contain blood and mucus.	24-48 h	Raw produce, contaminated drinking water, uncooked foods and cooked foods that are not reheated after contact with an infected food handler

Staphylococcus aureus	Staphylococcal food poisoning	1-6 h	Sudden onset of severe nausea and vomiting. Abdominal cramps. Diarrhea and fever may be present.	24-48 h	Unrefrigerated or improperly refrigerated meats, potato and egg salads, cream pastries
Vibrio parahaemolyticus	*V.parahaemolyticus* infection	4-96 h	Watery (occasionally bloody) diarrhea, abdominal cramps, nausea, vomiting, fever	2-5 d	Undercooked or raw seafood, such as shellfish
Vibrio vulnificus	*V.vulnificus* infection	1-7 d	Vomiting, diarrhea, abdominal pain, blood borne infection. Fever, bleeding within the skin, ulcers requiring surgical removal. Can be fatal to persons with liver disease or weakened immune systems.	2-8 days	Undercooked or raw seafood, such as shellfish (especially oysters)
Adopted from USFDA (2011)					

Part II; EMERGING PATHOGENS IN FISH AND FISHERY PRODUCTS: PUBLIC SAFETY ISSUES AND CONTROL MEASURES

First we will define the word 'emerging' clearly followed by a perusal into major challenges faced in keeping quality of fish and fishery products in relation to pathogenic bacteria. They included Relationship between human health and oceans; Emerging infections of the gastrointestinal tract; Fish and fishery products safety issues of small and medium entrepreneurs; Refrigerated Pasteurized Foods (RPF) and public health implications; identification, assessment and management of food related microbiological hazards: historical, fundamental and psycho-social essentials; information systems in food safety management; Aquaculture practices and potential human health risks: current knowledge and future priorities; bioterrorism; climate and food safety; challenges to global surveillance of disease pattern; Changes in preference patterns of fish and fishery products consumer and associated changes in risk exposure; technological innovations in food processing; control measures: An example and predictive microbiology

II.1. Definition

The definition the word 'emerging' means, 'to rise out of a state of depression or obscurity; to come to notice; to reappear after being eclipsed'. Thus is the state of infectious diseases throughout the world in the twenty-first century. Not only are new microorganisms being identified every year but some of the old established diseases are again gaining attention. More specifically, emerging diseases have been defined as those 'whose incidence in humans has increased in the past two decades or threatens to increase in the near future'.

II.2. Human health

There has been an increasing recognition of the inter-relationship between human health and the oceans. Traditionally, the focus of research and concern has been on the impact of human activities on the oceans, particularly through anthropogenic pollution and the exploitation of marine resources. More recently, there has been recognition of the potential direct impact of the oceans on human health, both detrimental and beneficial. Areas identified include: global change, harmful algal blooms (HABs), microbial and chemical contamination of marine waters and fish and fishery products, and marine models and natural products from the seas. It is hoped that through the recognition of the inter-dependence of the health of both humans and the oceans, efforts will be made to restore and preserve the oceans.

II.3. Emerging infections of the gastrointestinal tract

Infections account for significant GI morbidity and mortality worldwide. New organisms are being identified, associated with diarrheal illness and some with other gastrointestinal illness as well. Among GI viruses, Sapovirus is now recognized to cause diarrhoea, especially in children. A hyper virulent strain of Clostridium difficile has caused epidemics in many countries. Newly identified bacterial species that may cause diarrhoea included Campylobacter concisus, Arcobacteria, *Edwardsiella tarda*, Aeromonas, Plesiomonas, Laribacte and Helicobacteria.

II.4. Aquaculture practices and potential human health risks: current knowledge and future priorities.

Annual global aquaculture production has more than tripled within the past 15 years, and by 2015, aquaculture is predicted to account for 39% of total global fish and fishery products production by weight. Given that lack of adequate nutrition is a leading contributor to the global burden of disease, increased food production through aquaculture is a seemingly welcome sign. However, as production surges, aquaculture facilities increasingly rely on the heavy input of formulated feeds, antibiotics, antifungals, and agrochemicals. In the context of this current knowledge concerning major chemical, biological and emerging agents that are employed in modern aquaculture facilities and their potential impacts on public health were reviewed.

Studies indicate that current aquaculture practices can lead to elevated levels of antibiotic residues, antibiotic-resistant bacteria, persistent organic pollutants, metals, parasites, and viruses in aquacultured finfish and shellfish. Specific populations at risk of exposure to these contaminants include individuals working in aquaculture facilities, populations living around these facilities, and consumers of aquacultured food products.

Additional research is necessary not only to fully understand the human health risks associated with aquacultured fish versus wild-caught fish but also to develop appropriate interventions that could reduce or prevent these risks. In order to adequately understand, address and prevent these impacts at local, national and global scales, researchers, policy makers, governments, and aquaculture industries must collaborate and cooperate in exchanging critical information and developing targeted policies that are practical, effective and enforceable.

II.5. Bioterrorism

The bioterrorism potential of Brucella, *Burkholderia mallei* & pseudomallei, *Chlamydia psittaci*, *Coxiella burnetii*, *Rickettsia prowazekii*, Epsilon toxin of *Clostridium perfringens*, ricin toxin, Staphylococcal enterotoxin B, Alpha viruses and Bunva viruses, Flavi viruses needs special attention. Foodborne and waterborne pathogens that included bacteria, viruses and protozoans and the bioterrorism potential is equally important.

II.6 Climate and food safety

According to general consensus, the global climate is changing, which may also affect agricultural and livestock production. The potential impact of climate change on food security is a widely debated and investigated issue. Nonetheless, the specific impact on safety of food and feed for consumers has remained a less studied topic. Therefore, various food safety issues that are likely to be affected by changes in climate, particularly in Europe were assessed.

Amongst the issues identified are mycotoxins formed on plant products in the field or during storage; residues of pesticides in plant products affected by changes in pest pressure; trace elements and/or heavy metals in plant products depending on changes in their abundance and availability in soils; polycyclic aromatic hydrocarbons in foods following changes in long-range atmospheric transport and deposition into the environment; marine biotoxins in fish and fishery products following production of phycotoxins by harmful algal blooms; and the presence of pathogenic bacteria in foods following more frequent extreme weather conditions, such as flooding and heat waves. Research topics that are amenable to further research are highlighted.

II.7 Challenges to global surveillance of disease pattern

Surveillance systems for foodborne disease vary in capacity by country, especially for marine-related illnesses. Generally, the more developed the country is, the more funding that is put into its surveillance programs, but no country has an outstanding system that could serve as a model for all others. An additional problem is lack of consistency. Approaches to surveillance and available resources change over time, so that apparent trends may reflect more of an administrative function. Most countries have some passive system that allows data on foodborne illnesses to be sent to centralized authorities where summaries are generated. However, these depend on the uneven quality of the source data that vary according to the resources allocated at the local level. Active surveillance systems collect data targeted to answer specific epidemiological questions more efficiently, but at such a high cost that most countries do not have the resources, except on occasional basis. There is also the issue of what to do with the collected data. There has to be a conscious effort to translate the problems identified from the surveillance programs to consider strategies for prevention and control of foodborne disease. Otherwise, there is little value in having these kinds of monitoring programs. Another problem is lack of coordination in surveillance systems between most countries, so that information can be rapidly and efficiently shared. That being said, surveillance over the years had generated much interesting information on how disease agents are transmitted through the food supply, and where contamination and growth by pathogens in the food production and preparation chain typically occur. In addition, attempts are being made to create regional networks in different parts of the world usually initiated by organizations like WHO and PAHO (Pan American Health Organization). The kinds of information collected and programs being introduced are discussed in examples taken from both the developed and less developed world, followed by a series of recommendations for improving surveillance on a global basis. A recent burden in the surveillance system is the potential for a deliberate attack on the food supply with agents not usually involved with foodborne illness. At least in the US, a major concern is for the rapid detection and containment of a massive contamination of the food supply

II.8 Fish and fishery products safety issues small and medium entrepreneurs

Providing small food and catering operators, constituting a segment of the small and medium size enterprises (SME), with adequate guidance to ensure microbiologically safe fish and fishery products at the moment of ingestion constitutes a difficult endeavor. It culminates in street vending of foods, particularly in areas with poor sanitary environmental conditions and high ambient temperatures. The natural occurrence of pathogens on raw fish and fishery products is often compounded by an unreliable water supply, poor temperature control and lack of even a rudimentary knowledge of applied food microbiology. The mission statement of the **Codex Alimentarius Commission** nonetheless includes providing the entire sector of food and catering enterprises world-wide with Codes to enable the plentiful supply of unconditionally safe food.

A construct has been devised to gradually but substantially enhance the microbiological safety of products offered by SMEs- in essence complying with the HACCP maxim. Lord Plumb's extension of Bauman's HACCP model to longitudinally integrated safety assurance (LISA) has been chosen as the lead policy. Wilson's Triad, ensuring control of contamination and proliferation throughout the entire food chain provides the essential guidelines. An innovation consists of introducing the concept of attention points, where critical practices or sites cannot yet be brought under control. In this way the mental preparedness to pursue further improvements as required is perennially stimulated.

II.9 Public safety issues:

Public health implication of refrigerated pasteurized ('sous-vide') foods.

Food that upon pasteurization is stored in hermetically sealed containers at food temperatures not exceeding 3°C could be designated by the generic term Refrigerated Pasteurized Foods of Extended Durability, REPFEDs. If not properly processed or protected against recontamination, or if temperature-abused, REPFEDs may present serious health risks. However, control is possible through sound microbial ecology, supported by expert risk assessment, allows the design and introduction of longitudinally integrated manufacture, distribution, handling by outlets and consumers and culinary preparation, which result in the assurance of the wholesomeness of the commodity as eaten. The progress, including intrinsic preservation by the incorporation of starter cultures, bacteriocins or particular enzymes, opened new vistas for attractive developments. Once microbiological safety has been built into the REPFED-line, monitoring can be limited to,

(i) Real-time tests particularly applied to the factory environment; and

(ii) Rapid, simple examination for marker organisms of freshly manufactured products versus those approaching expiration dates.

This kind of audits will allow rapid retrieval of incidental process failure and its rectification. It also serves to substantiate measurements of food temperature and spot checks on intrinsic inhibitory attributes. The application of scientific knowledge and technological expertise should primarily be entrusted to the industry itself, heeding Lord Plumb's strategy of "partnership along the food production chain from farm to fork". It should be supported and validated by Public Health Authorities. At all stages safety communication with the public should be ensured.

Identification, assessment and management of food related microbiological hazards: historical, fundamental and psycho-social essentials.

Microbiological risk assessment aimed at devising measures of hazard management, should take into account all perceived hazards, including those not empirically identified. It should also recognize that safety cannot be "inspected into" a food. Rather hazard management should be the product of intervention strategies in accordance with the approach made mandatory in the EU Directive 93/43 and the USDA FSIS Pathogen Reduction HACCP system; Final Rule. It is essential too that the inherent variability of the biological attributes affecting food safety is recognized in any risk assessment. The above strategic principles may be conceptualized as a four-step sequence, involving

I. Identification and quantification of hazards;

II. Design and codification of longitudinally integrated ("holistic") technological processes and procedures to eliminate, or control growth and metabolism of, pathogenic and toxinogenic organisms;

III. Elaboration of microbiological analytical standard operating procedures, permitting validation of "due diligence" or responsible care, i.e. adherence to adopted intervention strategies. This should be supported by empirically assessed reference ranges, particularly for marker organisms, while the term "zero tolerance" is refined throughout to tolerable safety limit;

IV. When called for, the need to address concerns arising from lay perceptions of risk which may lack scientific foundation.

In relation to infectious and toxic hazards in the practical context the following general models for quantitative holistic risk assessment are presented:

a. The first order, basic lethality model;

b. Second approximation taking into account the amount of food ingested in a given period of time;

c. Further adjustment accounting for changes in colonization levels during storage and distribution of food commodities and the effects of these on proliferation of pathogens and toxin production by bacteria and moulds.

II.9.1 Guidelines are provided to address:

I. Unsubstantiated consumer concern over the wholesomeness of foods processed by an innovative procedure; and

II. Reluctance of small food businesses to adopt novel strategies in food safety. Progress here calls for close cooperation with behavioural scientists to ensure that investment in developing measures to contain risk deliver real benefit.

II.10 Information systems in food safety management

Information systems are concerned with data capture, storage, analysis and retrieval. In the context of food safety management, they are vital to assist decision making in a short time frame, potentially allowing decisions to be made and practices to be actioned in real time.

Databases with information on microorganisms pertinent to the identification of foodborne pathogens, response of microbial populations to the environment and characteristics of foods and processing conditions are the cornerstone of food safety management systems. Such databases find application in:

I. Identifying pathogens in food at the genus or species level using applied systematics in automated ways.

II. Identifying pathogens below the species level by molecular subtyping, an approach successfully applied in epidemiological investigations of foodborne disease and the basis for national surveillance programs.

III. Predictive modelling software, such as the Pathogen Modeling Program and Growth Predictor (that took over the main functions of Food Micromodel) the raw data of which were combined as the genesis of an international web based searchable database (ComBase).

IV. Expert systems combining databases on microbial characteristics, food composition and processing information with the resulting "pattern match" indicating problems that may arise from changes in product formulation or processing conditions.

V. Computer software packages to aid the practical application of HACCP and risk assessment and decision trees to bring logical sequences to establishing and modifying food safety management practices.

In addition, there are many other uses of information systems that benefit food safety more globally, including:

I. Rapid dissemination of information on foodborne disease outbreaks via websites or list servers carrying commentary from many sources, including the press and interest groups, on the reasons for and consequences of foodborne disease incidents.

II. Active surveillance networks allowing rapid dissemination of molecular subtyping information between public health agencies to detect foodborne outbreaks and limit the spread of human disease.

III. Traceability of individual animals or crops from (or before) conception or germination to the consumer as an integral part of food supply chain management.

IV. Provision of high quality, online educational packages to food industry personnel otherwise precluded from access to such courses.

II.12 Control Measures

Predictive food microbiology

Predictive food microbiology (PFM) is an emerging multidisciplinary area of food microbiology. It encompasses such disciplines as mathematics, microbiology, engineering and chemistry to develop and apply mathematical models to predict the responses of microorganisms to specified environmental variables. A critical review on the development of mathematical modelling with emphasis on modelling techniques, descriptions, classifications and their recent advances was given. The accuracy of predictive food microbiology will increase as understanding of the complex interactions between microorganisms and food becomes clearer. However, the reliance of food microbiology on laboratory techniques and skilled personnel to determine process and food safety is equally important.

The predictive microbiology was taken into consideration in the context of the Food Micro 2002 theme, “Microbial adaptation to changing environments”. To provide a reference point, the state of food microbiology knowledge in the mid-1970s is selected and from that time, the impact of social and demographic changes on microbial food safety is traced. A short chronology of the history of predictive microbiology provided context to discuss its relation to and interactions with hazard analysis critical control point (HACCP) and risk assessment. The need to take account of the implications of microbial adaptability and variable population responses is couched in terms of the dichotomy between classical versus quantal microbiology. The role of population response patterns and models as guides to underlying physiological processes draws attention to the value of predictive models in development of novel methods of food preservation. It also draws attention to the inconsistencies in food industry that is required to balance the “clean, green” aspirations of consumers with the risk, to safety or shelf life, of removing traditional barriers to microbial development. Further the discussion is dominated by consideration of models and responses that lead to stasis and inactivation of microbial populations. This highlights the consequence of change on predictive modelling where the need is to develop interface and non-thermal death models to deal with pathogens that have low infective doses for general and/or susceptible populations in the context of minimal preservation treatments. The challenge is to demonstrate the validity of such models and to develop applications of benefit to the food industry and consumers as was achieved with growth models to predict shelf life and the hygienic equivalence of food processing operations.

The future of predictive microbiology depends on exploring the balance that exists between science, applications and expectations. Attention is drawn to the development of predictive microbiology as a sub-discipline of food microbiology and of technologies that are required for its applications, including a recently developed biological indicator. As we move into the era of systems biology, in which physiological and molecular information will be increasingly available for incorporation into models, predictive microbiologists will be faced with new experimental and data handling challenges. Overcoming these hurdles may be assisted by interacting with microbiologists and mathematicians developing models to describe the microbial role in ecosystems other than food. Coupled with a commitment to maintain strategic research, as well as to develop innovative technologies, the future of predictive microbiology looks set to fulfill “great expectations.

II.13Technological innovations in food processing

During the last 25 years, consumer demands for more convenient and varied food products have grown exponentially, together with the need for faster production rates, improved quality and extension in shelf life. These requests together with the severity of the traditional food processing technologies were driving forces for improvements in existing technologies and for the development of new food preservation technologies. Therefore, many technological developments have been directed towards unit operations such as pasteurization, sterilization, cooking and drying, and currently the new technological approaches for food preservation are serious candidates to replace the traditional well-established preservation processes.

The environmental impact that some of the most promising novel food preservation technologies may represent in terms of energy efficiency, water savings and reduced emissions. The emergence of novel thermal and non-thermal technologies allows producing high quality products with improvements in terms of heating efficiency and, consequently, in energy savings. Most of these technologies are locally clean processes and therefore appear to be more environment-friendly, having less environmental impact than the traditional ones. Novel processing technologies are increasingly attracting the attention of food processors once they can provide food products with improved quality and a reduced environmental footprint, while reducing processing costs and improving the added-value of the products.

Part III: BENEFICIAL MICROBES ASSOCIATED WITH AQUATIC ENVIRONMENT

Microorganisms have major roles in aquaculture, particularly with respect to productivity, nutrient cycling, the nutrition of the cultured animals, water quality, disease control and environmental impact of the effluent. Management of the activities of microorganisms in food webs and nutrient cycling in ponds is necessary for optimizing production. Bacteria, micro algae and protozoans all have major roles in aquatic ecosystems. Of these microorganisms, microalgae and the blue-green algae, or the cyanobacteria as they are now called, are the most easily seen and the best known. Until the last decade the heterotrophic bacteria were often overlooked, possibly because the older methods used to study them are not adequate for natural environments. The classical methods of clinical microbiology, especially counting colonies of bacteria on nutrient-rich agar, were designed to isolate or count particular pathogenic bacteria. Some advances were made with these techniques, but the extent of the role of bacteria and protozoans in the decomposition of organic matter and the cycling of important elements has been fully recognized only recently.

In the last 15 years, major advances have been made in microbial ecology with new methods that have been developed for studying aquatic microorganisms and their activities. Epifluorescence microscopy has become a powerful tool for counting the total numbers of bacteria, estimating their biomass and determining their distribution in water, in sediments and on surfaces of submerged plants and man-made structures. This technique has shown that bacteria are anywhere from 10 to 100000 times more numerous than the classical microbiological techniques showed.

Biochemical techniques involving small compounds labelled with radioactive atoms (especially tritium and 14C) have been used to study the activities, growth rates and productivity of microorganisms in aquatic ecosystems. These methods enable microbial ecologists to study the functions of ecological groups of bacteria in their natural environment. The new tools of the microbial ecologist have an important application to aquaculture. By quantifying the productivity of bacteria, we can make scientifically-based judgments about the functional roles of bacteria, and thus improve pond management to optimize productivity.

Several factors influence the accuracy of bacterial productivity determinations, and these should be assessed before applying values in a model. These include the type of method used; the species composition i.e. variations in biochemistry; the physiological state of the bacteria, e.g. whether they are starved, or growing slowly or rapidly. Factors for converting growth rate to production or carbon flux depend on bacterial size and growth efficiency and these vary with species composition of the active populations (many bacteria in natural water bodies are in a non-growing state).

Figure: Microbial processes happening in aquatic environment

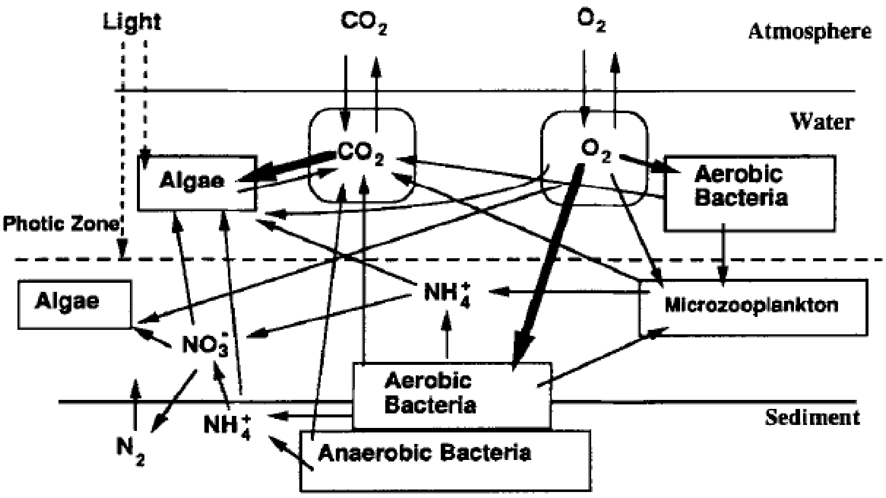


Fig. 1. Flows of oxygen, carbon dioxide and some nutrients between the principal microorganisms in a pond. In the photic zone, which is generally where the light intensity is more than 1% of the surface intensity, oxygen is produced by phytoplankton at a greater rate than it is consumed by respiration. Net mineralisation of nitrogen as ammonium by bacteria is only greater than uptake if the C:N ratio of detritus is less than 10:1. Where the C:N ratio is greater, bacteria will be net immobilisers of nitrogen and compete with the algae for it; microzooplankton mineralise the nitrogen when they feed on bacteria.

III.1 Bacterial disease and probiotics

Disease control needs a new approach, which is both cost-effective and environmentally safe. The use of beneficial bacteria (probiotics) to displace pathogens (by competitive processes or by release of growth inhibitors) is now gaining acceptance in the animal industry as a better, cheaper and more effective remedy than administering antibiotics to promote health of animals. The probiotic control of pathogens in fish culture has considerable. It is likely that antibiotic usage in hatcheries and ponds can be replaced by bacteria that inhibit pathogens.Antibiotics are often ineffective either because resistant bacteria develop or the pathogens are in a non-growing phase when they are insensitive to antibiotics.

Knowledge of the precise relationships between water column bacteria and those growing in or on the animals is essential for making informed decisions on management and operational procedures. Further research is needed on the nature of the bacterial populations associated with aquatic animals, both in the wild and in culture, in order to provide a basis for understanding the impact of control measures in hatcheries and ponds and on water released to the natural environment. If we can manipulate the bacterial species composition and in particular control pathogen numbers, larval survival and fitness will be enhanced in hatcheries and grow-out productivity will be increased, andthe risk of contaminating natural populations with antibiotic-resistant bacteria will be lowered. Many commercial products of viable bacteria are being used to control water quality in ponds; (one term for this is bio-augmentation). The ecological processes that govern the presumed efficacy of many of these preparations are not well defined, although it is presumed that the added bacteria produce greater quantities and a greater range of exoenzymes for breaking down organic compounds. Many users report that the products are effective, so a study of the ecology of the bacteria involved in those processes will lead to better control of water quality in ponds and the development of better products.This would have a flow-on to improvements to the microbial amelioration of pollution,not only in aquaculture, but in other industries that have an impact on coastalenvironments.

III.3 Probiotics are classified into following two groups

III.3.1 Feed Probiotics: Some bacterial, fungal strains can be blended with feeding pellets or by encapsulating into live feed stock or administered orally to feed rearing animals to prevent disease and enhance essential microbial flora of the gut. Viability of strains should be tested before feeding animals. Probiotics like lactic acid bacteria applied in the feed of fry of Atlantic cod, showed adequate growth, survival and immune response.

III.3.2 Water probiotics: water probiotics are applied to reduce organic pollutants and various contaminants in water by directly applying to rearing medium. These improve water quality by converting organic matter to smaller units.

Breakdown of organic matters evolve simpler substances like glucose and amino acids that are used as food for beneficial bacteria which reduce the accumulation of organic pressure and provide congenial environment to farmed stock. Probiotic bacteria such as *Bacillus* sp. can convert organic matter to CO_2 so that organic effluent can be minimized in aquatic system. By using nitrifying bacteria, the quantity of nitrate, nitrite, ammonia is reduced to a large extent. These lead to purify the water in the hatchery enhancing larval survival and growth.

III.4 Significance of Probiotics in Aquaculture

Probiotics use in aquaculture show great impact on aquatic organisms. Probiotics decrease accumulation of organic load and maintain water quality in an efficient way. A modern probiotic organism can easily fulfill the desires of sustainable aquaculture development because it can heighten two major key factors of growth performance and disease resistance. Lactic Acid Bacteria, a popular probiotic strain, can be applied to control bacterial pathogen. In addition, another well-known probiotic organism, *Bacillus* sp. is used to diminish metabolic waste in aquatic system. Many strains of *Aeromomas* sp., *Pseudomonas* sp., *Vibrio* sp. act against infectious hematopoietic necrosis virus to show antiviral activity. These probiotic organisms may be used singly or in combination such as incorporation of individual or combined supplementation of *Lactobacillus rhamnosus* and *Lactobacillus sporogenes* enhance health and disease resistance. Probiotics do not causewater pollution because of their eco-friendly nature, thus more and more suitable for aquaculture system. They not only promote animal health but also maintain consumer health safety. Uses of probiotics and their target aquatic organisms are briefly dealt in Table 1.

Table 1: Uses of Probiotic in aquaculture system (Cruz *et al.* [49])

Uses of Probiotic	Probiotic Species	Gram Positive/negative Bacteria	Target aquatic species
Water quality	*Bacillus* sp. *Vibrio* sp. NE 17 *Lactobacillus acidophilus*	+ve -ve +ve	*Penaeus monodon* *Macrobrachium rosenbergii* *Clarias gariepinus*
Control of diseases	*Enterococcus faecium* SF 68 *Pseudomonas fluorescens* *Lactococcus lactis* *Pseudomonas* sp. *Bacillus* sp. *Vibrio alginolyticus*	+ve -ve +ve -ve +ve -ve	*Anguilla Anguilla* *Oncorhynchus mykiss* *Epinephelus coioides* *Oncorhynchus mykiss* Penaeids Salmonids
Growth promoter	*Lactobacillus lactis* AR21 *Bacillus* sp. *Streptococcus thermophiles* *Bacillus coagulans* *Bacillus* NL 110	+ve +ve +ve +ve +ve	*Brachionus plicatilis* Catfish *Scophthalmus maximus* *Cyprinus carpio koi* *M. rosenbergii*
Digestion	*Lactobacillus acidophilus* *Vibrio* NE 17 *Lactobacillus helveticus*	+ve +ve +ve	*Clarias gariepinus* *M. rosenbergii* *Scophthalmus maximus*
Improvement of immune response	*Clostridium butyricum* *L. casei* *L. acidophilus*	+ve +ve +ve	*Rainbow trout* *Poecilopsis gracilis* *Paralichthys olivaceus*

III.4 Ammonia oxidizing bacteria:

Nitrifying bacteria were involved nitrification process to convert ammonia tonitrate via nitrite, and then they are applied in ammonia pollutedwater treatment technology especially in aquaculture. Nitrification is widely used to remove ammonia fromwastewater by biological oxidation. Wastewaters containinghigh concentrations of ammonia create environmentalproblems because ammonia may be toxic to aquatic organismsand can cause fertilization of lakes and reservoirswhich leads to algal growth and eutrophication. The overall biochemical process of oxidation of NH_4^+ to NO_2^-, then finally to NO_3^- is knownas nitrification. Nitrification is performed by the group ofbacteria known as nitrifiers. The nitrifying process takesplace in two steps and each step is carried out by a specificgroup of nitrifying organisms. The two microbes involvedhave been identified in many studies and are the aerobic autotrophic main genera *Nitrosomonas* and *Nitrobacter*. The reactions are as follows:

$2NH_4^+ + 3O_2 \rightarrow 2NO_2^- + 4H^+ + 2H2O$ + Nitrosomonas(AOB)

$2NO_2^- + O_2 \rightarrow 2NO_3^-$ + Nitrobacter (NOB)

AOB performs the first step by oxidizing ammonium to nitrite. NOB completes the oxidation by converting the nitriteto nitrate.

Nitrification is a two-step process where ammonia is first oxidized to nitrite by ammonia-oxidizing bacteria and/or archaea, and subsequently to nitrate by nitrite-oxidizing bacteria. Already described by Winogradsky in 1890, this division of labour between the two functional groups is a generally accepted characteristic of the biogeochemical nitrogen cycle. Complete oxidation of ammonia to nitrate in one organism (complete ammonia oxidation) is energetically feasible, and it was postulated that this process could occur under conditions selecting for species with lower growth rates but higher growth yields than canonical ammonia-oxidizing microorganisms. Still, organisms catalyzing this process have not yet been discovered. *Nitrospira* species encodes the enzymes necessary for ammonia oxidation via nitrite to nitrate in their genomes, and indeed completely oxidize ammonium to nitrate to conserve energy. Their ammonia monooxygenase (AMO) enzymes are phylogenetically distinct from currently identified AMOs, rendering recent acquisition by horizontal gene transfer from known ammonia-oxidizing microorganisms. The recognition of a novel amoA sequence group will lead to an improved understanding of the environmental abundance and distribution of ammonia-oxidizing microorganisms.

III.5 Sulphur oxidizing bacteria

Sulphur-oxidizing bacteria play an important role in the detoxification of sulphide in water and sediments. Sulphur reducing bacteria are anaerobic micro-organisms that are wide spread in anoxic habitats, where they use sulphate as a terminal electron acceptor for the degradation of organic compounds, resulting in the production of sulphide. Subsequently, the sulphide can be oxidized under anoxic conditions by chemolithootrophicsulphur bacteria or under anoxic conditions by phototrophic sulphur bacteria. Sulphur oxidizing chemolithotrophs growth is primarily aerobic, that is, using molecular oxygen as terminal electron acceptor. However, some species (*Beggiatoa* sp., *Thioploca* sp., *Thiobacillus denitrificans*, *Thiomicrospira denitrificans*) oxidize H_2S and aerobicallycoupling it to nitrate reduction. The large inputs of organic matter support high rates of heterotrophic metabolism. Since oxygen is usually depleted below a few millimeter depths, even where the sediment surface is exposed to air, anaerobic metabolism predominates with decom-position mediated primarily by fermentative and sulphate reducing bacteria. Sulphide formed as the product of bacterial sulphate reduction usually undergoes rapid digenetic transformations in coastal sediments. Hence, microbial sulphur transformation is a key process for the biogeochemical sulphur cycle in marine sediments and closely linked to the cycling of other elements like oxygen, nitrogen, and carbon.

The major processes of transformation involved in the cycling of sulphur in the environment are:

1. Mineralization of organic sulphur to the inorganic form, hydrogen sulphide, H_2S.

2. Immobilization

3. Oxidation and

4. Reduction

III.5.1 Mineralization

The breakdown/decomposition of large organic sulphur compounds to smaller units and their conversion into inorganic compounds (sulphates) by the microorganisms.

III.5.2 Immobilization

Immobilization involves microbial conversion of inorganic sulphur compounds to organic sulphur compounds. In the process of immobilization, microorganisms absorb inorganic sulphate and convert it into organic form for the synthesis of microbial tissue. If an abundant supply of carbon is available for energy then the entire inorganic sulphate in soil will be converted to organic form, but if little carbon is available then inorganic sulphate will be released from the organic matter.

III.5.3 Oxidation

Sulphate on the reductive side functions as an electron acceptor in metabolic pathways is used by a wide range of microorganisms and is converted to sulphide. Reducedsulphur compounds such as sulphide serve as electron donors for phototrophic or chemolithotrophic bacteria which convert these compounds to elemental sulphur or sulphate. When plant and animal proteins are degraded, sulphur is released and accumulates in the soil which is then oxidized to sulphates in the presence of oxygen and under anaerobic condition organic sulphur is decomposed to produce hydrogen sulphide (H_2S). H_2S can also accumulate during the reduction of sulphates under anaerobic conditions which can be further oxidized to sulphates under aerobic conditions.

The biological oxidation of elemental sulphur and inorganic sulphur compounds (such as H_2S, sulphite and thiosulphate) to sulphate (SO_4) is brought about by direct and indirect methods. In the direct approach photoautotrophic or chemolithotrophicsulphide oxidizing bacteria use sulphide as an electron donor and convert it to sulphur or sulphate. Photoautotrophs use CO_2 as the terminal electron acceptor, while with chemolithotrophs, oxygen (aerobic species) or nitrate and nitrite (anaerobic species) serve as terminal electron acceptors. In the indirect method oxidation of reduced sulphur compound is carried out chemically by ferric iron as the oxidizing agent, and iron oxidizing bacteria are used to regenerate the ferric iron for further use.

The purple sulphur bacteria encompass many generas such as *Chromatium*, *Thioalkalicoccus*, *Thiorhodococcus*, *Thiocapsa*, *Thiocystis*, *Thiococcus*, *Thiospirillum*,*Thiodictyon*, and *Thiopedia*. The colourless sulphur bacteria encompass many genera such as *Thiobacillus*, *Acidithiobacillus*,*Achromatium*, *Beggiatoa*, *Thiothrix*, *Thioplaca*, *Thiomicrospira*, *Thiosphaera*, and *Thermothrix* etc. *Achromatium*, a spherical sulphur oxidizer, is common in freshwater sediments containing sulphide.

III.5.4 Reduction

Two physiological types of sulphate reduction arerecognized. The first is assimilatory or biosynthetic sulphate reduction in which organisms reduces only enough sulphates to meet their nutritional requirements for sulphur. The assimilatory pathway generates reduced sulphur compounds for biosynthesis of amino acids and proteins. This pathway is considered to be in the pathway for the biosynthesis of cysteine and is usually under both coarse and fine metabolic regulation. The second sequence involved in the reduction of sulphate isthe dissimilatoryor respiratory pathway of sulphate reduction in which sulphate in the absence of oxygen serves as a terminal electron acceptor for anaerobic respiration. Sulphate can be reducedto hydrogen sulphide (H_2S) by sulphate reducing bacteria (*Desulfovibrio* and *Desulfatomaculum*) and may diminish the availability of sulphur. This is “dissimilatory sulphate reduction” which is not at all desirable from soil fertility. Dissimilatory sulphate-reduction is favoured by the alkaline and anaerobic conditions of soil and sulphates are reduced to hydrogen sulphide.

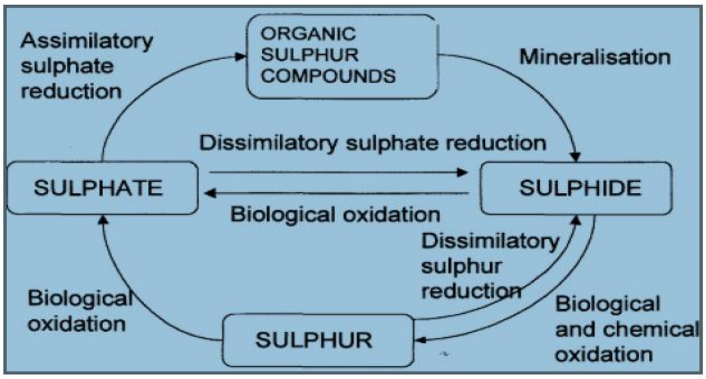


Figure: Sulphur cycle in aquaculture pond

Knowledge of the precise relationships between water column bacteria and thosegrowing in or on the animals is essential for making informed decisions on managementand operational procedures. Further research is needed on the nature of the bacterialpopulations associated with aquatic animals, both in the wild and in culture, in order toprovide a basis for understanding the impact of control measures in hatcheries and pondsand on water released to the natural environment. If we can manipulate the bacterialspecies composition and in particular control pathogen numbers, larval survival andfitness will be enhanced in hatcheries and grow-out productivity will be increased, andthe risk of contaminating natural populations with antibiotic-resistant bacteria will be lowered.

Part IV: FISH AND FISHERY PRODUCTS SAFETY GOALS

Fish and fishery products safety goals must achieve more than end-product probes. The absence of pathogens in final-product testing does not ensure food free of virulent microorganisms, according to a new expert report on food safety issues, and as pathogen contamination decreases this form of testing becomes more deficient. So as today's food safety continues to improve, more emphasis should be placed on monitoring processing capabilities and conditions through the application of science-based food systems.

The microbiological testing of finished fish and fishery products and can be misleading for the following reasons 1. Due to statistical limitations based on the amount of product sampled,

2. The percentage of product contaminated, and

3. The uniformity of the contamination distributed throughout the food.

The above mentioned negative results imply an absence of pathogens in foods, the report states, and can cause consumers to assume proper food selection and handling practices are unnecessary. Instead, the report urges everyone along the farm-to-fork fish and fishery products chain to be responsible for an important role in food safety management.

According to Douglas L. Archer of the University of Florida who contributed to IFT report “Current safety evaluations focus on microbes that may or may not be harmful to humans,” he added, “For example, some subtypes of *Listeria monocytogenes* found in or on food may not be associated with food borne illness. Yet their mere detection can be grounds for legal action against the manufacturer and force recalls of food that is unlikely to cause illness in the general population.”

The need science-based approach called Food Safety Objectives that would place specific values on public health goals, with reassurances those values are reached at key points along the pond to plate process. Those values would be flexible as hazards and public health goals change, science progresses, and unfettered data sharing improves, allowing for the quickest implementation of new safety improvements as they evolve, and a safer food supply.

The report urges intentional interaction of public health, regulatory, industrial and consumer agencies, calling the implementation of a flexible, science-based approach involving all these parties “as the best weapon against emerging microbiological food safety issues.”

IV.1 Steps in fish and fishery products Safety Management

Foodborne illness in India is a major and complex problem that is likely to become a greater problem as we become a more global society where every 5th person walking on this planet is going to be Indian. Nearly 10 million foodborne illnesses occur per year in India. To adequately address this complex problem, the need is to develop and implement a well-conceived strategic approach that quickly and accurately identifies hazards, ranks the hazards by level of importance, and identifies approaches for microbial control that have the greatest impact on reducing hazards, including strategies to address emerging hazards that were previously unrecognized.

IV.2 Policy Development

Scientific research has resulted in significant success in improving fish and fishery products safety, but the current science supporting the safety of our fish and fishery products supply is not sufficient to protect us from all the emerging issues associated with the complexity of the food supply. As new issues emerge, some will be best addressed through the application of control technologies during fish and fishery products production and processing, but others may be best addressed at the consumer level through modification of exposure or susceptibility.

Food safety policies should be developed as part of national initiatives, with input from all stakeholders. In addition, international coordination of food safety efforts should be encouraged. Globalization of the food supply has contributed to changing patterns of food consumption and foodborne illness, and global food trade has the potential to introduce pathogens to new geographic areas.

To achieve the maximum benefits, our food safety efforts and policies must be carefully prioritized, both in terms of research and in application of controls. As scientific advances provide a better picture of pathogenicity, the need of the hour is whether to focus the efforts on those pathogens that cause many cases of minor illness or instead focus on those pathogens with the greatest severity, despite the relatively low number of cases. In the move toward making decisions based on risk, the food safety policies need to weigh these issues, and communicate information about risk to all stakeholders, especially the public.

The body of scientific knowledge must be further developed, with the research efforts carefully prioritized to yield the greatest benefit. Food safety and regulatory policies must be based on science and must be applied in a flexible manner to incorporate new information as it becomes available and to implement new technologies quickly. The fish and fishery products industry, regulatory agencies and allied professionals should develop partnerships to improve food safety management.

To conclude

IV. 3 Fish and fishery products Supply and exports: The amount of exported fish and fishery products has increased significantly, and this trend is likely to continue. Consistent, widespread application of food safety systems, including Hazard Analysis and Critical Control Points systems and good manufacturing (GMP), must be encouraged for international trade.

IV. 4 New Fish and fishery products Processing Technologies and Novel sea foods Scientists continue to be challenged to adequately address all the parameters associated with the introduction of a novel fish and fishery products or alternative processing technology. Once developed, new technologies must be appropriately used and regulated to ensure their proper application and the product's safety.

IV.5 Increases in Organic Foods. The use of manure as a fish pond fertilization is a significant concern. Methods are needed to reduce the presence of pathogens in manure and to effectively eliminate them before they contaminate the aquatic environment and fish.

IV.6 Changes in Food Consumption. People's changing dietary patterns affect their risk of foodborne illness. The control and prevention methods will need to be adapted to these changing dynamics. For example, in India the number of high end consumers who prefer ready to eat foods are more than 300 million which is more or less equivalent to Europe

IV.7 At-Risk populations. It is likely that the number of persons at higher risk for foodborne disease will continue to increase with time. The population of India is going to be 150 crores. In addition, there are an increasing number of transplant recipients, people undergoing treatment for cancer, people with AIDS, and others with compromised immune system function.

IV.8 Pathogen Evolution. Microbial evolution has always happened and will continue to occur. Improved surveillance and new genomic technologies offer the potential to identify new potential foodborne pathogens before they cause significant illness. Another hope for the future is a better understanding of how human actions affect foodborne pathogens.

IV.9 Consumer Understanding. Education and risk communication will be necessary to share with consumers our growing knowledge of food safety risks and to encourage behavior modification, where needed.

Integrated Food Safety System. A farm to- fork or pond to plate table food safety system must involve many interested parties working together toward a common goal. The challenge is to build a system that applies science in a predictable, consistent, and transparent manner to enable harmonization within and between countries.

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Chapter 26

Prophylactic health products in aquaculture

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Introduction

Fisheries and aquaculture are important source of food, nutrition and livelihood for millions of people around the world. Aquaculture is the fastest growing food-production sector in the global aquaculture with production of 73.8 Million tonnes in 2014 (FAO, 2016) expanding into new directions, intensifying and diversifying. A persistent goal of global aquaculture is to maximize the efficiency of production to optimize profitability.

Infectious diseases pose of the most significant threats to successful aquaculture. Intensively cultured fish and shellfish are susceptible to infectious agents. The losses due to shrimp diseases in India is valued at Rs. 10, 221 million. Globally, the yield loss due to diseases in aquaculture is estimated to be $ 6 billion. A variety of antimicrobial and chemical treatments have been used for the control and treatment of bacterial diseases in aquaculture systems. The emergence of antimicrobial resistance in bacteria due to application of antibiotics in aquaculture and the toxic nature of chemicals led to the search for alternatives for the control of infection. Here we discuss the several alternatives to antibiotics that have been successfully used in aquaculture.

Probiotics in aquaculture

The interest in probiotics as an environmentally friendly alternative is increasing and its application is both empirical and scientific. At present, there are several commercial preparations of probiotics that contain one or more live microorganisms, which have been introduced to improve the cultivation of aquatic organisms. Probiotics can be used as a food additive, added directly to the aquaculture pond or mixed with food.

The origin of the term probiotic is attributed to Parker (1974). As the intestinal microbiota in aquatic animals constantly interacts with the environment and the host functions, a probiotic is defined as a live microbial adjunct which provides beneficial effects viz., (i) modify the host-associated microbial community, (ii) improve the use of feed or enhancing its nutritional value or (iii) improving the quality of its surrounding environment. The use of probiotics in aquaculture include improving the host growth, reducing the incidence of diseases thus requiring less chemotherapy. The microorganisms present in the shrimp and fish intestine vary based on the environment in which they live in. Desirable characteristics of potential probiotics include (i) not harmful to the host; (ii) acceptance by the host through ingestion, and colonization and proliferation within the host; (iii) ability to reach target organs where they can work; and (iv) no virulent resistance or antibacterial resistance genes.

A diverse range of Gram-positive bacteria is commonly used worldwide as probiotics. The wide applications belong to endospore-forming members of *Bacillus* genera, in which *Bacillus subtilis* is commonly used in aquaculture. A wide variety of Gram-negative bacteria also play a role as putative probiotics in aquaculture.

Probiotics can be administered orally or by water route or as feed additives. In aquatic animals, probiotics act by different methods. Probiotics occupy and colonize in digestive tracts, particularly the GI mucosal epithelium and they adhere and grow in the intestinal mucus. The probiotic may compete for adhesion receptors with pathogens. Some bacterial species produce a wide range of antagonistic and antibiotic compounds that can be valuable as probiotics. Therefore, probiotics can be used as a suitable alternative to the prophylactic use of antibiotics and chemicals. Probiotics have also proven their effectiveness in improving water quality. They enhance the decomposition of organic matter, reduce nitrogen and phosphorus concentrations, and control ammonia, nitrite, and hydrogen sulphide. Currently, commercial products are available in liquid or powder presentations and various technologies have been developed for their improvement. Probiotics have been used in aquaculture to increase the growth of cultivated species, in reality it is not known whether these products increase the appetite, or if, by their nature, improve digestibility. Probiotic microorganisms colonize the gastrointestinal tract when administered over a long period of time because they have a higher multiplication rate than the rate of expulsion, so as probiotics constantly added to fish cultures, they adhere to the intestinal mucosa of them, developing and exercising their multiple benefits. Probiotic microorganisms have the ability to release chemical substances with bactericidal or bacteriostatic effect on pathogenic bacteria that are in the intestine of the host, thus constituting a barrier against the proliferation of opportunistic pathogens. Probiotics also have a beneficial effect on the digestive processes of aquatic animals because probiotic strains synthesize extracellular enzymes such as proteases, amylases, and lipases as well as provide growth factors such as vitamins, fatty acids, and aminoacids. Therefore, nutrients are absorbed more efficiently when the feed is supplemented with probiotics. In shrimp species, *L. vannamei* and *F. indicus,* various strains of *Bacillus* have been used as probiotics to increase apparent digestibility of dry matter, crude protein, and phosphorus.

Because there was no international consensus to ensure efficiency and safety of probiotics, FAO and WHO recognized the need to create guidelines for a systematic approach for the evaluation of probiotics in food, in order to substantiate their health claims. As a result the "Guide for the Evaluation of Probiotics in Food" was presented, providing guidelines on the evaluation of health and nutrition properties of probiotics in food. Although the guide is not focused on aquaculture products, it creates a precedent for conducting studies to evaluate the safety of probiotics in this area.

Immunostimulants

Immunostimulants are dietary additives that enhance the innate (non-specific) defense mechanisms and increase resistance to specific pathogens. So far glucans, which are polymers of glucose, found in the cell walls of plants, fungi and bacteria appear to be most promising of all the immunostimulants investigated, in fish and shrimp culture ponds through oral application.

The main immunostimulants applied in aquaculture are polysaccharides, nutrients, oligosaccharides and herbs. Polysaccharides are important biological molecules and are present in plants, animals and microbes.

β-Glucans

Glucans mainly exists in the cell walls of bacteria and yeast. Glucans are recognized by the immune system of aquatic animals as a foreign molecular pattern. The application of glucans has been extensively studied in aquatic animals, and findings indicate that β-glucans promote growth in some of the aquatic animals. β-Glucans are found to activate phagocytic cells in fish, improving phagocytosis and the ability of the cells to kill pathogenic organisms.

Other polysaccharides

Peptidoglycans are composed of polymers that contain a chitosan chain, peptide bridge and peptide subunits within the cell wall of bacteria. Research demonstrates that peptidoglycans promote growth and enhance the resistance to pathogens and the immunity of aquatic animals. Peptidoglycans are important immunostimulants that regulate the immune system of aquatic animals.

Chitosan is a de-acetyl chitin, found in the shells of aquatic animals such as shrimp, crab and shellfish. The main activities of chitosan in aquaculture are to promote the growth of aquatic organisms, improve the immunity of aquatic animals, inhibit the growth of aquatic pathogens, purify the water used in aquaculture and enhance the disease resistance of aquatic animals. Ongoing research regarding the mechanisms of action of this group of immunostimulants within aquatic animals will provide more scientific evidence for increased standardization and effective application of polysaccharides in aquaculture.

Herbs

Recently, there has been a growing interest in the immune stimulating functions of several herbs in aquaculture. Herbal extracts show potential for application as immunostimulants in aquaculture primarily because they can be easily obtained and act against a broad spectrum of pathogens. Most herbs and herb extracts can be administered orally, which is the most convenient method of inducing immunostimulation. Fish treated with herbs typically exhibit enhanced phagocytosis. Further investigations into the stability of plant materials in the aquatic environment and their digestibility by fish, as well as in vitro and in vivo toxicological tests, are required to determine the safety of applying herbs to aquaculture .

Vitamins

Aquatic animals fed high doses of Vitamin C was found to exhibit improved immunity and resistance to disease. Different haematological and serological parameters, as well as non-specific immune parameters, are influenced by Vitamin C supplementation. Vitamin E also known as tocopherol, can enhance the generation of antibodies and complement activity in response to antigens, promote the proliferation and differentiation of lymphocytes and cytokine production and improve cytotoxicity and phagocytosis in fishes

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Chapter 27

Hygiene Indicator bacteria in sea-foods and aquaculture

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INTRODUCTION

Indicator bacteria are types of bacteria that are used to provide an indication of poor hygiene, inadequate processing and or post- process contamination in seafood's, water, feed, ice, equipments, workers, etc. Absence of indicator bacteria in seafood and aquaculture products provides a degree of quality assurance that the fishery products are hygienically good and employed proper processing methods whereas their presence clearly indicates either severe problem or failure occurred during the processing p, under-processing or post-process contamination. The indicator bacteria in fish and fishery products are mainly from enterobacteriaceae and coliforms group of bacteria. Traditionally, indicator micro-organisms have been used to suggest the presence of pathogens (Berg 1978) and it includes the general microbial Process indicators, Faecal indicators, andIndex and Model indicator organisms. The Process indicator is a group of organisms that indicates the efficacy of a processing and tested by Total Plate count (TPC)/ Total heterophilic count or toal coliforms (MPN method). Fecal indicator is a group of organisms that indicates the presence of fecal contamination and could be tested by fecal coliforms, thermotolerant coliforms (MPN method) and *E.coli* (EMB and IMViC test). An Index and model organisms is a group of organisms that indicates the presence of pathogens such as *E.coli* as an index for Salmonella and coliphages as model of human enteric viruses. The pathogenic indicator bacteria viz., Coliforms, Fecal coliforms, *E.coli, Klebsiella, Enterobacter, Citrobacter,* Fecal Streptococci,Sulphite reducing clostridia, *Clostridium perfringens*, Bifidobacteria, Bacteriophages, coliphages and *Bacteroides fragilis* baeriophages etc**.,** are associated with food poisoning. In addition, pathogenic viruses, protozoa and parasites also present in fecal matter. Fecal contamination is mainly from sewage of human source, livestock, poultry manure, pets and wildlife. Infection caused by these pathogens is mainly depending on the level of microbial load.

TYPES OF INDICATOR ORGANISMS

The indicator bacteria include **total coliforms** (Gram- negative, non-spore sproe-forming, oxidase- negative, rod shaped, facultative anaerobic, ferment lactose), **thermotolerant coliforms** (produce gas and acid from lactose at 44.5°C ± 0.2°C within 24 ± 2 hrs) and **fecal coliforms**(produce gas and acid from lactose at 37°C ± 0.2°C within 24 ± 2 hrs), which are found in the intestinal tracts of warm blooded animals. Total coliforms were used as fecal indicators by public agencies in the US as early as the 1920s. These organisms can be identified based on the fact that they all metabolize the sugar lactose, producing both acid and gas as byproducts. Fecal coliforms indicate that recent fecal contamination is being occurred. ***Escherichia coli*** (*E. coli*) and **enterococci** (all fecal streptococci grow at pH 9.6, between 10°C and 45°C, 6.5% NaCl and hydrolyzing 4-methlumbelliferyl-B-D-glucoside of thallium acetate, nalidixic acid and 2,3,5-triphenyltetrazolium chloride) are commonly used as indicators. The **Sulphite reducing clostridia** (SRC)-Gram-positive, spore forming, non- motile, strictly anaerobic rods that reduce sulphite to H_2S), ***Clostridium perfringens*** (As for SRC but also ferment lactose, sucrose, and inositol with the production of gas, produce stormy clot fermentation with milk, reduce nitrate, hydrolyse gelatin and produce lecithinase and acid phosphatase), **Bifidobacteria** (obligately anaerobic, non-acid fast, non spore forming, non motile, Gram positive bacilli which are highly pleomorphic and may exhibit branching bulbs-bifids, clubs, coccoid, coryneform, V and Y forms. All are catalase- negative and ferment lactose), **Bacteriophages** (bacterial viruses and are ubiquitous in the environment and are used as model to human eneteric viruses, eg., Somatic coliphages, male specific RNA coliphages and pahges phages infecting *Bacteroides fragilis*), **Coliphages** (Somatic coliphages attack *E.coli* strains via the cell wall and sex pili) and ***Bacteroides fragilis*** **baeriophages** (infect most abundant bacteria in the gut, eg. *B. fragilis* HSP40) etc., are also considered as fecal indicator microorganisms.

Total coliform bacteria are defined as the organisms that ferment lactose to produce acidic condition and change the colour of the medium to yellow within 24 ± 2 hours when incubated at 35.0 ± 0.5°C on MacConkey Broth and utilize BGLB (2%) by the observable growth and gas production within ± 2 hours of incubation at 35.0 ± 0.5°C.

Fecal coliform bacteria are defined as the organisms that grow and produce gas in *E coli* broth (EC broth) in 24 ± 2 hours when incubated at 35.0 ± 0.5°C.

E. coli are defined as the organisms that produce growth and gas production in tryptone broth (indole medium) in 24 ± 2 hours when incubated at 44.5 ± 0.2°C and is confirmed on Eosine Methylene Blue

(EMB) agar (a sterile platinum loopful of culture from EC broth is streak-dilution method and incubated at 37°C for 18-24 hrs produces well isolated colonies, 2-3mm dia with a greenish metallic sheen by reflected light & dark purple centre by transmitted lightand **IMViC** test (Indole-Degrade the amino acid tryptophan and produce indole, **Methyl Red**- *E.coli* use the mixed acid pathway, which produces acidic end products such as lactic, acetic, and formic acid. These acidic end products are stable and will remain acidic. When methyl red is added, if acidic end products are present, the methyl red will stay red, **Voges–Proskauer** - utilization of glucose to acetyl methyl carbinol (acetoin) and it will react with alpha-naphthol (VP reagent #1) and potassium hydroxide (VP reagent #2) to form a red color and**Citrate utilization**- Organisms which can utilize citrate as their sole carbon source by the presence of enzyme citrase or citrate-permease and convert the ammonium dihydrogen phosphate to ammonia and ammonium hydroxide-alkaline environment.
At pH 7.5 or above, bromthymol blue turns royal blue as positive. So the IMViC tests for *E. coli* as +, +, -and -).

Fecal streptococci are defined as the organisms that produce red or pink colonies within 48 ± 2 hours when incubated at 35.0 ± 0.5°C on Kennel Fecal Streptococcal medium.

Enterococci are defined as the organisms that produce pink to red colonies with a black or reddish-brown precipitate after primary culture for 48 to 50 hours at 41.0 ± 0.5°C on m-Eenterococcus medium followed by incubation for 20 minutes at 41.0°C on Eusculin Iron Agar medium (EIA medium).

DEVELOPMENT OF INDICATORS

Coliforms: Use of bacteria as indicators of the sanitary quality of water probably dates back to 1880 in human faeces (Geldreich 1978). In 1891, Franklands came up with the concept that organisms characteristic of sewage must be identified to provide evidence of potentially dangerous pollution. In 1893, 'Wurtz method' of enumerating *B. coli by direct plating of water samples on litmus* lactose agar was being used by sanitary bacteriologists, using the concept of acid from lactose as a diagnostic feature. This was followed by gas production, with the introduction of the Durham tube (Durham 1893). Sanitary significance of finding various coliforms along with streptococci and *C. perfringens were recognised by bacteriologists* by the start of the twentieth century (Hutchinson and Ridgway 1977). MacConkey (1905) described his now famous MacConkey's broth, which was diagnostic for lactose-fermenting bacteria tolerant of bile salts.

Coliform identification schemes: Various classification schemes for coliforms have emerged. MacConkey (1909) which has recognized 128 different coliform types. Bergey and Deehan (1908) identified 256. In early 1920s, differentiation of coliforms had come to a series of correlations that suggested indole production, gelatin liquefaction, sucrose fermentation and the Voges–Proskauer reaction were among the more important tests for determining faecal contamination (Hendricks 1978). These developments culminated in the IMViC (Indole, Methyl red, Voges–Proskauer and Citrate) tests for the differentiation of so-called faecal coliforms, soil coliforms and intermediates (Parr 1938); these tests are still in use today. Simpler to identify coliform group, despite being less faecal-specific and broader (*Escherichia, Klebsiella, Enterobacter* and *Citrobacter* were considered the most commongenera) was targeted. One of the first generally accepted methods for coliforms was called the Most Probable Number method (MPN) by Multiple-Tube Fermentation Test.

Faecal streptococci and enterococci: A group of Gram-positive coccoid bacteria known as faecal streptococci (FS) and investigated as an important pollution indicator bacterium.

Faecal streptococci: Until 1957, with the availability of the selective medium that enumeration of FS became popular. Since then, several media have been proposed for FS and/or enterococci to improve on the specificity. Taxonomically FS are represented by various *Enterococcus spp., Streptococcus bovis and S. equinus* (WHO 1997).Of the faecal streptococci, the preferred indicators of faecal pollution are the enterococci. The predominant intestinal enterococci are *E. faecalis, E. faecium* and *E. durans.* In addition, other *Enterococcus species* and some species of *Streptococcus* (*S. bovis and S. equinus)* may occasionally be detected. These streptococci however, do not survive for long in water and are probably not enumerated quantitatively. Thus, for water examination purposes enterococci can be regarded as indicators of faecal pollution, although some could occasionally originate from other habitats.

Sulphite-reducing clostridia and other anaerobes: Until bifidobacteria were suggested as faecal indicators by Mossel, 1958. *C. perfringens* was the only obligately anaerobic, enteric micro-organism seriouslyconsidered as a possible indicator of the sanitary quality of water. Anaerobic sulphite-reducing clostridia are much less prevalent than bifidobacteria in human faeces. But their spore-forming habit gives them high environmental resistance (Cabelli, 1978). *C. perfringens* is the species ofclostridia most often associated with the faeces of warm-blooded animals (Rosebury, 1962), but is only present in 13–35% of human faeces. Although *C. perfringens* has been considered a useful indicator species formore than a hundred years (Klein and Houston 1899). Perfringens as a faecal indicator and could present in the environment for long duration,which is considered to be significantly longer than enteric pathogens (Cabelli, 1978). Bonde (1963) suggested that all SRC in receiving waters are not indicators of faecal pollution, hence *C. perfringens* is the appropriate indicator.

Bacteriophages: Viruses which infect bacteria, first described from the intestinal tract of man in the early 1900s. Use of phages as models for indicating the likely presence of pathogenic enteric bacteria first appeared in the 1930s. Direct correlations are exists between the presence of certain bacteriophages and the intensity of faecal contamination. Evolving role for phages to coliforms, known as coliphages-model human enteric viruses.

Major groups of indicator coliphages (Leelere et al., 2000)	
Family	**Phage examples**
Myoviridae	T2, T4, T6
Siphoviridae	λ, T5
Podoviridae	T7, T3
Microviridae	ϕX174, S13
Inoviridae	SJ2, fd, AF-2, M13

EMERGING MICROBIOLOGICAL METHODS

Fast detections using chromogenic substances: Chromogenic substances are modified either by enzymes (bacteria) or by specific bacterial metabolites. Chromogenic substance changes its colour or fluorescence, easy detection of those colonies, avoids the need for isolation of pure cultures and confirmatory tests. Time required for the determination of different indicator bacteria can be reduced between 14 to 18 hours. Extended Spectrum of Beta Lactamase (ESBL) producing *E.coli* (ESBL) and *E.coli* O 157 are examples.

Application of monoclonal and polyclonal antibodies: Mab have been successfully used for the detection of indicator bacteria in water samples (Hübner *et al.* 1992;Obst *et al.* 1994).Detection of 'viable' indicators is the combination of immunofluorescence with a respiratory activity compound. Detection of *E. coli O157:H7, S. typhimurium* and *K.pneumoniae* in water(Pyle *et al.* 1995). Antibody technology is often used in medicine with enzyme amplification (ELISA).

IMS/culture and rapid culture-based methods: Immunomagnetic separation offers an alternative approach to rapid identification of culturable and non-culturable micro-organisms (Safarik *et al.* 1995).

Principles and application of the method are based on suitable antibody specificity. Purified antigens are typically biotinylated and bound to streptoavidin-coated paramagnetic particles. Raw sample is gently mixed with the immunomagnetic beads, then a specific magnet is used to hold the target organisms against the wall of the recovery vial, and non-bound material is poured off. Target organisms can then be cultured or identified by direct means. IMS approach may be applied to recovery of indicator bacteria from water, but is possibly more suited to replace labour-intensive methods for specific pathogens such as recovery of *E. coli* O157 from water(Anon, 1996).

Gene sequence-based methods: Based on the recognition of specific gene sequences. Usually rapid and can be tailored to detect specific strains of organisms. PCR (polymerase chain reaction), FISH (fluorescence *in situ*hybridization),uses gene probes with a fluorescent marker, typically targeting the 16S ribosomal RNA (16S rRNA).

LIMITATIONS IN DETECTIONG INDICATOR BACTERIA

- Some of the indicator bacteria are environmental origins i.e. environmental reservoirs
- Some of the indicator bacteria are both fecal and non-fecal origin
- Some of the tests for fecal indicator may also detect non-fecal microbes.

FUTURE DEVELOPMENTS:

- Microarrays and biosensors
- Biosensors based on antibody technology, with the antigen triggering a transducer or linking to an enzyme amplification system.
- Microarrays using DNA/RNA probe-based rRNA targets may be coupled to adjacent detectors.

CURRENT APPLICABILITY OF FAECAL INDICATORS

- Members of the total coliform group and faecal coliforms
- *E. coli* is considered as main source of recent faecal contamination and is now considered to be *E. coli* and enterococci.

Clostridium perfringens is considered as alternative indicators to *E. coli* and enterococci.

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Chapter 28

Antimicrobial resistance (AMR) in aquatic products

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Fisheries sector plays an important role in the food security and fish is now traded internationally. Shift in the trading policies (import and export) of seafood/aquatic products are happening at a rapid pace and consumption of seafood increased globally in substantial quantum. It is estimated that aquatic products export from Asian countries outcompetes earlier contributions to their importing partners year after year. Aquatic products includes chordates, molluscs and arthropods from freshwater, brackish and marine system. They are nutrient rich diet and perishable too in nature and this prompted the industry to process the seafood in to different forms such as frozen, canned, cured and dried to extend its shelf life and recently value addition step being followed to improve the customer satisfaction. Nevertheless the risk associated with the transboundary exchange of pathogens of seafood importance and its antibiotic resistance are generally cannot be disregarded. Majority of the pathogens are not a native flora of fish. Each step in the aquatic products production chain either in the captured or cultured fisheries involves the contact of the seafood to the environment where they are grown, various implements used, contact surfaces, handlers, water etc. This post harvest handling makes the seafood contaminated with the pathogens of seafood importance's such as *Escherichia coli*, *Salmonella* spp, *Clostridium botulinum*, *Listeria monocytogenes*, *Staphylococcus aureus*, *Vibrio cholerae*, *Vibrio parahemolyticus*, *Shigella* sp, *Aeromonas hydrophila*, *Plesiomonas shigelloides* and viral pathogens such as hepatitis A virus etc. Among these pathogens, *Escherichia coli*, *Salmonella* spp, *Staphylococcus aureus* and *Shigella* spp are non-indigenous to the aquatic environment and others are indigenous to the aquatic environment. Depending on the nature of the environment (contaminated water source), feeding habits(filter feeders), season of harvest (summer season) are very crucial factors which cause seafood inherently contaminated in nature.

In the present scenario, the risk is potentiated not only by the presence of these pathogens but also on the antibiotic resistances they possess. Worldwide research deviation is noticed on antibiotic resistant pathogens both from clinical sector and in the food producing animals. Antibiotic resistant pathogens of seafood importance are Methicillin-resistant *Staphylococcus aureus*, Extended spectrum Beta-lactamase producing Enterobacteriaceae *viz.*, ESBL *E. coli*, ESBL Salmonella; carbapenamase resistant Enterobacteriaceae viz., Klebsiella, *E. coli*; Vancomycin resistant Enterococci and so on. The link between the use of antimicrobial substances in food production and the presence of antibiotic resistant foodborne pathogens *Salmonella,* pathogenic *E.coli, Campylobacter, Staphylococcus* spp., *Enterococcus* spp.and extended-spectrum beta-lactamase (ESBL) has been already proved by various researchers. This perhaps shows the importances of studies on AMR pathogens in the food producing animals with special reference to the seafood or aquatic products development.

In general to exception of commercially sterile and other pro,pre and synbiotics food products, food have the proximity of getting contaminated to various microbes during entire production and processing chain. The raw food in general have the highest culturable bacterial concentrations, followedby minimally and fully processed foods. Minimally or fully processed food including ready-to-eat food contamination depends on the level of sanitary hygiene followed during the processing and preservation steps.

The food with acceptable microbiological quality range may also serve as the sink for the development of antibiotic resistances through bacteria, bacteriophages, bacterial DNA and mobile geneticelements, some of which may include AMR genes. Hence, the foodchain ecosystem may be conducive niches for genetransfer, selection and persistence of AMR bacteria and this route cannot be generally disregarded.

Antibiotic resistance in bacteria: definition

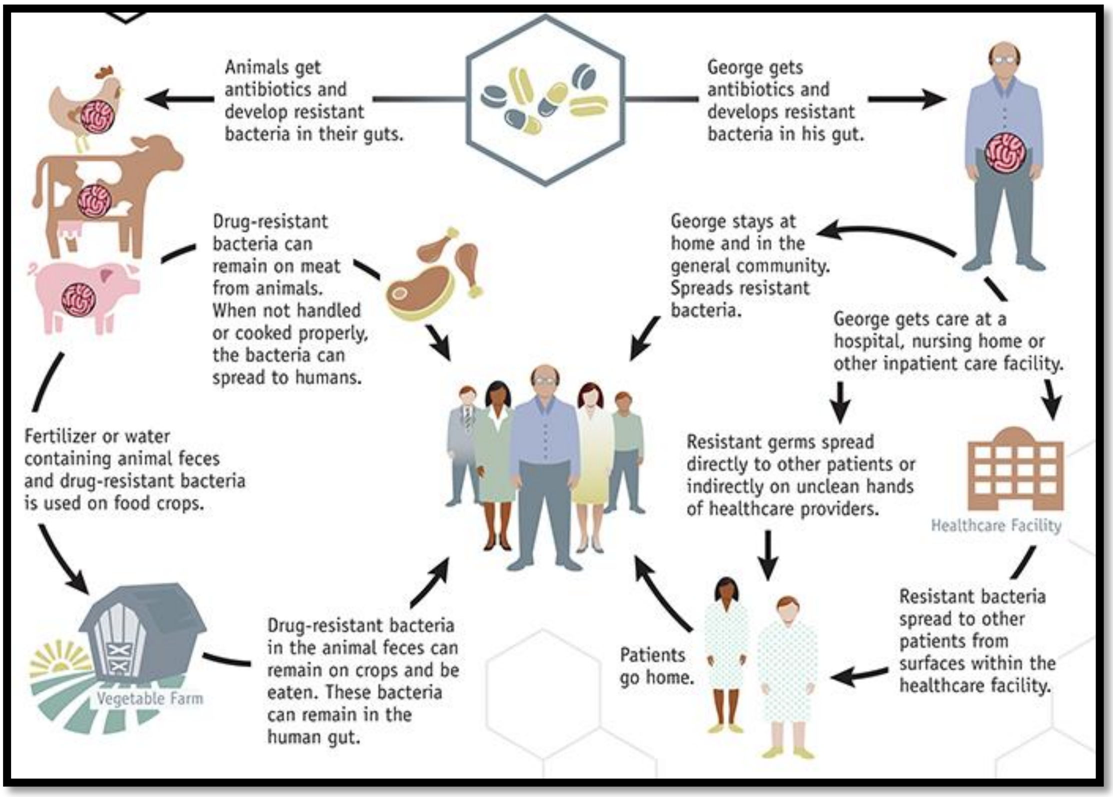
An antibiotic is a drug that kills or stops the growth of bacteria like penicillin and ciprofloxacin, whereas antimicrobial refers to all microbes *viz.*, bacteria, viruses, fungi, and parasites. Hence, Antibiotic or antimicrobial resistance (AMR) denotes the ability of microbes to resist the effects of drugs, so that either their growth is not stopped or they are not killed or both.

Mechanism of antibiotic resistance in bacteria

In general main mechanism of resistance to antimicrobial agents in bacteria may falls under any one of these categories, 1. Changes in the bacterial cell wall permeability or target sites, 2. enzymatic drug modifications or degradation and 3. membrane-bound efflux pumps removal of antibiotics through energy dependent.

Trends in antimicrobial resistance among various seafood borne bacterial pathogens

AMR is an increasing global public threat in various facets of healthcare system because of their rapid emergence of newer resistances and spread across the various countries. Its impact is felt across the globe. This results in prolonged illness, complications in surgical conditions due to infection with resistant organisms, severe fatal forms are also encountered. Antibiotic resistance development is a natural process occuring during due to change in genetic makeup of microbes in a longer time, however the current situation is happening at an elevated speed due various reasons such as misuse, overuse of antibiotics with or without professional oversight, as growth promoting substances in food producing animals, inadequate or inexistent programmes for infection prevention and control (IPC), poor-quality medicines, weak laboratory capacity, inadequate surveillance and insufficient regulation of the use of antimicrobial medicines. AMR organism are present in human, animal, food, and environment which makes the transmission more faster than before between or within human and animals.



Possible pathways of AMR spread

V. parahaemolyticus, V. vulnificus, V. alginolyticus, and V. cholerae are autochthonous Gram-negative bacilli to estuarine and marine environments and found associated with disease through wound infection or through consumption of contaminated seafood especially shellfish. Antimicrobial resistant Pathogenic bacteria released into aquatic environments through wastewater acts as potential spread of antibiotic resistant genes spread. In general Vibrios sp showed higher resistances towards Ampicillin and low tetracycline resistances. The frequency of resistance reported in aquatic products ranged from 16.6% to 50% level and 10 to 69% of the vibrio strains showed resistance to more than 4 molecules. Common antibiotics showed resistances are teicoplanin, pencillin, oxacillin, vancomycin and low level resistance for cephalosporin groups.

Highly resistant to penicillin, ampicillin, tetracycline, and vancomycin was observed in L. monocytogenes isolated from seafood and low level less than 10% for Tetracycline, enrofloxacin, and ciprofloxacin. The antibiotic resistance pattern and number changes between the serotypes of L. monocytogenes isolated from seafood, serotype 1/2a was found to be more resistant than other serotypes.

S. aureus isolated from fishery products were resistant to penicillin, chloramphenicol and ciprofloxacin and most of them were also resistant to tetracycline. In general to the β-lactams, Macrolides, aminoglycosides, ciprofloxacin, co-trimoxazole (4.7%) and tetracycline resistances were observed in most of the studies with varied percentage. Pencillin, Macrolides are above 50% and others were less than 50% level. Multidrug resistant strains were also reported in many studies.

Salmonella isolated from seafood were in general resistant to the Pencillin, Erythromycin, tetracycline and other antibiotics were less than 15% level. In a study conducted on imported seafood in to US from 20 countries, S. enterica strains of 36 serovarwere isolated and Twenty isolates showedresistance to at least one antibiotics. Five strains(serovars Bareily, Oslo, Hadar, Weltevreden and Rissen) were resistant to two or more antibiotics. Two *S. enterica* strains (serovars Bareily and Oslo) from seafood from Vietnam and India were resistant to trimethoprim/sulfamethoxazole, sulfisoxazole, ampicillin, tetracyclineand chloramphenicol. Multidrug resistant strains were also observed in Salmonella isolated from seafood.

In addition to this, Fish are reservoirs for zoonotic pathogens not only infecting the host animal but alsohumans in contact during aquaculture activity. The infections includes *Aeromonas hydrophilia*, *Mycobacterium marinum*, *Streptococcus iniae*, *Vibrio vulnificus*, and *Photobacterium damselae* etc are noted few.

All the study demonstrated that there is a change in the trend of antibiotic resistances which depends on the country of origin of the seafood, antibiotic usage in particular country for aquaculture practices etc.

Laboratory diagnosis of AMR in bacterial pathogens

Antimicrobial resistance can be detected either qualiatively or quantitatively. Qualitatively antibiotic resistances can be determined by disk diffusion assay for particular antibiotic against the pathogens. Quantitatively antibiotic resistances can be determined by minimum inhibitory concentration (MIC) either in broth dilution or agar dilution. In this the resistances are estimated for concentration from microgram to milligram. MIC can also be performed in microdilution or macrodilution in microtitre plate or tube respectively.

Antibiotic resistances determination can be divided into phenotypic and genotypic. Phenotypic is based on disk diffusion and MIC, whereas genotypic is based on the detection of genes responsible for the antibiotic resistances.

Now-a-days there is a shift in the adoption of methologies for determination of antibiotics resistances. Genotypic methods are implemented in high throughput level for better understanding of molecular mechanism of antibiotic resistance shown by these pathogens.

AMR and seafood trade implications

Last three decades has shown a remarkable increase in World trade of fishery and aquaculture products. 40% of fish producers are now engaged in international trade, majority from Asian countries. In which China gives major shares. Japan, EU and the US are the major importers of seafood for processed products of crustaceans, molluscs and aquatic invertebrates and fish, as well as cured and fresh/chilled fish. If transboundary diffusion of AMR pathogens occurs at greater pace, it may seriously impacts the seafood trade in near future. Already US and EU has put a control measure to counteract this based on the principle of quality management and process oriented controls throughout the entire food chain (from the fishing vessel or aquaculture farm to the consumer's table). Implementation of hygienic practices must be verified and certified by the national authorities. Each and every personnel's are responsible who are involved in the seafood production chain to interrupt the chain of contamination and spread of the AMR pathogens.

Controlling of AMR

AMR is a complex and indisciplinary issue, coherent efforts are required to bring down the burden of AMR among public. WHO, FAO and OIE have taken collective tripartite joint venture called one health approach to control AMR spread which are considered as national action plans to each countries. Key action plans proposed to control AMR are

1. Strengthen the surveillance system in healthcare, food producing animals on Antimicrobial usage and antimicrobial drug resistant bugs
2. Emphasis need to be given to the food and environmental sectors also
3. Strengthening the laboratory capacity for surveillance system
4. Guideline for the optimised use of antibiotics in human and animal health
5. Reduce the infection loss due to AMR pathogens by providing assured quality medicines
6. Awareness and understanding among the general public
7. Effective infection prevention and control programmes
8. Development of alternate to antibiotics protocols
9. Controlling the resistances development in bacteria for medically important antibiotics

The four pillars of the FAO plan of action to support the food and agriculture sector in addressing AMR

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Chapter 29

Designing Food Safety Management System

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Food is an important item in the life of consumer as it has a direct bearing on the sustenance of life. The food safety or over concern on the health hazards was notconsidered as an issue until recetly, particularly in the developing countries. This clearly indicates the shift in citizen's mind from availability of food to quality of food. This along with the changes in the food habits and type of products available in the market for his consumption, the incidence of food borne illness across the globe and his concern for his health contributed significantly to the development of food safety in the food arena.

Until recently food safety domain and regulation were confined to the government and its regulatory machinary. The globalisation of food and food products and the passage of food across international boarders paved way for the increased food safety concern across the globe and stresed the need for ensuring quality and safety of foodin international trade. The incidence of food borne illness increased with increase in the appearance of more and more derived products started in the market(Sivapalasingam, Friedman, Cohen, & Tauxe, 2004; Tauxe, Doyle, Kuchenmüller, Schlundt, & Stein, 2010). The production along the value chain, from primary production to the retailing happen in the world under different agroclimate conditions, in varied production lines from sinle handler to community production to large scale mechanised production and such a diversity led to concerns in the food safety system (McCullough, Prabhu, & Kostas, 2008). The individual operators in the chain operates a food safety management system based on the availablity and to suit his requirement based on the basic principles laid down by natinal and International bodies like *Codex Alimentarius Commission*. Now when you see the market at large, has pleanty of FSMS system which includes both from the governmental and private sectors. Therefore FSMS is the result of the implementation of available and relevant quality assurance guidelines and standards availble and in the primary production it could be the implementation of good practices including good hygienic proactices, good agricultural practices, good aquacultural priactices which have proved effective in the food sector. On the production and trade sector this may include good manufacturing practices, good hygienic practices, probably including HACCP principles.

In the process the FSMS may include essentially all the activites from equipment, procedures, programs, tools, organizational measures, and people necessary to execute the control and assuranceactivities aimed at ensuring chemical and microbial safety of fresh produce.

Despite the fact that the number of FSMS system available are large, there are indications that there are inadequacies in the existing systems, particularly for fresh produce and agind the requirements point out to related to insufficient sanitation, hygiene deficiencies, and improper production practices (Ilic et al., 2012; Johnston et al., 2006; Little & Gillespie, 2008). Therefore it is alwayss seen as a dynamic processes and the demand for the management system is on the increase and continues to draw the attention of both the producers and the consumers alike.

Food quality assurance systems

The FSMS system and its development mainly focuses on two aspects, one concerned with core control and the other the quality assurance activities and both are important as far as the system output is concerned (Luning et al. 2008). The control activities try to keep the production and processing activities within certain limits while the assurance activities mainly focus on changes, modification and evaluating the system to meet the requirements. The assessment of the system is typically based on the assessment reports, complaints as well as internal activities such as sampling, non-conformity etc. The performance of the system is actually assessed through indicator which clearly indicate the status of the system as the indicators are result of system driven process.

The control activities are basically three types based on the role namely preventive control, intervention and monitoringas indicated in the case of fresh produce (Kirezieva et al., 2013). The preventive control focuses on product contamination possibly by checking the relevant activities, invention is aimed at identifying and eliminating the contamination and the monitoring is concerned with evaluating the system to get the status of the system like whether the system is under control with reference to the quality envisaged. The preventive control activities are aimed at reducing the hazards in a system including the control of raw materials, hygiene system, sanitation programmes, personal hygiene and more importantly the storage at controlled conditions as required by the production process. Primarily this process addresses all the activities possibly controlled by Good Manufacturing protocol with the ultimate motive of controls entering the production process or value chain. Purchase of hazard free raw material is the important aspect of the value chain whether it is sources externally from a supplier or produced under conditions of the producer himself. Water quality, organic farming in the case of vegetables, pesticide free ecosystem for both agriculture and aquaculture, sanitation schedule at all important points in the production are all pertinent as far as quality of the product is concerned.

The intervention activities include activities which control the hazards in the raw materials so that the quality is maintained during the subsequent activities. The raw materials received are treated with chemical activities such as chlorination, ozonation, irradiation or any such activities wherein the hazard control is initiated in the raw materials or in the production area so that the purpose is addressed to a large extent. The aim of any FSMS is to control the hazards so that the role of food as disease propagator is controlled. In the real sense the intervention activities control the hazards to such levels that the hazards cannot prompt any effect on the consumers.

Monitoring activities involve three important activities namely identification hazards, evaluating risks and controlling the hazards at certain points in order to completely eliminate or reduce them to an acceptable level. The scientific understanding, the knowledge level with reference to a particular process and the traditional information all contribute to effective monitoring process. Monitoring the chemical and microbiological hazards definitely require the analytical setup which support the prediction that hazards are present or absent and to take remedial measures at the control steps. It's here the importance of good analytical facility and a third-party accreditation becomes significant.

Once the system is set then operation and control decide the actual validation of the process. The operational capability of the critical control and facilities including the reproducibility of the equipment, control systems, cooling systems, storage conditions etc. are all important in deciding the final output of the line and its consumer acceptance and is very important as far as the industrial production of food is concerned.

Food Safety Management systems

Hazard Analysis and Critical Control Points (HACCP) is a preventive strategy for risk management and it that identifies, evaluates, and controls hazards related to food safety throughout the food supply chain. HACCP can be implemented for control of chemical, biological and physical hazards in food throughout the operations and helps to the consumers and authorities to. HACCP operates on seven principles and ensures authorities and consumers that sufficient precaution is taking to assure food safety.

Principles of HACCP:

- Identification of food hazards and the necessary risk control measures

- Identification of the food safety Critical Control Points (CCPs)
- Determination of the critical limits for each CCP
- Establish monitoring procedures for CCPs
- Plan and take corrective action when critical limits are exceeded
- Establish verification procedures for the HACCP FSMS system
- Establish documentation and record keeping for the HACCP FSMS system

The **British Retail Consortium BRC**, introduced the BRC food technical standard for suppliers and food manufacturing plants. The main requirements of BRC are the adoption of HACCP besides control of factory environmental standards, process and personnel and is considered as a benchmark for best practice in food industry. 'due diligence' defence is the important slogan for BRC.

The **SQF 1000 / 2000 Codes** are HACCP quality management system that utilizes NACMCF and Codes HACCP Principles and Guidelines to reduce the incidence hazards and prevents unsafe food reaching the consumers. This covers two standards namely SQF 1000 Code for primary producers and growers and SQF 2000 Code for the manufacturing, processing and distribution sectors. The implementation of a SQF 1000/2000 management system addresses a buyer's food safety and quality requirements and provides the solution for businesses supplying local and global food markets.

The **International Food Standard (IFS)**, originated from Italy, is a standard for auditing retailer and wholesaler branded food product suppliers / manufacturers. The food standard is designed for companies doing processing, handling loose food products and primary packing activities. The requirements section of the Standard deals with Senior Management Responsibility, Quality Management System, Resource Management, Production Process and Measurements, Analysis, Improvements

GLOBALGAP's Fresh Fruit and Vegetable Standard was introduced by FoodPLUS GmbH, internationally recognised by European retailers, to raise standards in the production of fresh fruit and vegetables. It is concerned with food safety and quality which constantly improve systems to raise standards.

This International Standard **ISO 22000** is n international standard which specifies requirements for a food safety management system in an organization. The organisation needs to demonstrate its ability to control food safety hazards with the purpose of ensuring that food is safe at the time of human consumption. It is applicable to all organizations, regardless of size and the HACCP will be monitored closer by the QMS. It provides the clients a scientific and systematic approach for analyzing food and its processes for determining the possible hazards and designating the critical control points for its control, elimination or reduction to an acceptable level with aa view to prevent unsafe food from reaching the consumer. The ISO 22000 covers all the processes in the food chain and specifies the requirements for comprehensive food safety management systems by incorporating the elements of Good Manufacturing Practices (GMP) and Hazard Analysis Critical Control Points (HACCP). It builds and operates a food safety management system within a well-defined and clear framework that is flexible to the business needs and expectations.

Despite the programme followed for establishing the food safety management system, the overall aim of the process is the confirm that the human being is not affected by the food consumed by him. In the process, the system takes care of the trade across the countries and adds value for the product both nutritionally and economically. With the increase in the awareness of consumer in food safety issues, it can be considered that the requirement for safeguarding food and food products will only be increasing in the world , particularly with reference to the changing food habits of the consumer as well as the increased trade of food commodities across the globe.

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Chapter 30

Seafood quality assurance and safety regulations

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Food Safety has been the buzz word in recent days as there are increasing consumer awareness on hazards present in food as well as the ombudsmen role played by independent media. Although regulatory regime across the world has taken proactive steps, in most of the cases it has been a knee-jerk reaction to the impending crisis. Defining the actual goal of food safety has been an arduous task as there are umpteen interrelated factors that influence the intended goals. Some of the definitions on food safety put forward by international agencies are as follows:

- Concept that food will not cause harm to the consumer when it is prepared and/or eaten according to its intended use (ISO 22000:2005)
- A suitable product which when consumed orally either by a human or an animal does not cause health risk to consumer (USDA-FSIS)
- Range of food related activities from prevention and surveillance to detection and control (ASTHO)

Food Safety also encompasses many aspects of handling, preparation and storage that introduces or controls chemical, microphysical and microbiological hazards. Quality of raw material, presence of pathogens, processing methods, climate change and cross-contamination also significantly impacts any food safety measure.

Seafood is always in news as it is proclaimed to be most nutritious and healthy food as well as being linked to increasing number of foodborne outbreaks across the globe. In the nutritional front, fish accounts for 17 percent of the global population intake of animal protein and 6.7% of all protein consumed (FAO, 2016). The world per capita consumption of fish and fishery products has increased from 9.9 Kg in 1960s to 20 Kg in 2014.

Seafood trade apart from being highly volatile accounts for 10 percent of total agricultural exports and 1 percent of world merchandise trade in value terms. In 2010, the quantum of seafood trade has crossed US$109 billion. Ninety percent of global trade in fish and fishery products consists of processed products, where 39% of the total quantity is traded as frozen. This trend indicates high mobility of the fishery products across the globe, which demands stringent traceability system in place to track the movement of the commodity from harvest to consumers. Nearly 75% of the volume of seafood in international trade is imported by developed nations and 50% of that is exported by developing nations. Hence, food safety issues concerned with seafood is no more local or restricted to a particular geographical location, but has acquired global dimension. Some of the major food safety concerns linked to seafood are:

- presence of Ciguatera toxin in reef dwelling finfish
- histamine fish poisoning
- norovirus and *Vibrio parahaemolyticus* in raw shellfish
- Salmonella in shrimp products
- *Clostridium botulinum* in processed products
- high level of environmental pollutants
    - mercury, cadmium, lead
    - polychlorinated biphenyls and pesticides
- antimicrobial residues in aquaculture products

Apart from the above mentioned concerns which are mostly global, there are regional issues like use of adulterants like formaldehyde to retard decomposition process, ammonia to mask spoilage, use of un-approved additives (preservatives), high level of pesticides in dry fish and presence of emerging pathogens in fisheries environs.

The most challenging task for the policy makers has been to link incidences of foodborne illnesses with a particular food commodity. It needs a strong surveillance and monitoring mechanism to unequivocally attribute a particular food commodity. In USA, Centre for Disease Control (CDC) does the massive work of source tracking for major foodborne pathogens through pulsenet programmes. The recent report by CDC (Scallan et al., 2011) indicates that 31 major pathogens reported in the United States caused 9.4 million episodes of foodborne illness, 55,961 hospitalizations and 1,351 deaths during 2. Most (58%) illnesses were caused by norovirus, followed by non-typhoidal *Salmonella* spp. (11%), *Clostridium perfringens* (10%), and *Campylobacter* spp. (9%). Leading causes of hospitalization were non-typhoidal *Salmonella* spp. (35%), norovirus (26%), Campylobacter spp. (15%), and *Toxoplasma gondii* (8%). Leading causes of death were non-typhoidal *Salmonella* spp. (28%), *T. gondii* (24%), *Listeria monocytogenes* (19%), and norovirus (11%). In India, the recently established National Centre for Disease Control (formerly, National Institute of Communicable Diseases), Ministry of Health and Family Welfare, Government of India has a similar mandate to undertake activities on outbreak investigation and provide referral diagnostic services.

In absence of etiological data linked to seafood, the export rejection figures provides an indirect account of food safety hazards associated with seafood. Import refusals and rejections from countries like USA, Japan, Russia and EU are on the rise because of presence of biological and chemical hazards in seafood, leading to heavy economic loss by seafood industries. The most common import refusal of seafood by USA is due to presence of *Salmonella*, Listeria, filth or illegal veterinary drugs. The RASFF portal of EU indicates alert notifications due to presence of veterinary drug residues, heavy metals, histamine, foreign bodies, biotoxin, defective packaging, incorrect labelling, improper health certificate, unapproved colour and additives and organoleptic aspects. In recent months most of the rejections from Japan had been due to presence of furazolidone (AOZ) and Ethoxyquin in shrimp. Seafood rejections from Russia are mostly due to presence of high load of mesophilic bacteria, coliforms, pathogens and presence of crystal violet.

Genesis of Food Safety Standards and Regulations

Food safety standards can be classified as regulatory, voluntary, Government/Statutory, private, domestic, international or benchmarked depending upon its scope and range of application. Most of these standards have evolved based upon sanitary and phyto-sanitary (SPS) requirements, economic interest, risk analysis or as precautionary approach. The precautionary approach mostly relies on perception i.e. equivalent level of protection, appropriate level of protection (ALOP) or as low as reasonably achievable (ALARA).

In international trade, sanitary and phytosanitary measures are envisioned to be based on sound scientific principles that ensure food safety and do not anyway compromise the production potential and resources of a particular country. These measures should not be linked to prevent market access based on non-scientific reasons, and are requirements but not sufficient condition of trade. As per the Annex A of WTO Agreement, Sanitary and phytosanitary measures are applied to (i) protect animal or plant life or health within the territory of the Member from risks arising from the entry, establishment or spread of pests, diseases, disease-carrying organisms or disease-causing organisms (ii) to protect human or animal life or health within the territory of the Member from risks arising from additives, contaminants, toxins or disease-causing organisms in foods, beverages or feedstuffs (iii) from risks arising from diseases carried by animals, plants or products thereof, or from the entry, establishment or spread of pests and (iv) to prevent or limit other damage within the territory of the Member from the entry, establishment or spread of pests. WTO encourages members to use accepted International standards by Codex Alimentarius Commission, OIE (World Organization for Animal Health) and IPPC (International Plant Protection Convention). Countries may introduce or maintain SPS measures that provide higher level of protection than the current international or Codex standards.

Salient features of some Export regulations related to Seafood

European Union

European Union is the biggest importer of fish and fishery products in the world. The food safety regulations set by EU is harmonised, gets periodically updated, transparent and based on principles of risk assessment. The key elements of EU requirements for import of seafood are (a) certification by a competent authority (b) compliance to hygiene and public health requirements in terms of structure of vessels, landing sites, processing establishments and on operational processes, freezing and storage (c) certified production area for bivalves (d) national control plan on heavy metals, contaminants, residues of pesticides and veterinary drugs (e) approval of establishments.

The legal acts of EU are managed through regulations, directives, decision, recommendations and opinions.

Regulation: A binding legislative act applied in entirety across EU

Directives: A "directive" is a legislative act that sets out a goal that all EU countries must achieve.

Decision: A "decision" is binding on those to whom it is addressed (e.g. an EU country or an individual company) and is directly applicable.

Recommendations: A "recommendation" is not binding act that allows the institutions to make their views known and to suggest a line of action without imposing any legal obligation on those to whom it is addressed.

Opinions: An "opinion" is an instrument that allows the institutions to make a statement in a non-binding fashion, in other words without imposing any legal obligation on those to whom it is addressed.

Some of the important EU legislations related to food safety issues of fish and fishery products are as follows:

Regulation (EC) No 178/2002: General principles and requirements of food law, establishing the European Food Safety Authority and laying down procedures in matters of food safety

Regulation (EC) No 852/2004: Hygiene of foodstuffs.

Regulation (EC) No 853/2004: Specific hygiene rules for food of animal origin

Regulation (EC) No 854/2004: Specific rules for the organisation of official controls on products of animal origin intended for human consumption

Regulation (EC) No 2073/2005: Microbiological criteria for foodstuffs

Regulation (EC) No 882/2004: Official controls performed to ensure the verification of compliance with feed and food law, animal health and animal welfare rules

Regulation (EC) No 1881/2006: Maximum levels for certain contaminants in foodstuffs

Regulation (EC) No 333/2007: Methods of sampling and analysis for the official controls for the levels of lead, cadmium, mercury, inorganic tin, 3-MCPD and benzo(a)pyrene in foodstuffs

Regulation (EC) No 1883/2006: Methods of sampling and analysis for the official control of levels of dioxins and dioxin-like PCBs in certain foodstuffs

Regulation (EC) No 396/2005: Maximum residue levels of pesticides in or on food and feed of plant and animal origin

Council Directive 96/23/EC: Measures to monitor certain substances and residues thereof in live animals and animal products

Commission Decision (2005/34/EC): Harmonised standards for the testing for certain residues in products of animal origin imported from third countries

Commission Decision (2002/657/EC): Implementing Council Directive 96/23/EC concerning the performance of analytical methods and the interpretation of results

Commission Decision (98/179/EC): Official sampling for the monitoring of certain substances and residues thereof in live animals and animal products

Commission Decision (2004/432/EC): Approval of residue monitoring plans submitted by third countries in accordance with Council Directive 96/23/EC

Council Directive 96/22/EC: Prohibition on the use in stock farming of certain substances having a hormonal or thyrostatic action and of beta-agonists

Regulation (EC) No 470/2009: Community procedures for the establishment of residue limits of pharmacologically active substances in foodstuffs of animal origin

Commission Regulation (EU) No 37/2010: Pharmacologically active substances and their classification regarding maximum residue limits in foodstuffs of animal origin

Commission Regulation (EC) No 2023/2006: Good manufacturing practice for materials and articles intended to come into contact with food

Commission Regulation (EC) No 1935/2004: Materials and articles intended to come into contact with food

Commission Regulation (EU) No 1129/2011: Amendment to Annex II to Regulation (EC) No 1333/2008 of the European Parliament and of the Council by establishing a Union list of food additives

Commission Regulation (EC) No 1333/2008 : Food Additives

Commission Regulation (EC) No 1334/2008: Flavourings and certain food ingredients with flavouring properties for use in and on foods

Commission Regulation (EC) No 1331/2008: Establishing a common authorisation procedure for food additives, food enzymes and food flavourings

Directive 2000/13/EC: Labelling, presentation and advertising of foodstuffs (until 12 December 2014)

Commission Regulation (EU) No 1169/2011: Provision of food information to consumers, amending Regulations

Commission Regulation (EU) No 1379/2013: Common organisation of the markets in fishery and aquaculture products

USA

In USA both Federal and State Regulatory agencies are involved in ensuring safety and quality of seafood. Multiple federal agencies are involved in regulatory oversight of seafood for both importation and export.

United States Department of Agriculture (USDA) oversees the implementation of country of origin labelling (COOL) regulation enacted under the Farm Security and Rural Investment Act of 2002. This law requires that all retailers, such as full-line grocery stores or supermarkets must notify their customers with information regarding the source of certain foods.TheCOOL regulation for fish and shellfish (7 CFR Part 60) came into force in 2005. Apart from the country of origin, all fish and shellfish covered commodities must be labelled to indicate whether they are wild caught or farm-raised.

United States Fisheries and Wildlife Service (USFWS) is also involved in regulation of import and export of shellfish and fishery products through Convention on International Trade in Endangered Species (CITES) act (50 CFR Part 23), Endangered Species Act (50 CFR Part 17), General Permit Procedures (50 CFR Part 13), Lacey Act (injurious wildlife) (50 CFR Part 16), Marine Mammal Protection Act (50 CFR Part 18) and Wildlife (import/export/transport) act (50 CFR Part 14). Live farm-raised fish and farm-raised fish eggs are exempted from export declaration and licensing requirements. Imports or exports of any sturgeon or paddlefish product, including meat, caviar, and cosmetics made from sturgeon eggs, dead un-eviscerated salmon, trout and char and live fertilized eggs from these salmonid fish require a permit. Aquatic invertebrates and other animals that are imported or exported for human or animal consumption but that do not meet the definition of shellfish such as squid, octopus, cuttlefish, land snails, sea urchins, sea cucumbers and frogs are also covered under this provisions.

National Oceanic and Atmospheric Administration (NOAA) functioning under the United States Department of Commerce (USDC) provides voluntary seafood inspection program for fish, shellfish, and fishery products to the industry as per the 1946 Agricultural Marketing Act. The NOAA Seafood Inspection Programme often referred to as the U.S. Department of Commerce (USDC) Seafood Inspection Programme provides services such as establishment sanitation inspection, system and process audits, product inspection and grading, product lot inspection, laboratory analyses, training, consultation and export certification. NOAA Fisheries is the Competent Authority for export health certification and IUU catch documentation for US seafood products meant for export to EU and non-EU countries.

The U.S. Food and Drug Administration (USFDA) is vested with the primary Federal responsibility for the safety of seafood products in the United States. It operates a mandatory safety program for all fish and fishery products under the provisions of the Federal Food, Drug and Cosmetic (FD&C) Act, the Public Health Service Act, and related regulations. The most important regulation enacted by USFDA was "Procedures for the Safe and Sanitary Processing and Importing of Fish and Fishery Products" published as final rule 21 CFR 123 on 18th December 1995 and came into force on 18th December 1997. It required processors to adopt the preventive system of food safety controls known as HACCP (Hazard Analysis and Critical Control Point). Seafood was the first food commodity in the U.S. to adopt HACCP in USA. For screening imports, USFDA uses a tool "Predictive Risk-based Evaluation for Dynamic Import Compliance Targeting (PREDICT)", that targets higher risk products for examination and sampling and minimizes the delay in shipments of lower risk products.

Food Safety and Modernization Act (FSMA) is the most important milestone event in the food safety scenario in USA. It was signed in to law on 4th January 2011 which sifted the focus from responding to a contamination to prevention of the actual cause. The salient features of FSMA act are as follows:

Sec. 103.Hazard analysis and risk-based preventive controls (HARPC): Requires human and animal food facilities to

- evaluate hazards that could affect food safety;
- Identify and implement preventive controls to prevent hazards;
- Monitor controls and maintain monitoring records; and
- Conduct verification activities

Sec. 106.Protection against intentional adulteration

Sec. 111. Sanitary Transportation of Food

Sec. 301. Foreign supplier verification program

- Requires importers to verify their suppliers use risk-based preventive controls that provide same level of protection as U.S. requirements.

Sec. 302. Voluntary qualified importer program

- Allows for expedited review and entry; facility certification required

Sec. 303. Certification for high-risk food imports

- FDA has discretionary authority to require assurances of compliance for high-risk foods

Sec. 304. Prior notice of imported food shipments

- Requires information on prior refusals to be added to prior notice submission
- Effective July 3, 2011

Sec. 307. Accreditation of third-party auditors

- FDA can rely on accredited third parties to certify that foreign food facilities meet U.S. requirements

Sec. 308. Foreign Offices of the Food and Drug Administration.

- Establish offices in foreign countries to provide assistance on food safety measures for food exported to the U.S.

Sec. 309. Smuggled Food

- In coordination with DHS, better identify and prevent entry of smuggled food
- Rules on anti-smuggling strategy is already framed

China

In recent years China has strengthened its SPS measures and has taken a number of precautionary steps to ensure safety to its population. Some of the important regulations enacted by Peoples Republic of China are as follows:

- GB 2763—2012: National food safety standard on Maximum residue limits for pesticides in food
- GB 2762—2012: National food safety standard on Contaminants in Food
- GB-2010: National Food Safety Standard for Pathogen Limits in Food (GAIN Report No. 12063)
- GB 2733-2005: Hygienic Standard for Fresh and Frozen Marine Products of Animal Origin
- GB 2760-2011 additives
- GB 10136-1988 Hygienic standard for salt & liquor-saturated aquatic products of animal origin

Russia

Russia has a comprehensive regulatory framework for fish and fishery products. The hygienic requirements are different from other countries as some of the microbiological parameters are expressed as absent in 0.001g or 0.01g. Also some different nomenclature like QMAFAnM is followed instead of APC. The Russian regulation currently in force pertaining to fish and fishery products is as follows:

- Hygienic requirements for safety and nutrition value of food products. Sanitary and epidemiological rules and regulations, sanpin 2.3.2.1078-01

Japan

Compared to other countries, SPS measures followed by Japan is very stringent. Many additives which are in the approved list of Codex are banned or prohibited in Japan. Japan uses a positive list system for MRL of agricultural chemicals in foods. A uniform limit of 0.01 ppm is followed for the compounds for which no risk assessment is done but which are included in the positive list (MHLW Notification No. 497, 2005). MHLW uses a toxicological threshold of 1.5 μg/day as the basis to determine the uniform limit. Substances having no potential to cause damage to human health are specified by MHLW Notification No.498. 2005. The MRL list is mentioned as compositional specification of foods (MHW Notification, No. 370, 1959, amendment No.499 2005, updated as on March 15, 2013)

The relevant food safety acts of Japan as enacted by Ministry of Health, Labour and Welfare and other agencies are as follows:

- Food Sanitation Act (Act No.233, 1947): Latest Revision on June 5, 2009, Act No. 49)
- Specifications and Standards for Food and Food Additives, Latest Revision on September 6, 2010, MHLW Notification No. 336
- Japan's Specifications and Standards for Food Additives" (Eighth Edition). Published by the Ministry of Health, Labour and Welfare in 2007
- Food Safety Basic Act (Act No. 48, 2003)
- Agricultural Chemicals Regulation Law (Law No. 82, 1948)

Codex Alimentarius Commission

The Codex Alimentarius Commission (CAC) was established in 1961-1963 by the Food and Agriculture Organization of the United Nations (FAO) and the World Health Organization (WHO) to implement their Joint FAO/WHO Food Standards Programme. CAC has the mandate to formulate food standards, code of practice, guidelines and recommendations to protect health of consumers, Ensure fair practices in food trade and to promote coordination of all food standards work undertaken by international governmental and non-governmental organizations. Codex operates through thee standing expert scientific bodies convened under the auspices of FAO and WHO to generate food data and provide risk-assessment type advice:

- Joint Expert Committee on Food Additives (JECFA)
- Joint Meeting on Pesticide Residues (JMPR)
- Joint Meeting on Microbiological Risk Assessment (JEMRA)

Different subject committees and commodity committees, adhoc inter-governmental task forces and regional coordinating committees function and under codex. Codex Committee on Fish and Fisheries Products (CCFFP) is entrusted with the task of formulating standards for different product categories. Although Codex standards on Fish and Fishery Products specifically do not address food safety requirements, but provide a strong framework for production, hygienic requirements and sampling.

Available Codex Standard for Fish and Fishery Products

1.	Standard for Canned Salmon	CODEX STAN 3-1981
2.	Standard for Quick Frozen Finfish, Eviscerated or Uneviscerated	CODEX STAN 36-1981
3.	Standard for Canned Shrimps or Prawns	CODEX STAN 37-1981
4.	Standard for Canned Tuna and Bonito	CODEX STAN 70-1981
5.	Standard for Canned Crab Meat	CODEX STAN 90-1981
6.	Standard for Quick Frozen Shrimps or Prawns	CODEX STAN 92-1981
7.	Standard for Sardines and Sardine-Type Products	CODEX STAN 94-1981
8.	Standard for Quick Frozen Lobsters	CODEX STAN 95-1981
9.	Standard for Canned Finfish	CODEX STAN 119-1981
10	Standard for Quick Frozen Blocks of Fish Fillets, Minced Fish Flesh and Mixtures of Fillets and Minced Fish Flesh	CODEX STAN 165-1989
11	Standard for Quick Frozen Fish Sticks (Fish Fingers), Fish Portions and Fish Fillets - Breaded or in Batter	CODEX STAN 166-1989
12	Standard for Salted Fish and Dried Salted Fish of the Gadidae Family of Fishes	CODEX STAN 167-1989

13	Standard for Dried Shark Fins	CODEX STAN 189-1993
14	General Standard for Quick Frozen Fish Fillets	CODEX STAN 190-1995
15	Standard for Quick Frozen Raw Squid	CODEX STAN 191-1995
16	Standard for Crackers from Marine and Freshwater Fish, Crustaceans and Molluscan Shellfish	CODEX STAN 222-2001
17	Standard for Boiled Dried Salted Anchovies	CODEX STAN 236-2003
18	Standard for Salted Atlantic Herring and Salted Sprat	CODEX STAN 244-2004
19	Standard for Sturgeon Caviar	CODEX STAN 291-2010
20	Standard for Live and Raw Bivalve Molluscs	CODEX STAN 292-2008
21	Standard for Fish Sauce	CODEX STAN 302-2011

Code of Practice

Code of Practice for Fish and Fishery Products	CAC/RCP 52-2003

Guidelines

Guidelines for the Sensory Evaluation of Fish and Shellfish in Laboratories	CAC/GL 31-1999
Guidelines on the Application of General Principles of Food Hygiene to the Control of Pathogenic Vibrio Species in Seafood	CAC/GL 73-2010
Guidelines on the Application of General Principles of Food Hygiene to the Control of Viruses in Food	CAC/GL 79-2012
Model Certificate for Fish and Fishery Products	CAC/GL 48-2004
Guideline Procedures for the Visual Inspection of Lots of Canned Foods for Unacceptable Defects	CAC/GL 17-1993
Guidelines on Good Laboratory Practice in Pesticide Residue Analysis	CAC/GL 40-1993
General guidelines on sampling	CAC/GL 50-2004
Guidelines on the Use of Mass Spectrometry (MS) for Identification, Confirmation and Quantitative Determination of Residues	CAC/GL 56-2005

Codex standard applicable to Fish and Fishery Products

General Standard for Contaminants and Toxins in Food and Feed	CODEX STAN 193-1995
General Standard for the Labelling of Prepackaged Foods	CODEX STAN 1-1985
Standard for Food Grade Salt	CODEX STAN 150-1985
General Standard for Food Additives	CODEX STAN 192-1995
General Methods of Analysis for Contaminants	CODEX STAN 228-2001
Recommended Methods of Analysis and Sampling	CODEX STAN 234-1999
General Methods of Analysis for Food Additives	CODEX STAN 239-2003

Bureau of Indian Standards (BIS)

Bureau of Indian Standards (BIS) functioning under the Ministry of Consumer Affairs, Food and Public Distribution, Government of India. It came into existence on 01 April 1987 through an Act of Parliament on 26 November 1986. It was functioning previously as Indian Standards Institution which was established on 06 January 1947. BIS has so far formulated 64 standards related to fish and fishery products, out of which 33 are active. All these standards are voluntary, which addresses method of production, quality and safety requirements. It also stipulates the method of testing and sampling. There is an attempt by FSSAI to re-draft all BIS standards related to fish and fishery products as most of the food safety requirements are not in sync with the current national standards.

BIS Standards on Fish and Fishery Products

IS 2168	1971	Pomfret Canned in Oil
IS 2236	1968	Prawns/Shrimp Caned in Brine
IS 2237	1997	Prawns (Shrimps) - Frozen
IS 3336	1965	Shark Liver Oil for Veterinary Use
IS 3892	1975	Frozen Lobster Tails
IS 4304	1976	Tuna Canned in Oil
IS	1978	Pomfret, Fresh

4780		
IS 4793	1997	Whole Pomfret - Frozen
IS 5734	1970	Sardine Oil
IS 6121	1985	*Lactarius* sp Canned in Oil
IS 6122	1997	Seer Fish (*Scomberomorus* Sp.) - Frozen
IS 6123	1971	Seer Fish (*Scomberomorus* spp.), Fresh
IS 7143	1973	Crab Meat Canned in Brine
IS 7313	1974	Glossary of Important Fish Species of India
IS 7582	1975	Crab Meat, Solid Packed
IS 8076	2000	Frozen Cuttlefish and Squid
IS 9808	1981	Fish Protein Concentrate
IS 10059	1981	Edible Fish Powder
IS 10760	1983	Mussels Canned in Oil
IS 10762	1983	Tuna Canned in Curry
IS 10763	1983	Frozen Minced Fish Meat
IS 11427	2001	Fish and Fisheries Products - Sampling
IS 14513	1998	Beche-de-mer
IS 14514	1998	Clam Meat - Frozen
IS 14515	1998	Fish Pickles
IS 14516	1998	Cured fish and fisheries products - Processing and storage - Code of Practice
IS 14517	1998	Fish Processing Industry - Water and Ice - Technical Requirements
IS 14520	1998	Fish Industry - Operational Cleanliness and layout of market - Guidelines (Amalgamated Revision of IS 5735, 7581 and 8082)
IS 14890	2001	Sardines - Fresh, Frozen and Canned (Amalgamated revision of IS 2421, 6677,8652,8653, 9750 and 10761

4891	2001	Mackerel - Fresh, Frozen and Canned (Amalgamated Revision of IS 2420, 3849,6032, 6033 and 9312)
IS 14892	2000	Threadfin - Fresh and Frozen
IS 14949	2001	Accelerated Freeze Dried Prawns (Shrimps) (Amalgamated revision of IS 4781 and 4796
IS 14950	2001	Fish - Dried and Dry-Salted

Food Safety and Standards Authority of India (FSSAI)

The Food Safety and Standards Authority of India was established under the Food Safety and Standards Act, 2006 as a statutory body for laying down science based standards for articles of food and regulating manufacturing, processing, distribution, sale and import of food so as to ensure safe and wholesome food for human consumption. Various central acts including the erstwhile Prevention of Food Adulteration Act (1954) were merged under this act

The Food Safety and Standards Regulations (FSSR) came into force in 2011, which is divided to following sections:

- FSS (Licensing and Registration of Food businesses) regulation, 2011
- FSS (Packaging and Labelling) regulation, 2011
- FSS (Food product standards and Food Additives) regulation, 2011 (part I)
- FSS (Food product standards and food additives) regulation, 2011 (part II)
- FSS (Prohibition and Restriction on sales) regulation, 2011
- FSS (contaminants, toxins and residues) regulation, 2011
- FSS (Laboratory and sampling analysis) regulation, 2011

Recently, standards related to microbiological specifications of fish and fishery products, limit of heavy metals, PAH, PCBs and biotoxins have been incorporated in the FSSR.

HACCP CONCEPT IN SEAFOOD QUALITY ASSURANCE

Concept of HACCP was developed in the late 1950s and initiated in the early 1960s by the Pillsbury Company, in collaboration with NASA and the Natick Laboratories of the U.S. Army, and the U.S. Air Force Space Laboratory Project Group. The concepts designed were based on the principles of Failure Mode and Effect analysis (FEMA). It was first presented to regulatory community during National Conference on Food Protection in 1971 by Howard Bauman of the Pillsbury Company and first applied to low acid canned foods in 1974. In 1980s, other food processing companies embraced it voluntarily and at the same time FDA and USDA continued regulatory interest. HACCP gained regulatory approval from USFDA and USDA after it was endorsed by National Academy of Sciences and further by 9National Advisory Committee on Microbiological Specifications of Foods (NACMSF). On December 18, 1995, The Food and Drug Administration (FDA) published as a final rule 21 CFR 123, "Procedures for the Safe and Sanitary Processing and Importing of Fish and Fishery Products" that requires processors of fish and fishery products to develop and implement Hazard Analysis Critical Control Point (HACCP) systems for their operations. The regulation became effective December 18, 1997. HACCP was recommended by Codex Alimentarius Commission (CAC) in 1997 which is recognized as “Recommended International Code of Practice-General Principles of Food Hygiene” (CAC/RCP 1-1969, Rev 3, 1997). In European countries, the EU Directive 93/43/EEC mandated the implementation of HACCP in all local legislation by December 1995. Subsequently the EC hygiene regulations 852/2004 and 853/2004 mandated that all food business operators should establish and operate food safety programmes and procedure based on HACCP principles. Since then HACCP has gained acceptance by many countries in Europe, Canada, New Zealand, Australia, Central and South America and many Asian countries. In India voluntary HACCP standards are given by Bureau of Indian Standards (IS 15000:1998)

Hazard Analysis Critical Control Point (HACCP)

The HACCP system is an internationally recognized system used to manage food safety. It has been endorsed by the *Codex Alimentarius Commission* as a tool that can be used to systematically identify hazards specific to individual products and processes and describe measures for their control to ensure the safety of fish and fish products. It is a dynamic system, capable of accommodating change in the system viz., changes in equipment design, processing procedures and technological advancements.

HACCP is defined as a system which identifies, evaluates, and controls hazards which are significant for food safety

HACCP is a structured, systematic approach for the control of food safety throughout the food system, from the farm to fork. It requires a good understanding of the relationship between cause and effect in order to be more pro-active. HACCP is supported by pre-requisite programmes like Good Manufacturing Practice (GMP), Good Hygienic Practices (GHP), SSOP (Sanitation standard operating procedures), Good Agricultural Practices (GAP), and Good Storage Practices (GSP), etc.

Pre-requisite programmes

Prerequisite programs provide a foundation for an effective HACCP system. They are often facility-wide programs rather than process or product specific. They reduce the likelihood of certain hazards. Prerequisite programs set the stage for a HACCP system and provide on-going support for the establishment's food safety system. They keep potential hazards from becoming serious enough to adversely impact the safety of foods produced. Without clean working conditions free from microbiological, chemical, and physical contamination from many sources, a HACCP plan cannot be effective.

Prerequisite programmes are practices and conditions needed prior to and during the implementation of HACCP and which are essential for food safety -WHO

Some of the prerequisite programmes include GAP, GMP and GHP which must be working effectively within a commodity system before HACCP is applied. Establishments should revise their prerequisite programs, as necessary, to ensure their effectiveness, and should take appropriate corrective actions when they determine that their prerequisite programs may have failed to prevent contamination and/or adulteration of product. Good Agricultural Practices are "practices that address environmental, economic and social sustainability for on-farm processes, and result in safe and quality food and non-food agricultural products" (FAO)

The Good Manufacturing Practices commonly referred as current good manufacturing practices (cGMPs, 21 CFR 110) give details as to what specific procedures must be followed to comply with the regulation. Standard operating procedures (SOPs) are the steps your company takes to assure that the GMPs are met. They include stepwise procedures, employee training, monitoring methods, and records used by your company. Similarly, SSOP covers eight key sanitation conditions as required by USFDA.

Good hygiene practices include all practices regarding the conditions and measures necessary to ensure the safety and suitability of food at all stages of the food chain

Basic principles of HACCP

There are seven discrete activities that are necessary to establish, implement and maintain a HACCP plan, and these are referred to as the 'seven principles' in the Codex Guideline (1997).

The seven Principles of HACCP are

Principle 1: **Conduct a hazard analysis.**

Hazard: A biological, chemical or physical agent in, or condition of, food with the potential to cause an adverse health effect.

Hazard analysis: The process of collecting and evaluating information on hazards and conditions leading to their presence to decide which are significant for food safety and therefore should be addressed in the HACCP plan.

Principle 2: **Determine the Critical Control Points (CCPs)**

A step at which control can be applied and is essential to prevent or eliminate a food safety hazard or reduce it to an acceptable level.

Principle 3: **Establish critical limits.**

A criterion which separates acceptability from unacceptability, when monitoring a critical control point.

Principle 4: **Establish a monitoring system**

The act of conducting a planned sequence of observations or measurements of control parameters to assess whether a CCP is under control.

Principle 5: **Establish a procedure for corrective action,**

Any action to be taken when the results of monitoring at the CCP indicate a loss of control.

Principle 6: **Establish procedures for verification**

The application of methods, procedures, tests and other evaluations, in addition to monitoring to determine compliance with the HACCP plan.

Principle 7: **Establish documentation concerning all procedures and records appropriate to these principles and their application**

Developing a HACCP plan (FAO guidelines)

The all-important principles form the essential requirements of a food safety system and are designed to ensure that enough precaution is taken so that any hazard which can interfere with consumer health is addressed. The first principle of HACCP is hazard analysis. But understanding the product thoroughly is extremely important to get an idea on the possible hazards which could be associated with the product so that appropriate action can be taken to control or minimize the hazard. The seven principles of HACCP are usually carried out in twelve steps, as given below.

Step 1 - Establish a HACCP team

Hazard profile is related to the commodity. Therefore in order to understand fully the commodity, to identify the hazards associated, the CCP and to work out a control measures it is pertinent to have a team which has the knowledge about the product or commodity, its production process and shelf-life. This would facilitate the proper implementation of HACCP for the production of the product. Therefore, it is important that the HACCP team is made up of people from a wide range of disciplines. The team should include:

- A team leader to lead the group and direct the team to carry out the work as per the system requirements. He should be well versed with the techniques and manage the team members to contribute to the cause.
- A person conversant with the production system who knows full details of the flow of production.
- Persons from varied field viz., biochemist, microbiologist, toxicologist, quality control manager or an engineer with an understanding of particular hazards and associated risks.
- Others who are involved in the varied activates of the system viz., packaging specialists, raw material buyers, distribution staff or production staff, farmers, brokers, who are involved with the process, and have working knowledge of it in order to provide expert opinion.

- Possibly one person to help the team with secretarial requirements.

Task 2 - Describe the product

Understanding the product is the important step as the hazard associated with depends on the product. To start a hazard analysis, a full description of the product, including customer specification, should be prepared. This should include information relevant to safety, regulation/target level, and composition, physical/chemical properties of the raw materials and the final product, the water activity of the product (a_w), the pH etc. There should information on the packaging, storage and distribution as well as information on the temperature of storage, distribution, labelling information and shelf-life of the product. This information helps the audit team to understand the possible hazards and their control measures.

Task 3 - Identify the product's intended use

Information on the intended use of the commodity or product as well as the information on the mode of consumption viz., direct consumption, cooked before hazard analysis will have bearing on the hazard analysis. The nature of the target group for the product may also be relevant, particularly if it includes susceptible groups such as infants, the elderly, and the malnourished. The likelihood of misuse of a product should also be considered, such as the use of pet food as a human food, either by accident or design.

Task 4 - Draw up the commodity flow diagram

The first function of the team is inspect the detailed commodity flow diagram (CFD) of the commodity system and the expertise of the production manager or product expert is important at this stage as far as hazard analysis is concerned.

Task 5 - On site confirmation of flow diagram

After studying the commodity flow diagram the team should visit the system where HACCP is implemented or proposed to be implemented which may include any step in the production viz., procurement of raw material, store, production area, packaging area, storage section where the product is kept before distribution, nature of distribution, conditions of distribution etc. The is known as 'walking the line ', a step by step checking to get information on whether relevant requirements of the system are considered while making the production line. The site for which the HACCP plan is being designed should be visited as many times as possible to ensure that all relevant information has been collected.

Task 6 - Identify and analyse hazard(s) - (Principle 1)

Effective hazard identification and hazard analysis are the keys to a successful HACCP Plan. All real or potential hazards that may occur in each ingredient and at each stage of the commodity system should be considered. Food safety hazards for HACCP programmes have been classified into three types of hazards:

- Biological: typically foodborne bacterial pathogens such as *Salmonella*, *Listeria* and *E. coli,* also viruses, algae, parasites and fungi.
- Chemical: There are three principle types of chemical toxins found in foods: naturally occurring chemicals, e.g. cyanides in some root crops, and allergenic compounds in peanuts; toxins produced by micro-organisms, e.g. mycotoxins, and algal toxins; and chemicals added to the commodity by man to control an identified problem, e.g fungicides or insecticides.
- Physical: contaminants such as broken glass, metal fragments, insects or stones.

The probability that a hazard will occur is called a risk. The risk may take a value from zero to one depending on the degree of certainty that the hazard will be absent or that it will be present. After hazard identification, a hazard analysis must be conducted to understand the relative health risk to man or animal posed by the hazard. It is a way of organizing and analysing the available scientific information on the nature and size of the health risk associated with the hazard. The risk may have to be assessed subjectively and simply classified as low, medium, or high.

Once a food safety hazard has been identified, then appropriate control measures should be considered. These are any action or activity that can be used to control the identified hazard, such that it is prevented, eliminated, or reduced to an acceptable level. The control measure may also include training of personnel for a particular operation, covered by GAP, GMP, and GHP.

Task 7 - Determine the critical control points (CCPs) - (Principle 2).

Each step in the commodity flow diagram, within the scope of the HACCP study, should be taken in turn and the relevance of each identified hazard should be considered. The team must determine whether the hazard can occur at this step, and if so whether control measures exist. If the hazard can be controlled adequately, and is not best controlled at another step, and is essential for food safety, then this step is a CCP for the specified hazard.

If a step is identified where a food safety hazard exists, but no adequate control measures can be put in place either at this step or subsequently, then the product is unsafe for human consumption. Production should cease until control measures are available and a CCP can be introduced.

Task 8 - Establish critical limits for each CCP - (Principle 3)

Critical limits must be specified and validated for each CCP. Criteria often used include measurements of temperature, time, moisture level, pH, water activity, and sensory parameters such as visual appearance. All critical limits, and the associated permissible tolerances, must be documented in the HACCP Plan Worksheet, and included as specifications in operating procedures and work instructions.

Task 9 - Establish a monitoring procedure - (Principle 4)

Monitoring is the mechanism for confirming that critical limits at each CCP are being met. The method chosen for monitoring must be sensitive and produce a rapid result so that trained operatives are able to detect any loss of control of the step. This is imperative so that corrective action can be taken as quickly as possible so that loss of product will be avoided or minimized.

Monitoring can be carried out by observation or by measurement, on samples taken in accordance with a statistically based sampling plan. Monitoring by visual observation is basic but gives rapid results, and can therefore be acted upon quickly. The most common measurements taken are time, temperature and moisture content.

Task 10 - Establish corrective action - (Principle 5)

If monitoring indicates that critical limits are not being met, thus demonstrating that the process is out of control, corrective action must be taken immediately. The corrective action should take into account the worst case scenario, but must also be based on the assessment of hazards, risk and severity, and on the final use of the product. Operatives responsible for monitoring CCPs should be familiar with and have received comprehensive training in how to effect a corrective action.

Corrective actions must ensure that the CCP has been brought back under control. Corrective action can then be applied to pre-empt a deviation and prevent the need for any product disposition.

Task 11 - Verify the HACCP plan - (Principle 6)

Once the HACCP plan has been drawn up, and all of the CCPs have been validated, then the complete plan must be verified. Once the HACCP plan is in routine operation, it must be verified and reviewed at regular intervals. This should be a task of the person charged with the responsibility for that particular component of the commodity system. The appropriateness of CCPs and control measures can thus be determined, and the extent and effectiveness of monitoring can be verified. Microbiological and/or alternative chemical tests can be used to confirm that the plan is in control and the product is meeting customer specifications. A formal internal auditing plan of the system will also demonstrate an ongoing commitment to keep the HACCP plan up to date, as well as representing an essential verification activity.

Task 12 - Keep record - (Principle 7)

Record keeping is an essential part of the HACCP process. It demonstrates that the correct procedures have been followed from the start to the end of the process, offering product traceability. It provides a record of compliance with the critical limits set, and can be used to identify problem areas. Records that should be kept include: all processes and procedures linked to CCP monitoring, deviations, and corrective actions.

Steps involved in developing HACCP system

(Based on Codex 1997)

Step 1.	Assemble HACCP team	Preliminary Steps
Step 2.	Describe product	

Step 3.	Identify intended use	
Step 4.	Construct flow diagram	
Step 5.	On-site confirmation of flow diagram	
Step 6.	Conduct hazard analysis	HACCP Principle I
Step 7.	Determine Critical Control Points	HACCP Principle II
Step 8.	Establish critical limits for each CCP	HACCP Principle III
Step 9.	Establish a monitoring system for each CCP	HACCP Principle IV
Step 10.	Establish corrective actions	HACCP Principle V
Step 11.	Establish verification procedures	HACCP Principle VI
Step 12.	Establish Documentation and Record Keeping	HACCP Principle VII

HACCP is a core component in all national and international food safety standards such as IS 15000, ISO 22000:2005, USFDA Seafood HACCP regulation (CFR 123, Title 21), Dutch HACCP, BRC Global Standard for Food, SQF 2000, IFS, etc. Hence understanding concepts of HACCP would help in easy implementation of any food safety standard(s) deemed necessary to ensure safety of fish and fishery products.

Definitions in HACCP

Control (verb): To take all necessary actions to ensure and maintain compliance with criteria established in the HACCP plan.

Control (noun): The state wherein correct procedures are being followed and criteria are being met.

Control measure: Any action and activity that can be used to prevent or eliminate a food safety hazard or reduce it to an acceptable level.

Corrective action: Any action to be taken when the results of monitoring at the CCP indicate a loss of control.

Critical Control Point (CCP): A step at which control can be applied and is essential to prevent or eliminate a food safety hazard or reduce it to an acceptable level.

Critical limit: A criterion which separates acceptability from unacceptability, when monitoring a critical control point.

Deviation: Failure to meet a critical limit.

Flow diagram: A systematic representation of the sequence of steps or operations used in the production or manufacture of a particular food item.

HACCP plan: A document prepared in accordance with the principles of HACCP to ensure control of hazards which are significant for food safety in the segment of the food chain under consideration.

Hazard: A biological, chemical or physical agent in, or condition of, food with the potential to cause an adverse health effect.

Hazard analysis: The process of collecting and evaluating information on hazards and conditions leading to their presence to decide which are significant for food safety and therefore should be addressed in the HACCP plan.

Monitor: The act of conducting a planned sequence of observations or measurements of control parameters to assess whether a CCP is under control.

Step: A point, procedure, operation or stage in the food chain including raw materials, from primary production to final consumption.

Validation: Obtaining evidence that the elements of the HACCP plan are effective.

Verification: The application of methods, procedures, tests and other evaluations, in addition to monitoring to determine compliance with the HACCP plan.

Chapter 31

Determination of chemical and biological contaminants in seafood

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Seafood has grown in consumption as it has become an important part of a diet. Simultaneously their safety is a rising concern for human health. However, seafood may contain harmful chemicals as well as biological agents that could pose health risks to consumers. Fishes are harvested from waters that are contaminated by varying amounts of industrial chemicals, heavy metals, pesticides and antibiotics. These contaminants may accumulate in fish at levels that can cause human health problems (e.g. carcinogenic and mutagenic effects).The seafood may also get contaminated with various pathogenic bacteria due to unhygienic handling practices, cross contamination of raw foods with cooked or ready-to eat foods, and lack of proper temperature control. Pathogenic bacteria can cause illness in human, either by infection or intoxication. Food borne infections are caused by swallowing live pathogens that grow within the body, usually in the intestinal tract. Intoxication is a condition caused by swallowing preformed toxins i.e. toxins produced by microorganisms in the food before it is eaten. Food can become contaminated at any point during production, distribution and preparation. Everyone along the production chain, from producer to consumer, has a role to ensure the safety of seafood.

Chemical Contaminants

The number of chemical contaminants is increasing day by day, hence threats associated with chemical contamination of seafood is also increasing. Environmental contaminants mainly include ubiquitous pollutants such as heavy metals and dioxins. Even though they are naturally present in the environment their level can be increased due to anthropogenic influences. Contaminants can also come as toxins produced by fungi (e.g. aflatoxins) and algae (e.g. ciguatoxin). The different chemical contaminants in seafood can also include food additives that are intentionally added like preservatives, colour retention agents etc. The contaminants can also generate during processing or cooking which include acrylamide and heterocyclic amines. Residue of agricultural chemicals resulting from previous application of pesticides, and veterinary drugs during production and storage of food crops and animals, have been considered as human health hazards. But these types of contaminants have a great potential in control by proper conditions of usage and their presence. Also some natural components of food can also act as contaminant like allergic substances and phytohaemagglutinin.

Basically the chemical contaminants are classified into three main groups such as:

(i) **Naturally occurring** – allergens,Mycotoxins, Scomberotoxin (Histamine), Ciguatera poison, Puffer fish poison, Shellfish toxins (PSP, DSP, NSP, ASP)

(ii) **Unintentionally or incidentally added chemicals** – Pesticides, Fungicides, Fertilizers, Toxic compounds, Toxic metals

(iii) **Intentionally added chemicals and food additives** - Food preservatives, Food additives, Vitamins, Minerals, Antibiotics used in aquaculture, Sulfites used in shrimp to prevent melanosis, Nitrites as preservatives, Colouring agents, Detergents

Heavymetals

Heavy metals are toxic metals and above a normal level can affect the quality, safety and marketability of seafood. They are “Cumulative poisons” which can irreversibly accumulate in the body. They have atomic weight higher than 40.04 and specific density >5g/ cm. The main threats are Arsenic, Cadmium, Mercury and Lead. These metals have no beneficial effects in human and they have no homeostasis mechanism. These contaminants are highly depend upon geographic location, species and fish size, feeding pattern, solubility of chemical and their persistence in the environment.

Lead is mostly deposited in bones and not in soft tissues. But, from food safety point of view lead accumulation in edible parts is important. Compared to fish lead content is higher in shellfishes as it is getting accumulated in hepatopancreas. The organic form of lead, tetra alkyl lead is mostly found in fish. In fishes Cd is mostly deposited in kidney and liver and in muscles the level is quite low. In invertebrates like Cephalopods it can go as high as 30 ppm in digestive glands. Hence the digestive gland must be removed immediately after catch. Both Cd and Pb are carcinogenic in nature. Mercury is one of the most toxic heavy metal in the environment. Among metal contaminants methyl mercury ha s elicited the most concern among consumers. It is toxic to the nervous system especially the developing brain. Arsenic is a widely distributed metalloid and major contaminant in case of ground water. IARC has classified inorganic arsenic as a human carcinogen.

The most widely used techniques for detection and quantification of heavy metals are Atomic Absorption Spectrometry, Inductively Coupled Plasma Optical Emission Spectrometry (ICP-OES) and Inductively Coupled Plasma-Mass Spectrometry (ICP-MS).

Histamine in fish

Though all types of biogenic amines can be formed in fish, the most toxic amine detected in fish is histamine. Histamine poisoning is the most common form of toxicity caused by ingestion of fish and is generally due to the ingestion of foods containing unusually high levels of histamine. The commonly implicated incidents of histamine poisoning are associated with the fish families Scombridae and Scomberesocidae. It is also known as Scombroid poisoning. Histamine is a powerful biologically active chemical present in the mast cells and basophils in larger amounts. Histamine poisoning is often manifested by a wide variety of symptoms. Major symptoms affecting the cutaneous system include rashes, urticaria, edema and localized inflammation etc. gastrointestinal effects include nausea, vomiting, diarrhoea and abdominal cramps. Also include symptoms like hypotension, headache, palpitation, tingling and flushing. Severe suffocation and respiratory distress have been reported in severe cases of histamine poisoning. The onset of histamine poisoning can extend from 10 minutes to 1 hour following consumption of contaminated fish and can last from 12 hour to a few days. Histamine concentration required to produce poisoning varies with respect to the susceptibility of each individual. In case of susceptible individuals concentration between 5 and 10 mg/100g can cause symptoms. Many foods contain small amounts of histamine which can be tolerated easily.

As per USFDA guideline the toxicity and defect action level established are 50 mg/100g and 5 mg/100g respectively. According to EU regulation No 2073/2005 mean value all samples (nine) must not exceed 10 mg/100g, two samples may be > 10 mg/100g but < 20 mg/100g and no sample may exceed 20 mg/ 100g. According to USFDA guideline for the control of histamine production a core temperature of 4.4 °C or less should be achieved and maintained throughout handling, processing and distribution of susceptible species.

A wide variety of procedure for the determination of histamine and biogenic amines is available. Include both semi quantitative and quantitative methods. Methods based on colorimetry, fluorometry and enzyme-linked immunosorbent assay (ELISA) are available. Mostly biogenic amines including histamine is analysed by High Performance Liquid Chromatography (HPLC) methods with pre and post column derivatisation and UV–visible or fluorescence detection. LC with tandem mass spectrometry (MS/MS) can also be a useful approach for an unequivocal confirmation of the studied analytes.

Biotoxins

Marine biotoxins are responsible for many seafood borne diseases. It includes both shellfish toxins and ichthyotoxins (fishtoxins). Shellfish toxins include Paralytic shellfish toxins, Diarrhetic shellfish toxins, Azaspriacid shellfish toxins, Neurotoxic shellfish toxin and Amnesic shellfish toxins. Ichthyotoxins include Ciguatera toxin andTetradotoxin. Fish poisoning is caused by consuming fish containing poisonous tissues and shellfish poisoning results from ingestion of shellfish that have accumulated toxins from the plankton they have consumed.

(i)Tetradotoxin(Puffer fish poison): It is the most lethal of all fish poisons.Toxin production is due to the activity of symbiotic bacteria. Toxin will be accumulated in liver, ovaries and intestine as a defence mechanism.But the muscle is free of toxin. It is also called as Tetradon poisoning or Fugu poisoning. It is 275 times more toxic than cyanide.On an average a dose of 1-2mg of purified tetrodotoxin can be lethal to humans.

(ii) Ciguatera - Ciguatera is a clinical syndrome caused by eating the flesh of toxic fish caught in tropical reef and island waters.Most common fish poisoning and the fish becomes toxic due to feeding of toxic algae – dinoflagellates,*Gambeirdiscustoxicus.*Red snapper *(Lutjanusbohar),* Grouper *(Variola louti) and* Moray eel are recorded as ciguateric. More than 400 species have been implicated in ciguatera poisoning.

(iii)Paralytic shell fish poisoning (PSP) –This is associated with dinoflagellate blooms (*Alexandrium catenella, Gonyaulax tamerensis*). Heat stable saxitoxin will be accumulated inmussels, clams, oysters, scallops etc. grown in algal bloom areas. Greater number of human deaths is reported due to consumption of contaminated shellfish.The current regulatory level for fresh bivalve molluscs in most countries is 80 μg/100 g.

(iv)Diarrhetic shellfish poisoning (DSP) - Dinoflagellate *Dinophysis forti* is the algae which producesokadoic acid, the causative of DSP.Primary symptom is acute diarrhoea.Regulatory level in fresh bivalvemolluscs in most countries is 0-60 μg /100 g.

Mouse bioassay and analysis by HPLC are the important methods for monitoring biotoxins. Reliable sampling plans are required for effective monitoring.

Pesticides

Pesticides are substances used for preventing, destroying or controlling any pest. The major chemical types of pesticides include (i) Organochlorine pesticides – mostly banned because of its lipophilic nature. Have properties of bioaccumulation and high persistence (Eg: DDT and its derivatives, BHC, Endosulfan, aldrin, dieldrin etc). (ii) Carbamates – widely used insecticides(Eg: carbaryl, carbofuran, carbosulfan). (iii) Organophosphates – have rapid aciton at lower concentration, easy biodegradable in nature(Eg: malathon, Moncrotophos).(iv) Pyrethroids – have low mammalian toxicity and knock down effect against insects (Eg: Deltamethrin, Cypermethrin, Cyhalothrin, Fenvalerate etc.). Pesticide contamination in fish mainly comes though agricultural runoff and municipal sewage effluent.

Persistent organic pollutants (POPs) – they are organic chemicals that remain intact in the environment for long periods, become widely distributed, bio accumulate in food chain and are toxic to humans, wild life and environment. The POPs to which seafood consumers are most likely exposed are dioxins and PCBs. The Stockhome convention on POPs initially identified twelve POPs, called as 'dirty dozen' include 9 pesticides, 2 industrial chemicals and 1 un intentional by product. They are aldrin, chlordane,DDT, dieldrin, endrin, heptachlor, hexachlorobenzene, mirex, toxaphene, polychlorinated biphenyls (PCBs), dioxins and furans. Later nine new chemicals were again added to Stockhome convention.

The chromatographic techniques mainly Gas chromatography (GC), Gas chromatography-tandem mass spectrometry (GC-MS/MS) and Liquid chromatography-tandem mass spectrometry (LC-MS/MS) are used for the analysis of pesticide residues.

Antibiotics

Illegal use of antibiotics for veterinary purposes has become a matter of public concern. Antibiotics are used in aquaculture as prophylactics, as growth promoters and for treatment of diseases. They are usually administered in feeds and most commercial shrimp feeds contain antibiotics.The feeding of antibiotics as growth promoters is associated with decrease in animal gut mass, increased intestinal absorption of nutrients and energy sparing. But inappropriate and frequently abusive, use of antibiotics can affect human health. The two major concerns are the presence of antimicrobial residues in edible tissues and the emergence of antimicrobial resistance, which represents a huge threat to public health worldwide.

The greatest potential risk to public health associated with antimicrobial use in aquaculture is the development of a reservoir of transferable resistance genes in bacteriaof aquatic environments. The antibiotics lose their efficacy over time because of the emergence and dissemination of resistance among bacterial pathogens.

EU implemented “zero tolerance policy” regarding antibiotic residue. Using LCMSMS method EU laboratories are equipped to detect traces of prohibited carcinogenic antibiotics like chloramphenicol up to 0.3 ppb and nitrofuran up to 1 ppb levels. Many of the antibiotics are listed as prohibited substance in fish and fishery products. In India the tolerance limit has been set only for the following antibiotics

Antibiotic	**MRL (ppm)**
Tetracycline	0.1
Oxytetracycline	0.1
Trimethoprim	0.05
Oxolinic Acid	0.3

The monitoring of antimicrobial residues in fish tissues requires sensitive and selective analytical methodologies to verify the accomplishment of the legal framework and reach the desirable high standards of quality and food safety. The methods can be microbiological, immunochemical or physico chemical. European council directive 96/23/EC, 1996 gives direction on measures of monitoring residues in live and animal products. It specifies spectrometric detection, GC, HPLC, ELISA and LC-MS/MS methods.

Biological contaminants

Biological contaminantsof food are harmful and hazardous substances of biological origin in the food that can cause foodborne illness when they are consumed. Pathogenic bacteria can cause illness in human, either by infection or intoxication. Food borne infections are caused by swallowing live pathogens that grow within the body, usually in the intestinal tract. Intoxication is a condition caused by swallowing preformed toxins i.e. toxins produced by microorganisms in the food before it is eaten.

Bacterial Pathogens:

Bacillus cereus
Campylobacter jejuni
Clostridium botulinum
Clostridium perfringens
Pathogenic Escherichia coli
Listeria monocytogenes
Salmonella spp.
Shigella spp.
Staphylococcus aureus
Vibrio cholerae
V. parahaemolyticus
V. vulnificus
Yersinia enterocolitica
Aeromonas spp.
Plesiomonas shigelloides

1. Bacillus cereus

Bacillus cereus is a gram-positive, rod-shaped, facultatively anaerobic, motile bacterium. Bacillus cereus is a common food contaminant and well-known causative agent of food-borne illness. It is commonly found in soil, on vegetables, and in many raw and processed foods. Their infection is not commonly reported because of its usually mild symptoms. A fatal case due to liver failure Food poisoning caused by B. cereus may occur when foods are prepared and held without proper refrigeration for several hours before being served. Consumption of foods that contain 10^6 CFU /g may result in food poisoning. Foods incriminated in food poisoning outbreaks include cooked meat and vegetables, boiled or fried rice, vanilla sauce, custards, soups, and raw vegetable sprouts as well as fish. Two types of illnesses have been related to *B. cereus*. The first is characterized by abdominal pain and diarrhea. It has an incubation period of 4-16 hours and symptoms that last for 12-24 hours. The second is characterized by an acute attack of nausea and vomiting. It has an incubation period of 1-5 hours. Diarrhea is not common with the second type of illness. The organism has possible severity of the emetic syndrome which emphasise the importance of adequate refrigeration of prepared food. Because the emetic toxin is pre-formed in the food and not inactivated by heat treatment, it is important to prevent growth and the production of cereulide during storage. Some *B. cereus* strains are known to be psychrotrophic and to have the highest emetic toxin production between 12- and 15°C.

Cooking of seafood cannot inactivate the spores of *B. cereus*hence this is not appropriate to control this pathogen. Proper hygiene and appropriate temperature control are needed to prevent *B. cereus* illness.

2. *Campylobacter jejuni*

These are very small, gram-negative, microaerophilic, curved thin rods with corkscrew motility. *C. jejuni* is widely distributed in the intestinal tract of poultry, livestock, and warm-blooded domestic animals. It is a very common and important cause of diarrheal illness in humans. Eating raw seafood is a risk factor for sporadic *Campylobacter* infection. Symptoms include profuse diarrhea (sometimes bloody), abdominal pain, headache, weakness, and fever. Profuse diarrhoea, abdominal pain, headache & fever and meningitis occur in neonates. Many infections occur without symptoms. *C. jejuni* is transmitted through contaminated foods, including raw clams, mussels and oysters, person-to-person contact and contaminated water. Cross-contamination of foods by dirty food-contact surfaces, including cutting boards and hands, may be the most frequent route of transmission. Infective dose ranges from 500 to 10,000 cells. This organism survives refrigeration and freezing.

C. jejuni can be controlled by thorough cooking of seafood and proper hygiene and sanitary food-handling practices. Preventing campylobacteriosis from consumption of raw shellfish depends on protecting shellfish growing waters from fecal contamination.

3. *Clostridium botulinum*

Clostridium botulinum is a gram positive, spore-forming rod shaped bacteria that grows anaerobic atmosphere. This organism is considered as a dangerous pathogenwhich produce a very deadly, exotoxin (neurotoxin) when grows in food. The food poisoning is called 'botulism". The spores are highly heat resistant. Eight different toxins i.e. A, B, C1, C2, D, E, F & G known to exist at present. Food poisoning is due to the ingestion of toxin develop symptoms within 12-24 h of consuming infected food. Nausea, vomiting, fatigue, headache, paralysis, difficulty to talk, double vision and sound in the ear are the usual symptoms. Death occurs due to respiratory failure.

This organism is found throughout the environment and has been isolated from soil, water, vegetables, meats, dairy products, ocean sediments, the intestinal tracts of fish, and the gills and viscera of crabs and other shellfish. Botulism has been most commonly associated with improperly canned food (usually home canned). Semi-preserved seafood, including smoked, salted and fermented fish.

The *C. botulinum* Type E that is most common in fish and fishery products is of particular concern because it grows at temperatures as low as 3.3^{o}C and produces little noticeable evidence of spoilage. *C. botulinum* Type A is the form of this bacteria that is most common in land-based products. It is a common contaminant on processing equipment.

Proper thermal processes for canned seafood destroy the bacteria are required to control this pathogen. Heavy salting or drying to reduce the water activity below 0.93 and fermentation or acidification to below pH 4.6 is effective means of preventing *C. botulinum* growth.

4. *Clostridium perfringens*

It is agram positive, spore-forming rod shaped anaerobic bacterium. Food poisoning caused by *C. perfringens* may occur when foods such as meat or poultry are cooked and held without maintaining adequate heat or refrigeration before serving. The illness is a self-limiting gastroenteritis with an incubation period of 8-15 hours and duration of 12-24 hours. The symptoms, which include intense abdominal cramps, gas, and diarrhea, have been attributed to a protein enterotoxin produced during sporulation of the organism in the intestine.

C. perfringens is commonly found in soil, dust, and the intestinal tract of animals.The presence of small numbers of *C. perfringens* is not uncommon in raw meats, poultry, dehydrated soups and sauces, raw vegetables, and spices.

Control measures emphasize proper food preparation and storage techniques, especially temperature control. There is need to maintain food preparation areas free of soil and dust and good personal hygiene.

5. *Pathogenic Escherichia coli*

E. coli are gram-negative, rod-shaped, non-spore forming facultatively anaerobic bacteria. Most forms of the bacteria are not pathogenic and serve useful functions in the intestine. There are *six categories of diarrheagenic E. coli* which include Enterotoxigenic *E. coli (*ETEC*),* Enteropathogenic *E. coli (*EPEC*),* Enteroinvasive *E.coli (*EIEC*),* Enterohemorrhagic *E. coli (*EHEC*,* Shiga toxin-producing *E. coli or* STEC*),* Enteroaggregative *E. coli (*EAEC *or* EAggEc*)* andDiffusely adherent *E. coli (*DAEC*).*Pathogenic strains of E. coli are transferred to seafood through sewage pollution of the coastal environment or by contamination after harvest. E. coli food infection causes abdominal cramping, water or bloody diarrhea, fever, nausea, and vomiting.

The primary habitat of the organism is intestinal tract of man and animals and its presence in food in food is generally considered as an indication of faecal contamination. Natural water get contaminated with E. coli either by direct contact with faeces or by mixing up with sewage. This water, when used for seafood processing, contaminates the product. Similar possibilities arise when the ice used for preservation or the utensils used for processing are contaminated with *E. coli.* Improperly cleaned boat deck and containers used onboard trawlers can also act be source of contamination.

The pathogenic *E. coli* can be prevented by heating seafood sufficiently, holding chilled seafoods below 4.4^{o}C, preventing post-cooking cross-contamination, and adoption of hygienic and sanitation practices inseafood processing.

6. Listeria monocytogenes

This organism is gram-positive, non-spore forming, motile rods and facultative ananerobic bacteria. It can survive freezing and thawing. *L. monocytogenes* grows in refrigerated temperatures (even at 1°C) and it can survive both acidic and alkaline pH. This is the most heat resistant pathogenic bacteria among non-spore formers.It causes listeriosis in humans. Most healthy individuals are either unaffected by L. monocytogenes or experience only mild flu-like symptoms. Victims of severe listeriosis are usually immunocompromised. Persons who are at highest risk include: cancer patients, individuals taking drugs that affect the body’s immune system, alcoholics, pregnant women, persons with low stomach acidity and individuals with AIDS. Severe listeriosis can cause meningitis, abortions, septicemia and a number of other maladies, some of which may lead to death.

L. monocytogenes is widespread in nature and has been isolated from soil, vegetation, marine sediments and water. About 1% of human population is known to carry *L. monocytogenes.* This organismis present in various kinds of foods including raw fish, cooked crabs, raw and cooked shrimp, raw lobster, surimi and smoked fish. The greatest threat of listeriosis is from ready-to-eat products.

Hazards from *L. monocytogenes* can be prevented by thoroughly cooking seafood and by preventing cross-contamination once the seafood is cooked.

7. *Salmonella* spp.

Salmonella are gram-negative rods, non-spore forming, mostly motile (exception *S. pullorum* and *S. gallinarum*) facultative anaerobic bacteria. More than 3000 serotypes of this organism are known to exist at present. All serotypes of salmonella can survive freezing at -40°C and also survive for months together at frozen condition (-18°C).

Salmonella are enteric organisms producing enteric fever and food borne gastroenteritis. Food poisoning due to salmonella is known as "Salmonellosis" infants, elderly and the under nourished are more susceptible to the disease and in such individuals salmonellosis is known to occur even from one single cell of Salmonella. *Salmonella* food infection causes nausea, vomiting, abdominal cramps and fever. Outbreaks of Salmonella food infection have been associated with raw oysters, salmon, tuna salad, shrimp cocktail, stuffed sole and gefilte fish.

Salmonella is naturally found in the intestinal tracts of mammals, birds, amphibians and reptiles but not in fish, crustaceans or mollusks. Salmonella is transferred to seafood through sewage pollution of the harvest environment or by contamination after harvest.

Preventive measures from *Salmonella*include heating seafood sufficiently to kill the bacteria, holding chilled seafood below 4°C, preventing post-cooking cross-contamination,Proper pest controls and prohibiting carries people from working. Polluted waters for washing and any activity related must be avoided.

8. *Shigella spp.*

Shigella are gram-negative, facultatively anaerobic, non-sporulating, non-motile, rod shaped bacteria. They are the most difficult enteric pathogens to isolate as not indigenous in foods. The disease caused by *Shigella* is generally known as `shigellosis', which causes mild diarrhea, fever, abdominal cramps and severe fluid loss. This organism are transmitted through food or water contaminated with human excreta. Shigella is naturally found in the intestinal tract of humans.The organisms pass the acid barrier of the intestine, multiply in the gut and produce ulceration of large intestine followed by dysentery. *S. dysenteriae* causes the most severe illness. Shigella is transferred to seafood through sewage pollution of the coastal environment or by contamination after harvest. The transmission of the organism from one individual to another is by means of contaminated food, water, ice, flies, contaminated contact surface or food handlers who are carriers of this organism. They survive longest when food holding temperatures are 25°C or lower.

Shigella contamination can be prevented by eliminating human waste contamination of water supplies and by improved personal hygiene for people who are ill or are carriers of *Shigella* and work in food operations. Avoidance of time/temperature abuse, pest control, and Use properly chlorinated water for processing will be help to overcome this organism.

9. Staphylococcus aureus

Staphylococcus aureus is a gram-positive, round-shaped bacterium. The contamination of food with coagulase positive staphylococci could cause food poisoning, as the organism growing in food materials in considerable numbers, secretes exotoxin. S. aureus food poisoning causes nausea, vomiting, abdominal cramping, watery or bloody diarrhea, and fever. S. aureus are known to produce 9 different types of enterotoxins designated as enterotoxin A, B, C1, C2, D, E, F, G and H. This organism can produce a toxin if allowed to grow in food. The toxin is not destroyed by the cooking or canning processes. S. aureus has the ability to grow and produce toxins in food with very little available water (0.85 a_w, 10 percent salt), which would prevent the growth of other pathogens. This is the most drought resistant pathogenic bacteria and they cannot compete with general bacterial flora.

Humans and animals are the primary reservoirs for *S. aureus*. *S. aureus* can be found in the nose and throat and on the hair and skin of healthy individuals. However, the bacteria can be found in air, dust, sewage and surfaces of food-processing equipment. When the material is taken onboard and handled by workers, contamination takes place. So its presence in seafood indicates lapse in maintaining personal hygiene.

S. aureus can be prevented by minimizing time/temperature abuse of seafood, especially after cooking, and requiring that food handlers engage in proper hygiene. Refrigeration (below 4°C) of the material during handling and processing may be good control.

10. Vibrio cholerae

V. cholerae are gram-negative, coma shaped aerobic, non-spore forming, and motile bacteria. This facultative anaerobe has a flagellum at one cell pole as well as pili. *V. cholerae*consists of the classical (non-hemolytic) and El Tor (hemolytic) biovars. The El Tor *vibrios* are generally more infectious than the classical *V. cholera serotypes* and it can survive longer in the environment.

It is the causative agent of cholera.There are a number of types of *V. cholerae*, and these produce very different symptoms. One type, *Vibrio cholerae* 01 (Ogawa, Inaba and Hikojima), initially causes abdominal discomfort and mild diarrhea. As the illness progresses, the symptoms may include: watery diarrhea, abdominal cramps, vomiting and dehydration. Death can occur. Another type of *V. cholerae*, non-01 (non-agglutinable vibrios (NAG'S) or non-cholerae vibrios (NCVs)), causes diarrhea, abdominal cramps and fever. Nausea, vomiting and bloody diarrhea have also been reported. *V. cholerae* 0139 Bengal has been appears to be a hybrid of the 01 strain and the non-01 strain.

The only natural habitat of *V. cholerae* is man. Contamination occurs through food, water, flies and contaminated hands.*V. cholerae* is found in estuaries, bays, and brackish waters. It is naturally occurring and is not necessarily related to sewage contamination. *V. cholerae* tends to be more numerous in the environment during warmer months.

Contamination from *V. cholerae* can be prevented by cooking seafood thoroughly and by preventing cross-contamination once the seafood is cooked and strict personal hygiene of seafood handlers.

11. Vibrio parahaemolyticus

Vibrio parahaemolyticus is a gram-negative halophilic rod shaped bacteria which are non-sporulating, motile, and oxidase-positive bacterium.*V. parahaemolyticus* is the leading causal agent of human acute gastroenteritis following the consumption of raw, undercooked, or mishandled marine products. The most commonly experienced symptoms of *V. parahaemolyticus* illness include: diarrhea, abdominal cramps, nausea, vomiting and headache. Fever and chills are less frequently reported. The illness has been associated with consuming contaminated crabs, oysters, shrimp and lobster.

They are found in estuarine, marine and coastal environments. The incidence of *V. parahaemolyticus* (Kanagawa-positive strains), infection has been increasing in many parts of the world, and this has been attributed to the emergence of a new clone of the 03:K6 serotype carrying only the *tdh* gene.

Hazards from *V. parahaemolyticus* can be controlled by thoroughly cooking seafood and preventing cross-contamination after cooking. Control of time/temperature abuse is also an important preventative measure. Icing the material immediately after catch, washing with potable water and improvement of hygiene are considered as remedial measures.

12. *Vibrio vulnificus*

V. vulnificus is gram-negative, halophilic, lactose-positive, rod shaped bacteria. It is an emerging pathogen, phenotypically similar to *V. parahaemolyticus.* This is the etiological agent for three syndromes- a. primary septicemia b. skin infections c. acute diarrhoea. All strains are pathogenic; infection dose is not known. Infection is associated with the consumption of raw seafood particularly oysters. *V. vulnificus* is a naturally occurring marine bacterium. This bacterium is part of the normal bacterial flora of estuarine and marine waters. *V. vulnificus* requires salt for survival and is commonly isolated at salinities of 7 ppt to 16 ppt. The numbers of the bacterium in the environment are highest during the warmer months.

This organism enters through two portals which are one by ingestion of raw sea foods and other by exposure of skin lesions in seafood handlers. The most common symptoms include: skin lesions, septic shock, fever, chills and nausea. Abdominal pain, vomiting and diarrhea are less frequently reported. Death occurs in about 50 percent of the cases. A number of medical conditions make individuals more susceptible to the life threatening effects of this bacterium, including: liver disease, alcohol abuse, cancer, diabetes, chronic kidney disease, immunosuppressive drug or steroid usage, low stomach acidity and AIDS. *V. vulnificus* sepsis has been associated with the consumption of certain molluscan shellstock.

*V. vulnificus*hazards can be controlled by thorough cooking of shellfish and by preventing cross-contamination once the seafood is cooked. Icing is very effective to reduce the load of the organism.

13. *Yersinia enterocolitica*

Yersinia enterocolitica belongs to family *Enterobacteriaceae*, are psychrotrophic, gram negative, oxidase negative, catalase positive and non-lactose fermenting bacilli. *Y. enterocolitica* is naturally found in soil, water and domesticated and wild animals. Yersiniosis causes diarrhea, vomiting, abdominal pain and fever, often mimicking appendicitis. Outbreaks have been associated with oysters and fish.

The most common transmission route of pathogenic *Y. enterocolitica* is faecal-oral via contaminated food. Food is one of the major vehicles for transmission of human yersiniosis. The widespread occurrence of *Y. enterocolitica* in nature, and its ability to colonize food animals, to persist within animals and the environment, and to proliferate at refrigeration temperature make it important to consider for safety.

This microorganism known to occur in different countries in various foods fish, crabs, cockles and oysters including meats, vegetables, and milk, beef, lamb, chicken, raw milk and pasteurized milk as well as water.

Y. enterocolitica can be prevented by heating seafood sufficiently to kill the bacteria, holding chilled seafoods below 4ºC and preventing post-cooking cross-contamination.

14. *Aeromonas hydrophila*

*Aeromonas hydrophila*is a gram-negative, facultatively anaerobic, oxidasepositive, glucose-fermenting rod-shaped bacterium which is known as emerging food-borne pathogens. This psychrotrophs are enteropathogenic are able to grow at 4-5°C and produce toxin in oysters at 5°C.

The infections caused by *A. hydrophila* are gastrointestinal infection, skin and soft-tissue infection, and bacteremia in immunocompromised individuals. It has also been implicated as a cause of peritonitis, cholangitis, meningitis, septic arthritis, osteomyelitis, myositis, ocular infections, urinary tract infections, pneumonia, and hemolytic uremic syndrome.

This organism is natural members of aquatic environments and is commonly found in fish and fish products of all aquatic environments. *A. hydrophila* is very resistant organism and it can survive in food items stored in cold for long period. Oysters have been implicated in food-borne disease.

Combination of chilling, salting and/or acidification is effective means of preventing the growth of *Aeromonas.*Treatment water can significantly reduce levels of *Aeromonas* which can be used for fish processing.

15. Plesiomonas shigelloides

The *Plesiomonas* are gram-negative, facultatively anaerobic, oxidase positive, glucose fermenting, rod-shaped bacteria, generally motile. It is an emerging pathogen, mostly associated with fresh water and seawater in warm months.

This organism may result in gastroenteritis or extra-intestinal infections. Clinical symptoms of gastroenteritis include fever, secretory or dysenteric diarrhea, abdominal pain, vomiting, nausea, chills, arthralgia, and headache. This organism is known causative agent for diarrhoea in seafood cinsumersas its predominant association with seafood.

The primary reservoirs of *P. shigelloides* are aquatic environments, including freshwater, estuarine water, and seawater. This organism can be transmitted through the fecal-oral route, through the consumption of infected seafood (especially oysters), contaminated water and contaminated vegetables, and through exposure to amphibians and reptiles.

Preventive measures for *P. shigelloides*include maintenance of chilled condition for seafoods and adoption of good sanitary practices.

Viral Pathogens

Viruses contaminate the foods same way as bacteria. It reproduces only within susceptible living cells. A ready to eat food containing a pathogenic virus is a health hazard. Viruses don't reproduce in food; it exists in foods without growing, so they need no food, water or air to survive. Viruses don't cause spoilage but may cause illness. It can survive in human intestine, water, frozen foods etc. for months. Viruses can be found in people who were previously ill. Adequate cooking can destroy it.

1. **Hepatitis A virus**

HAV is a member of the genus Hepatovirus in the family Picornaviridae. Two clinical forms of hepatitis designated hepatitis A and hepatitis B. Hepatitis A infection, caused by hepatitis A virus (HAV) is the leading cause of human viral hepatitis throughout the world and is mainly propagated via the fecal–oral route. Transnational outbreaks of food-borne infections are reported with increasing frequency as a consequence of international food trade.Hepatitis A virus infection includes epidemic jaundice, acute catarrhal jaundice, and campaign jaundice.HAV infection is usually a self-limited illness that does not become chronic.The fatality rate is low, and deaths primarily occur among the elderly and individuals with underlying diseases.

Food-borne outbreaks caused by HAV are mainly associated with bivalve molluscs, produce (soft fruits and leafy greens), and ready-to-eat meals.This virus can survive in seawater and sediments for long periods (over a year). It can also survive better in lower temperature and killed in higher temperature.Humans are the only known reservoir.

Hepatitis A can be prevented by thoroughly cooking seafood and by preventing cross-contamination of cooked seafood. High-risk groups should avoid to consume previously prepared or uncooked seafood.

2. *Norovirus* (formely called *Norwalk*) *virus*

Norwalk virus is a small round-structured virus (SRSV) and was the first virus to be clearly associated with gastroenteritis. Norwalk virus is considered a major cause of nonbacterial intestinal illness (gastroenteritis). Illness from Norwalk virus has been associated with eating clams (raw and steamed), oysters and cockles. Norwalk virus causes nausea, vomiting, diarrhea, abdominal cramps, and occasionally fever in humans.

Norovirus illness spreads easily and is often called stomach flu or viral gastroenteritis. People who are infected can spread it directly to other people, or can contaminate food or drinks they prepare for other people. The virus can also survive on surfaces that have been contaminated with the virus or be spread through contact with an infected person.

This hazard can be prevented by thorough cooking and preventing cross contamination of cooked foods.Controlling overboard discharge of untreated sewage from shellfish harvesting vessels would reduce the incidence of illness attributable to Norwalk virus.

Parasites

Parasites in seafood come naturally, not by contamination. For most food borne parasites, the food is part of their life cycle. Some parasites may be transmitted through food or water that is contaminated by faecal material shed by infected host.Parasites become a concern when consumers eat raw or lightly preserved fish such as sashimi, sushi etc.

There are two types of parasites that can infect people through food or water includes:

(a) Parasitic worms

(b) Protozoan parasites.

Parasitic worms

1. ***Anisakis simplex***

Anisakis simplex, commonly called herring worm, is a parasitic nematode or roundworm. Its final hosts are dolphins, porpoises and sperm whales. The human illness caused by thisis called as “Anisakiasis”. Anisakiasis is caused by ingesting the larvae of several types of roundworm which are found in saltwater fish such as cod and is associated with eating raw fish (sushi, sashimi, lomi lomi, ceviche, sunomono, Dutch green herring, marinated fish and cold-smoked fish) or undercooked fish. The larval (wormlike) stage in fish and squid is usually 18 to 36 millimeters in length, 0.24 to 0.69 millimeters in width and pinkish to whitish in color. Parasites in fish are considered a hazard only in fish will be served raw or undercooked.

In other products, parasites are considered filth but not hazardous. The FDA has established three freezing processes to kill parasites. Freezing and storing at -4°F (-20°C) or below for 7 days (total time), or freezing at -31°F (-35°C) or below for 15 hours, or freezing at -31°F (-35°C) or below until solid and storing at -4°F (-20°C) or below for 24 hours is sufficient to kill parasites.

2. *Pseudoterranova decipiens*

Pseudoterranova decipiens commonly called "codworm" or "sealworm," is another parasitic nematode or roundworm. The usual final hosts of Pseudoterranova are gray seals, harbor seals, sea lions and walruses. The larval stages in fish are 5 to 58 millimeters in length, 0.3 to 1.2 millimeters in width and yellowish, brownish or reddish in color.

These nematodes are related to *Anisakis simplex* and the disease associated with infections is also termed anisakiasis. These nematodes are also transmitted to humans through raw or undercooked fish. Control of *Pseudoterranova* is the same as for *Anisakis simplex*.

3. *Diphyllobothrium latum*

Diphyllobothrium latum is a cestode, or tapeworm, that parasitizes a variety of fish-eating mammals of the northern latitudes. A similar species is found in the southern latitudes and is associated with seal hosts. Tapeworm infections occur after ingesting the larvae of diphyllobothrium which is found in freshwater fish such as pike, perch etc. Cestodes have a structure that allows them to attach to the intestinal wall of their host and have segmented bodies. Cestode larvae found in fish range from a few millimeters to several centimeters in length and are white or gray in color.

Diphyllobothrium tapeworms primarily infect freshwater fish. *Diphyllobothrium* tapeworms are usually found unencysted and coiled in musculature or encysted in viscera. These tapeworms can mature and cause disease in humans. These cestodes are also transmitted to humans through raw or undercooked fish. Control of *Diphyllobothrium* is the same as for *Anisakis simplex*.

Protozoan Parasites

Protozoan Parasitesare single celled animals which are responsible for infecting human comprises:

1. Entamoeba histolytica can cause severe disease as classical amoebic dysentery which may be fatal if the parasites invade extra-intestinal tissues, such as liver, lungs, or brain.

2. ***Giardia lamblia*** areassociated with diarrhoea, constipation and gastrointestinal pains, rarely invade the tissues.
3. ***Toxoplasma gondii:*** Illness caused is "Toxoplasmosis". Its symptoms are hydrocephalus, blindness in children. Less severe in adults. Source of infection under cooked or raw meats i.e. pork, lamb, beef, poultry & cats. Intermediate host is domestic cat.

Preventive measures to eliminate parasites from seafood are proper cooking, freezing and good post processing hygiene control.

Chapter 32

HACCP - A preventive strategy

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Food-borne diseases, i.e. illnesses due to consumption of contaminated foodare one of the most prevalent health problem in India as well as in other parts of the world. (WHO, 1984). In spite of efforts taken, food-borne diseases are increasing in number and frequency all over the world. This problem is likely tc continue to grow, unless new methods and strategies are adopted to counter them (WHO, 1991). This feature can be attributed to the insufficiency of the traditional approaches of quality control in controlling and preventing food-borne diseases. Hence, it is imperative that a concerted approach to food safer be developed. World Health Organisation's suggestion for this is to combine an effective food safety infrastructure with an adequate educational programme (WHO, 1991). This could be achieved by combining two types of information. The information on the socio-cultural and economic situation and (ii) the technical information related to food manufacture and food habits obtained through the application of the Hazard Analysis and Critical Control Point orHACCP (WHO, 1993).

HACCP is a rational method, increasingly adopted by food manufacturers throughout the world for the prevention of food-borne diseases (WHO, 1993).Itis a system of controls in a food processing industry, which helps them to identify and prevent problems even before they occur. This system is systematic an': scientifically based and is considered as a tool for ensuring food safety throughoutthe world (Brian, 1992).

Even though HACCP was introduced in food system as early as 1960's, it found its way in India only recently. Interestingly among the various food processing activities, this system was initially introduced in the fish processing sector. This changeover is rather forced upon the seafood processors because of the emergence of the European Union Market, which contributes to more than 40% of the total export market of marine products from India.

WHO defined HACCP as a `Systematic approach to the identification and assessment of the hazards and risks associated with a food operation and defining of the means of their control' (WHO, 1993). Any thing which has the potential to cause harm to consumer safety should be considered a hazard.

World Health Organisation and International Commission of Microbiological specification of Foods recommended HACCP for food safety in developing countries (WHO/ICMSF, 1980). European Commission (European Commission 1991 and 1994)has made HACCP based quality management system mandatory in fisheries to export shrimp/fish products to European markets. Such systems are recommended by ISFDA for countries exporting seafood to USA. the Codex Alimentarius Commission is currently encouraging practical implementation of HACCP systems in food industries (Codex, 1991). Recent legislation from the EC (European Commission, 1991 and 1994)also requires the use of HACCP – based quality management systems in countries wishing to export shrimp products to the single european market fro the start of 1993. HACCP based quality management systems are also advocated in the USFDA/NOAA Voluntary Seafood Inspection Programme and will be required from early 1998 by the USFDA for countries exporting seafoods to the USA.

HACCP an overview

HACCP is a management tool that provides a more structured approach to the control of identified hazards that that available by traditional inspection and quality control procedure. When applying the HACCP concept in food processing, control is transferred solely from end product testing |(i.e. testing for failure). There will, however, always be a need for some end product testing particularly for verification purposes and in product development.

The process variables that are used to control the operation are identified by a HACCP review. Much of the effectiveness of HACCP is achieved through the use of a multi-disciplinary team of experts. The team should have members from relevant area, e.g. microbiology, food chemistry, production, quality assurance, food technology and food engineering. HACCP involves the identification and analysis of hazards associated with all stages of food processing chemical and physical hazards should be all considered if they affect production safety. Following hazards analysis, Critical Control Points (CCPs) are identified with appropriate measures which can be applied to control each hazard. Finally, monitoring and verification systems are put in place to ensure that the HACCP is working.

The benefits from the use of HACCP are many and can be summarized as follows (Anon, 1996):

- HACCP is a systematic approach covering all aspects of food safety from raw materials, growth, harvesting and purchase to final product use.
- Use of HACCP will move a company from sole retrospective end product testing approach towards a preventive quality assurance approach.
- HACCP provides for a cost-effective control of food borne hazards
- Use of HACCP focuses technical resources into critical parts of seafood processing.
- The use of preventive approaches such as HACCP leads to reduced product losses.
- International bodies recommend HACCP as the most effective means for controlling food-borne diseases.
- Demonstrating that a HACCP quality management system is in place in processing plant will assist in meeting standards in importing countries and contribute to customer satisfaction.

Principles of HACCP

HACCP is a powerful system which can be applied to a wide range of simple and complex operations. For food processors to implement HACCP they must investigate not only their own product and production methods, but must also apply HACCP to their raw material supplies and to final product storage must consider distribution and retail operations up to and including the point of consumption. The HACCP system consists of the following basic principles(Codex, 1991):

Principle 1: Conduct a hazard analysis. Prepare a flow diagram of the steps in the process. Identify and list the hazards and specify the control measures.

Principle 2: Identify the CCPs in the process using a decision tree.

Principle 3: Establish target levels and tolerances which must be met to ensure each CCP is under control.

Principle 4: Establish a monitoring system to ensure control of the CCP by schedule testing or observations.

Principle 5: Establish the corrective action or preventive measures to be taken when monitoring indicates that a particular CCP is moving out of control.

Principle 6: Establish documentation concerning all procedures and records appropriate to these principles and their application.

Principle 7: Establish verification procedures which include appropriate supplementary tests, together with a review which confirms that HACCP is working effectively.

Definition of terms used

The definition of various terms employed in HACCP study is described by Codex (1991).

Preventive measures-those actions and/or activities that are required to eliminate hazards or reduce their occurrence to an acceptable level.

Corrective Action-the action to be taken when results of monitoring the CCPs indicate a trend towards loss of control.

Critical Control Point (CCP)-a step which, if controlled, will eliminate reduce a hazard to an acceptable level. A step is any stage in production and/or manufacture. This includes raw materials, transport to processing plants, processing and storage etc.

Hazard-this means the potential to cause harm. Hazards can be microbiological, chemical or physical. The National Marine Fisheries Services, also includes economic fraud as hazard, examples of which are species substitution, underweight, excess water in the glaze of frozen products etc.

Monitoring-checking that a processing or handling procedure at each critical control point meets the established criteria. Monitoring may be accomplished by:

(a) Observing handling practices and cleaning procedures;

(b) Measuring time/temperature, detergent/disinfection concentration, container/package condition, chlorine concentration in glaze water etc.

Verification-the use of supplemental tests and/or the review of monitoring records to determine whether the HACCP system is in place and is functioning as planned and to ensure that monitoring is carried out effectively and efficiently.

HACCP analysis

Before starting any study, senior management of the company must be committed to providing the necessary resources for the exercise to be completed and to implementing the findings of the exercise, including reviews and updates. Without such commitment there is little point in beginning the study. When conducting a HACCP study the seven principles are applied in the following stages (Anon, 1996):

(a) Define terms of references and set up the HACCP team;

(b) Describe the product-a full description of the product and the study, e.g. raw, frozen, peeled and de-veined shrimp together with a description of packaging methods, storage and distribution conditions, shelf-life and instructions for use;

(c) Identify intended use-this should be done in collaboration with the customer and the customer target groups should be defined;

(d) Construct a flow diagram-the format of the flow diagram is a matter of choice, but on-site verification of the flow diagram should be carried out;

(e) List all the hazards associated with each process step and list all measures which will control the hazards;

(f) Identify all the critical control points, which can be conveniently carried out using a CCP decision tree;

(g) Establish a monitoring system for each CCP; EG.RAW MATERIAL SHOULD BE STORED BELOW 5^{o}C;

(h) Establish a monitoring system for each CCP;

(i) Establish a corrective action plan;

(j) Establish a record keeping system and

(k) Establish verification procedures and review of HACCP plan.

HACCP Team

In order to fully understand the process and to be able to identify all likely hazards and CCPs, it is important that the HACCP team is made up of people from a wide range of disciplines. Dillon and Griffith (1996) described various functions that the team should cover.

There must be a chairman to convene the group and to direct the work of the team, ensuring that the concept is properly applied. It is, therefore, important that this person is familiar with the technique and is a good listener, allowing everyone to participate. Someone with a detailed knowledge of the production processes (a production specialist) is required to draw up the initial flow diagrams. Several specialists may be involved in the team, each with the understanding of particular hazards and associated risks, e.g. microbiologist, chemist, QC manager. A process engineer with detailed knowledge, and a good understanding of mechanical operations and performance of processing stages is required to be on the team. People, such as packaging specialists, raw material buyers or distribution staff, may be brought into the team temporarily in order to provide relevant expertise.

The team's progress and results of the analysis should be recorded, a technical secretary should ideally be used to allow all members of the team to play a full role in the discussions.

Process flow diagram

The first function of the team is to draw up a detailed flow diagram of the process. The expertise of the production specialist is important at this stage. Processes will differ in detail in different plants, and an accurate flow diagram depends on detailed knowledge of the process. Issues that may influence considerations of the process include:

(a) Management routine (e.g. shift patterns, skill levels)
(b) Process details (e.g. hygiene and design of equipment, plant layout)
(c) Other operations (e.g. design, storage areas, security)

An example of process flow diagram is given in Fig. 1.

Defining product characteristics

The team must next examine the product and identify its characteristics and way in which it will be used and handled. This analysis will help the team to determine the hazards that will threaten the product or consumer. The following headings can be used as a guideline to this process(Dillon and Griffith,1996)

Storage: All products are handles and stored by the consumer. There is an opportunity for storage abuse that may lead to spoilage of the product in the case of raw orcompromise the safety in the case of packaged products.

Preservation: Specific preservation systems may be used to extend the shelf life of foods and improve the safety. Traditional systems are being constantly modified to meet marketing demands and it is critical to understand the implications of these changes to the stablility of the product.

Packaging: Packaging will physically protect some products, and will also act as a barrier to microbial or chemical contamination.

Fig 1. Example of flow charting IQF raw shrimp processing

Reception of raw materials
v
Washing (in chilled water at 5ºC)
v
Sorting by hand
v
Peeling by hand
v
Washing (in chilled water at 5ºC)
v
Grading by hand
v
Chilling to 0-3ºC
v
IQF Freezing at -40ºC
v
Glazing and hardening at-30ºC
v
Packing in cases and coding
v
Mastering
v
Frozen storage at <-18ºC
v
Distribution at <-15ºC

Types of physical hazards

Hazard	Source or cause
Glass	Bottles, jars, light fixtures, utensils, gauge covers, Thermometers
Metal	Nuts, bolts, screws, steel wool, wire, meat hooks
Stones	Raw materials
Plastics	Packaging materials, raw materials
Bone	Raw material, improper plant processing
Bullet/BB Shot/needles	Animals shot in field, hypodermic needles used for Infections
Jewellery	Pens/pencils, buttons, careless employee practices

Agriculture chemicals: pesticides, herbicides, animal drugs, fertilizers, etc.

1. Plant chemicals: cleaners, sanitizers, oils, lubricants, paints, pesticides, etc.
2. Naturally-occurring toxicants: products of plant, animal or microbial metabolisms such as aflatoxins, etc.

3. Food chemicals: preservatives, acids, food additives, sulfating agents, processing aids, etc.

Environmental contaminants: lead, cadmium, mercury, arsenic, PCBs.

BIOLOGICAL HAZARDS

Biological hazards, which are mainly bacterial, can cause either food-borne infections or intoxications. A food- borne infection is caused by a person ingesting number of pathogenic micro-organisms sufficient to cause infection as a result of their multiplication, e.g. salmonellosis. A food- borne intoxication is caused by the ingestion of already formed toxins produced by some bacteria when they multiply in food, e.g. staphylococcal enterotoxin.

When assessing bacterial hazards to human health in meat and poultry products ,nine pathogenic bacteria must be considered. The following identifies and discusses the pathogenic micro organisms of concern.

Hazard Analysi scan also be performed by employing HACCP worksheet. Hazard analysis worksheet or HACCP work sheet is a tool used to evaluate all hazards in each processing step and to check whether that processing step is a Critical Control Point (CCP). Once CCP's are determined, HACCP planform is used for effectively manage and control all identified CCP's.

Hazard-AnalysisWorksheet

A hazard-analysis work sheet can be used to organize and document the considerations in identifying food-safety hazards. The worksheet addresses the first two principles of HACCP. Although there is no specific or required form, the worksheet should document specific information as required by FDA(Food and Drug Administration, USA). The first two principles of HACCP is being taken care by HACCP worksheet. A typical worksheet is depicted in Annex

1. Each work sheet should have the name and address of the production unit,name of the product, intended use of the product and target consumers and method of storage and distribution.Obviously separate worksheet is required for each class of products.

DescriptionofFisheryProducts/IntendedUse

The HACCP team look at all the fishery products produced in the facility and decide which products to be included in the HACCP Plan. Once the products are identified, the team has to prepare its description, which include details such as composition,structure and physical characteristics, processing method, packaging, conditions for storage and distribution, shelf life, instructions for use and microbiological and/or chemical criteria (if any) of the product.

The HACCP team also has to state the intended use for the product which describes, target consumers, anticipated preparation and use of the product by consumers,special considerations if any (for example if the product is to be used in institutions or by traveler, etc. or are these dangers in use for any vulnerable groups in the population who might obtains the product) and specific requirements imposed by the importer or importing country. Examples of Product description and intended use of the product are given below.

PRODUCTDESCRIPTIONOFFROZENRAWSHRIMP

1.	Species	1. Penaeus indicus(white/NARAN) 2. Penaeus monodon(Tiger)
2.	Type	1.Headon(whole) 2.Headless(HL)3.Peeledand Deveined (PD) 4. PDTailon 5. Peeled and undeveined
3.	Count	
4.	FreezingMethod	IQF/BlockFrozen
5.	Packaging	Packed in LDPE bags or laminated duplex cartons whicharepackedin5or7PLpaperboard
6.	Storing	Stored at a temperature-18°C or below
7.	Instructions for use	To be fully cooked before use or further processed in aproduct
8.	Shipment/Transport	Refrigerated containers at a temperature-18°Cor below

INTENDED USE OF THE PRODUCT

1.	Name of the product	Frozen raw shrimp
2.	Consumer	General public/and processing
3.	Anticipated	Fully cooked before consumption
4.	Special considerations	NIL

Fig1 depicts a model of HACCP worksheet followed by Indian seafoodindustry. This model is adapted from USFDA. Each processing step should be listed serially in Column1 as given in the verified process flow diagram.

All the identified hazards biological, chemical and physical–for each processing step are listed in Column 2. Our assessment of each hazard, based on the evaluation of its significance and severity should be entered in Column 3. Your decision in column 3 should be logically and clearly justified in Column4. The possible preventive or control measures for each hazard are listed in column5.

Control or Preventive Measures

Control measures are actions and activities that can be used to prevent or eliminate a food-safety hazard or reduce it to an acceptable level. Control measures for various hazards can be obtained from stand ard literature, hazard guides, labelsetc. Examples of control measures are listed below:

A.Control measures for biological hazards

Bacteria and other pathogenic micro organisms Control of time and temperature (Minimum storage time and adequate maintenance of temperature by icing, refrigeration etc will mimize the growth of harmful bacteria)

Retorting, Cooking, frying, drying (high temperature exposure for the required time / removal of moisture to attain required water activity, will kill bacterial population) Quick Freezing, Chilling, Cooling (will minimize / prevent the growth of bacteria) Fermentation, pickling or addition of preservatives etc (These will prevent the growth of some bacteria)

Source control (These controls assumes importance, when a particular hazard cannot be controlled by any processing activities. For example in the case of block frozen shrimps, salmonella can be controlled by developing suitable standard operating procedures to ensure that no contamination occur while harvesting and handling)

HACCPWORKSHEET

Name of the firm	
Address	

Product description	
Method of distribution and storage	
Intended use and Consumer	

HAZARD ANALYSIS WORKSHEET					
1	2	3	4	5	6
Ingredient/ processing step	**Identify potential hazards Introduced controlled or enhanced at this step**	**Are any potential Food safety Hazards significant**	**Justify your decision for column(3)**	**What control measure(s) can be applied to prevent the significant Hazards?**	**In this step A critical control point**
	Biological				
	Chemical				
	Physical				

B. Control measures for Chemical hazards

1. Source control (Antibiotics can be controlled by harvesting them from farms which practices approved standard operation procedures for application of antibiotics or by using only permitted antibiotics. These can be verified by auditing the farm facilities during the time of application of antibiotics. This is supplemented with supplier guarantee declaration and third party testing).

2. Production control (eg., Use and application of chemicals under expert guidance).

3. Labeling control (eg., finished product properly labeled with ingredients and known allergens).

C. Control measures for Physical Hazards

1. Source control (eg., vendor certification and raw-material testing).

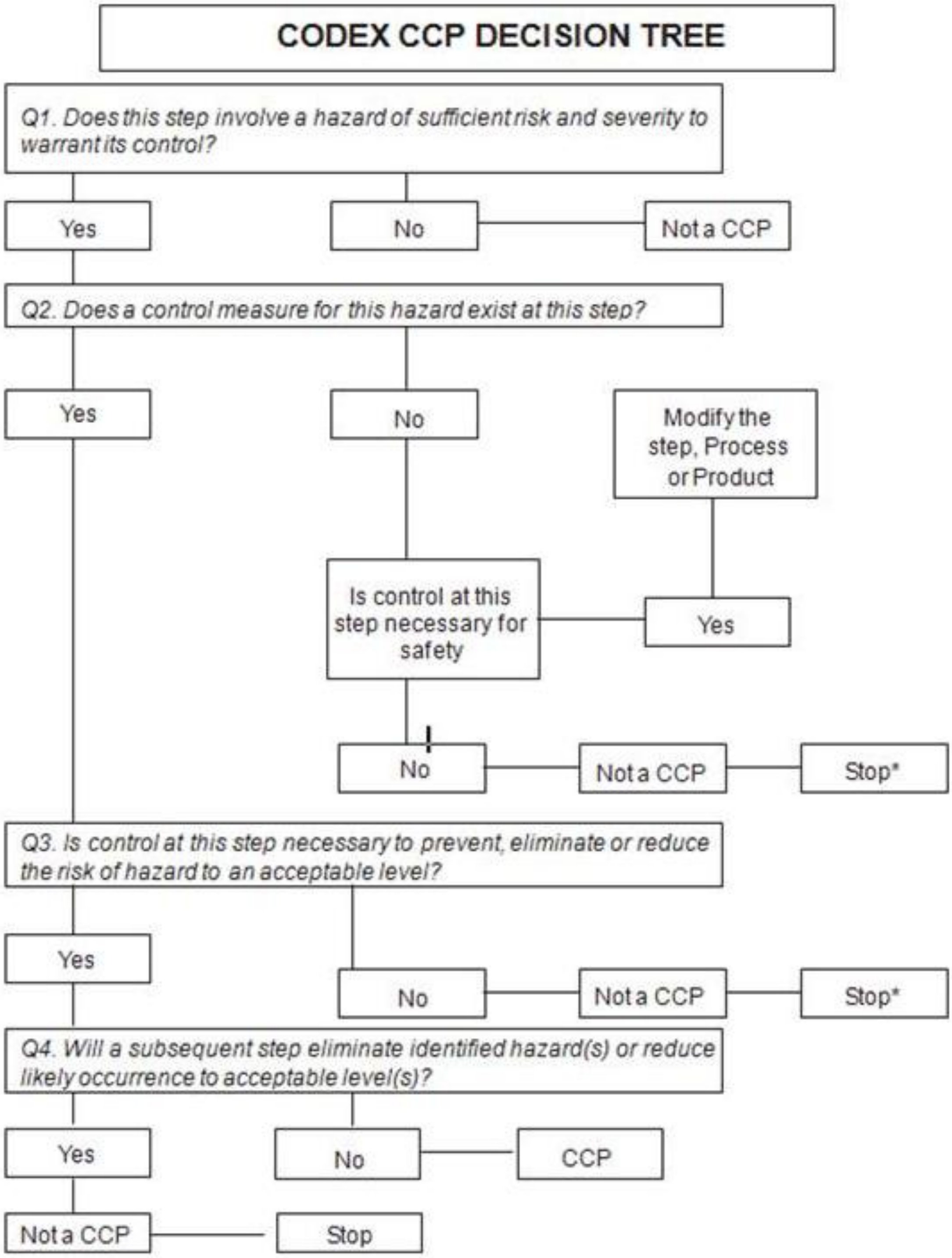
2. Production control (eg., use of magnets, metal detectors, sifter screens, destoners, clarifiers, air tumblers, x-ray equipment, and visual inspection).

Determination the Critical Control Points

The next important step is to ascertain whether the processing step in question is a Critical Control Point (CCP). This has to be entered in(Col no 6) of the worksheet. For each significant hazard, there should be a CCP in which the hazard in question is totally eliminated or brought below the permitted limit. The determination of CCP is facilitated by the applying the decision tree developed by Codex Alimentarius Commission. (Fig 5.) A CCP is defined as that processing step, which effectively prevents and eliminates a food safety hazard or reduce it to an acceptable level. CCPs are product and process specific and CCP seen in one processing unit may not be applicable to another.

Description of CCP Decision Tree

CCP decision tree is a tool developed by Codex Alimentarius Commission, which can be employed to determine whether a particular processing step is a CCP. The decision tree consists of a series of questions the processor has to answer. Based on the answers, we will be guided to other related questions and determine whether the activity is a CCP. If properly used, the decision tree can be a useful tool for identifying CCP's. But as FDA says, the CCP decision tree is not a subsitute for the expert knowledge, since complete reliance on the decision tree might lead to false conclusions.


CODEX CCP DECISION TREE
Q1. Does this step involve a hazard of sufficient risk and severity to warrant its control?
Yes
No
Not a CCP
Q2. Does a control measure for this hazard exist at this step?
Yes
No
Modify the step, Process or Product
Is control at this step necessary for safety
Yes
No
Not a CCP
Stop*
Q3. Is control at this step necessary to prevent, eliminate or reduce the risk of hazard to an acceptable level?
Yes
No
Not a CCP
Stop*
Q4. Will a subsequent step eliminate identified hazard(s) or reduce likely occurrence to acceptable level(s)?
Yes
No
CCP
Not a CCP
Stop

Let us take an example of peeled and cooked prawn.The flowchart of the product is given in fig 6

Question1. Does a control measure(s)
exist at this step or subsequent steps in the process flow for the identified hazard?

If your answer is yes, proceed to Question 2. If you cannot identify a control measure in the process for the hazard, select No for the answer.

If No is selected,then ask:Is control at this step necessary forsafety?

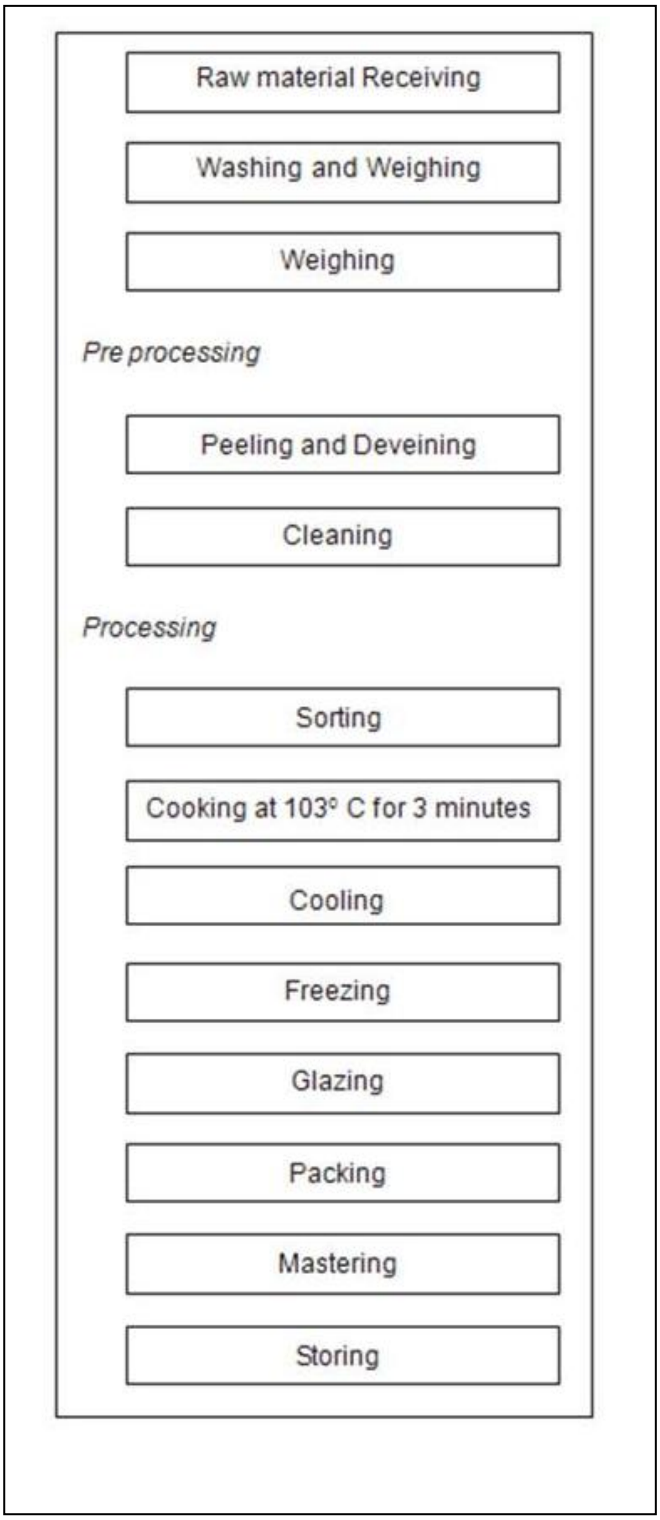
If you have no as the answer here also, then this step is not a CCP for that hazard.Movetothenextprocessin gstep.

But If the answer is yes, then you have identified a significant hazard that is not being controlled. That means,your process or product must be redesigned to includea control measure.

Question 2. Does this step eliminate or reduce the likely occurrence of asignificant hazard to an acceptable level?

To answer this question, consider whether this is the **best** step control the hazard? If the answer is yes, then the step is a CCP. Move to the next food-safety hazard.

If the answer is no,Proceedto Question3.



Question3. Could contamination with an identified hazard or hazard so ccurin excess of acceptable levels,or could these increase to unacceptable levels?

The question refers whether contamination that already exists increases at this step. If the answer is no, then the step is not a CCP for that hazard. Move to the next hazard at that step or thenextstep with afood-safetyhazard.

If the answer is yes,then proceed to the fourth question.

Question4. Will a subsequent step eliminate the identified hazard or hazard or reduce the likely occurrence to an acceptable level?

If you answer no,then this step is a CCP.If you answer yes,then this step is not a CCP for this hazard.In this case,be sure the hazardi scontrolled by a subsequent processing step.

HACCP Plan Form

HACCP plan form is tool which helps to manage each CCPs.The plan form will address the last five principles of HACCP. A typical plan form is given in fig7.

Like in the worksheet, each plan form should bear the name and address of the production unit, name of the product, intended use of the product and target consumers and method of storage anddistribution.

The plan form will help you to1)set critical limits 2)establish monitoring procedures 3) determine corrective actions and4)design records (to positively document that the process is in control) for identified hazards in each CCP.

The plan form has ten columns. The Column1 in the HACCP Planform contains the CCP's,which are identified using HACCP worksheet.Column2 lists the hazards and critical limits are listed in column 3. Columns 4 to7 are meant for entering monitoring procedures, in which details of what to be monitored, how the monitoring is done, frequency of monitoring and the person sresponsible for monitoring are entered.Column8 details the corrective actions to be taken inc ase of any deviation.Column9 lists the various verification procedures required to validate our HACCP plan and column10 details the relevant records which are to b emaintained.

CriticalLimit

A maximum and/or minimum value to which a biological, chemical or physical parameter must be controlled at a CCP to prevent,eliminate or reduce to an acceptable level the occurrence of a food-safetyhazard.

A critical limit represents the boundaries that are used to ensure that an operation produces safe products. EachCCP must have oneormorecriticallimitsforeachfood-safety hazard. When the process deviates from the critical limit, a corrective action must be taken to ensurefoodsafety.

HACCP PLAN FORM

:

Name of the firm	:	
Address	:	

Product Description	:	
Method of Distribution and storage	:	
Intended use and Consumer	:	

HAZARD PLAN FORM									
1	2	3	4	5	6	7	8	9	10
Critical Control Point (CCP)	Significant Hazard	Critical Limits	Monitoring				Corrective Action (s)	Records	verification
			What	How	Frequency	Who			

HowtoestablishCriticalLimits:

Critical limit for the operation may not be available ready made.They have to be fixed by conducting tests and validating them with competent laboratories.These tests may be designed and conducted in association with reputed laboratories or by consulting scientific publications, regulatory guidelines,in house experiments etc.

Generalsource	Exampl
Scientific publications	Journal articles,foodsciencetexts, microbiology textsetc

Regulatory guidelines	National/International guidelines, BIS,EIA/MPEDA publications, tolerance and action levels, FDA or EU
Subject experts	CIFT,CIBA,CMFRI,thermal process authorities,
Experimental studies	Inhouse experiments, Accredited laboratories

A few examples of critical limits are given below

Hazard	CCP	Critical Limit
Microbial Pathogens	Cooking	85^0C for 3minutes for elimination of
Microbial Pathogens	Drying	a_w <0.7
Microbial Pathogens	Acidification	Batchschedule–pH<2,time28h

We should understand that a variety of options are available for managing and controlling a hazard. Only experience and practicality will help you to select the best control measure that has to be adopted.

Monitoring :

Monitoring is the process by which hazard control is effected by ensuring the operations is well under critical limit. It is a planned sequence of observations or measurements to assess whether a CCP is under control. Monitoring also helps to produce an accurate record of operation,which will be useful verification.

Monitoring procedures can either be qualitative or quantitative.Sensory observation for decomposition is an example of a qualitative observation, whereas a temperature reading from a thermometeris aquantitative observation. Monitoring can be performed either in a continuous or in a periodic (non-continuous)basis. It is always desirable to have a continuous monitoring procedure, however, if it is non continuous, procedures should be reliably indicate that the hazard is under control.The means by which the observation is done should be given in the HACCP plan.Monitoring should be done on a realtime basis, so that corrective actions can be taken in time,whenever deviations are observed.

Monitoring a CCP can be categorised into five viz.visual observation,sensory evaluation, physical measurement, chemical testing and microbiological examination. Visual monitoring needs no expensive equipment and may not even require highly specialized staff. Sensory evaluation can sometimes providea quick indication of loss of control. It can be used to check the quality of incoming raw materials.Bad odours can also provide a quick indication of loss of control. Physical measurements such a temperature, pH,water activity, humidity canbe made rapidly and are thus useful in monitoring processes where these factors are the means to control a particular CCP. Rapid chemical tests (eg. Chlorine level in water) are useful as means of monitoring CCPs. Microbiological testing and detailed chemical analysis areof limited use in monitoring CCPs. It can be employed for the testing of rawmaterials before starting processing, and fortesting critical finished products (eg.Ready to eat fish curry)before release. Monitoring also provide sarecord that products were produced incompliance with the HACCP plan.This information is useful inthe verification of the HACCPplan as discussed in Principle 7.

Components of MonitoringSystem

The monitoring procedure ensures that the required control measures are effective and hazards are kept below critical limits. This is done in the plan form by indentifying following parameters:

•What will be monitored(Direct/Indirect).(Column4)

•How the critical limits and control measures will be monitored.(Column5)

•How frequently monitoring will be performed.(Column6)

•Who will perform the monitoring.(Column7)

Whatwillbemonitored

It can be a measurement of a product characterestcora processing

Examples

•Measurement of boiler compartment temperature

•Measurement of the pH of pickle.

•Measurement of convey or belt speed

It can also a subjective measurement which involves observation of a control measure to manage a hazard..

Examples

•Checking that a supplier's certificate accompanies a lot of raw material.

• Auditing the farm premises to check whether the fish farmer is using the permitted antibiotic and whether he applies it as per guidelines.

How Critical Limits and Control Measures will be monitored?

Monitoring must be designed to provide rapid (real-time) results. There is no time for lengthy analytical testing because critical limit failures must be detected quickly and an appropriate correctiv eaction instituted before distribution.

Examples

- Time and temperature using a calibrated thermometer and to watch.
- Water Activity (a) using a calibrated RH meter.
- Acidity (pH) using a calibrated pHmeter.

•Visual observation for subjective evidences like supplier's guarentee, freshness using sensory evaluation etc.

Frequency of monitoring

As mentioned above, monitoring can be continuous or non-continuous.Where possible, continuous monitoring should be used. Continuous monitoring is possible for many types of physical and chemical parameters.

Examples of continuous monitoring include:

The time and temperature of a batch cooker process for IQF shrimps may be continuously monitored and recorded on a temperature-recording chart.

Checking for presence of metals in frozen shrimp blocks using a metal detector.

Examples of non-continuous monitoring include:

- Routine,dailychecksfortemperatureofstoredfishwaitingforprocessing.

Periodic sensory examination for decomposition in histamine forming seafood.

Who will do the Monitoring?

Assignment of there sponsibility for monitoring is an important consideration when developing a HACCP plan.

Individual sassigned to CCP monitoring can be:

•Line personnel,

•Equipment operators,

•Supervisors,

•Technologist

CorrectiveActions

Corrective actions are predetermined procedures to be adopted when criticallimits at a CCP is compromised. These procedures should restore process control and state clearly the method of disposing the product produced during the deviation.

An effective corrective action plans must:

Correct and eliminate the cause of the non compliance to assure that the CCP is brought back under control.

Segregate, assess and determine the disposition of the non compliant product.

All corrective actions taken must be documented. Documentation will assist the firm in identifying recurring problemss othat the HACCP plan can be modified. Additionally,corrective action records provide proof of product disposition.

An example of disposition procedure for an affected product is given below:

Isolating and holding product for safety evaluation. If the product was found to be safe, release the product

Diverting the affected product or ingredients to another line where deviation woul dnot be considered critical.

- Reprocessing.
- Destroying product.

It may be necessary to determine the cause of the deviation to prevent future recurrence. A critical limit failure that was not anticipated or reoccur sshould result in an adjustment to the product or processor are-evaluation of the HACCPplan.

Verification procedures

Verification are those activities, other than monitoring, that determine the validity of the HACCP plan and that verify the system is operating according to the plan. The purpose of the HACCP plan is to prevent food-safety hazards, and the purpose of verification is to provide a level of confidence that the plan is based on solid scientific principles, is adequate to control the hazards associated with the product and process,and is being followed.

Parts of Verification:

•Validation

•CCP verification activities

–Calibration of monitoring devices

– Calibration record review

– Targeted sampling and testing

– CCP record review

•HACCP system verification

–Observations and reviews

–Microbiological end-product testing

• Regulatory agencies

Validation: Th eelement of verification focused on collecting and evaluating scientific and technical information to determine if the HACCP plan, when properly implemented, will effectivelycontrol the hazards.Validation can be performed bytheHACCP team or byan individual qualified by training or experience.. Validation involves a scientific and technical review of the rationale behind eachpart oftheHACCP plan from hazard analysis through each CCP verification strategy.

Verificationof CCPs Verification activities developed for CCP sare essential to ensure that the control procedures used are properly functioning and that they are operating and calibrated within appropriate ranges for food-safety control. CCP verification may also include targeted sampling and testing.

- ***Calibration***

Verification activities at CCPs include calibration of monitoring devices to ensure the accuracy of the measurements taken with traceability. Calibration is conducted to verify that monitoring results are accurate.

Calibration of CCP monitoring equipment is fundamenta lto the successful implementation and operation of theHACCP plan. If the equipment isout of calibration,then monitoring results will be unreliable.Frequencyof calibration should also be influenced by equipment sensitivity.

- ***Calibration Record Review***

Reviewing the equipment calibration records involves checking the dates andmethods of calibration and the test results

- ***Targeted Sampling and Testing***

Verification may also include targeted sampling,testing and other periodic activities. Vendor compliance may be checked by targeted sampling when receipt of materialisa CCP and purchase specification are relied on critical limits.Typically,when a monitoring procedure is not as stringent as desired,it shouldbe coupledwith a strong verification strategy.

- ***CCP Record Review***

Atleast two types of record sare generated at each CCP:monitoring and corrective action. These records are valuable management tools,providing documentation that CCP sare operating within established safety parameters and that deviations are handled in a safe and appropriate manner. However, records alone are meaningless unless someone in a supervisory capacity reviews them on a periodic basis to “verify” that the HACCP plan is being followed.

HACCP System verification

In addition to the verification activities for CCPs, strategies should be developed for scheduled verification of the complete HACCP system. The frequency of the system-wide verification should be yearly (at a minimum) or whenever there is a system failure or a significant change in the product or process. The HACCP team is responsible for ensuring that this verification function is performed.Often, the HACCP team will contract an independent third party to conduct the system-wide verification

Activities

•***System Verification Activities***

Systematic verification activities include on-site observations and record reviews.Reviews are usually performed by an unbiased person who is not responsible for performing the monitoring activities.System verification should occur at a frequency that ensures the HACCP plan is being followed continuously. This frequency depend son a number of conditions,such as the variability of the process and product.

•***End-Product Microbiological Testing in HACCP Verification***

As explained in Chapter 2, microbiological testing is ineffective for routine monitoring but can be used as a verification tool. Microbiological testing can be used to determine (e.g., during verification audits or on periodic basis that the overall operation is under control.)

Record-Keeping Procedures

Accurate record keeping is an essential part of a successful HACCP program.Records provide documentation that the critical limits have been metor that appropriate corrective actions were taken when the limits were exceeded.Likewise,they provide a means ofmonitoring so that process adjustments can be made to prevent a loss of control.

Four kinds of categories are kept as part of the HACCP system.

1.HACCP plan and support documentation used in developing the plan
2.Records of CCP monitoring
3.Records of corrective action
4.Records of verification activities

Conclusion

HACCP was designed to prevent hazardous products from leaving the manufacturing or processing facility. The key tothe success of HACCP is employee training, behavior and attitude. Some companies are under them is conception that theyalready havea HACCP plan because they are adequately controlling all area where safety could be compromised.The difference is that, rather than monitoring isolated processing steps, an HACCP approach controls the entire production process as an integrated system.

Although HACCP provides insurance that poultry is safe, there is no way to completely eliminate all hazards.HACCP is most effective when usedwith other control systems. Total Quality Management programs and Standard Operating Procedures should be used along with HACCP to improveproduct safety,product quality, and plant productivity by providing intimate knowledge of the production process, production environment and processing equipment.

Chapter 33

Innovative extension approaches for technology dissemination in fisheries

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Trends in aquaculture and fisheries

Global fisheries have made rapid strides in recent years by establishing its strong hold over increasing food supply, generating job opportunities, raising nutritional level and earning foreign exchanges. These benefits become particularly important when placed in the context of current food production challenges, social change and growing climate change uncertainties. Fish and fishery products are the most traded food commodities in the world accounting for 9% of total agricultural exports and 1% of world merchandise trade, in value terms (FAO, 2014). About 38% of the global fish production enters international trade in various forms and shapes, generating an export earnings of US$148.1 billion with a record import at US$140.6 billion in 2014. The value of the global fish trade exceeds the value of international trade in all other animal proteins combined. Mostly the developing countries that account for over 60% of global fish catch, which is continued to expand at an average annual rate of 8.8% (FAO, 2009 & 2012), play a major role in the global trade of fish and fish products; about 50% of all fishery exports in value terms and more than 60% in quantity terms are supplied by them (World Bank 2011). At the same time, demand for fish products are likely to increase as a result of rising populations that are expected to reach 9.3 billion by 2050. Furthermore, developing countries now display a positive trade balance due to their increasing involvement in global fisheries trade. It is estimated that fish production generally contributes 0.5 – 2.5 % of GDP globally (Allison 2011). In spite of that globally an estimated more than 1.3 billion people are in extreme poverty (2016), 795 million people (2015-16) are estimated to be chronically hungry and an estimated one third of children in the developing world under five years of age are stunted (Conway 2012). Fish is considered as the most affordable and frequently consumed animal-source food in low income food deficit countries in sub-Saharan Africa, Latin America and Asia (World Bank, 2006) which contains intrinsic nutrients like high quality protein, a range of micro-nutrients, and fatty acids essential for human brain development (Tacon and Metian,2013) thus contributing to a great extent to food and nutrition security in many Asian and African countries where large numbers of people are still under starvation and under nourished (Kent,1987). Despite the important contributions by the sunrise sector, global debates on fisheries issues and policies appear to be dominated by concerns over environmental sustainability, overfishing and overcapacity. In this context, it is alarming to note that the sector did not receive adequate attention from the social scientists to understand its various socio-economic dynamics to prove the sunrise sector fisheries as a potential driver of local and national economic development.

Major concerns in fisheries

Food security has become the prime concern with the increasing trend of population growth in a country. Over the last fifty years, the food grain production in India has increased considerably, but the advantage of this increase in food grain production has not been reflected in the per capita availability of food grains. As per estimate, the human population and food grain production in India was grown up by 2.09% and 2.36%, respectively from 1961 to 2011, whereas the annual per capita availability of food grains was came down from 171.1 kg in 1961 to a level of 169 kg in 2011 showing a decreasing trend of 1.17 %. In case of fish, Asia accounts for almost two-thirds of global fish consumption i.e. 21.4 kg per capita in 2011 – a level similar to Europe (22.0 kg/cap/yr) and North America (21.7 kg/cap/yr), and close to the levels of Oceania (25.1 kg/cap/yr). Africa, Latin America and Near-East have lowest per-capita consumption (10.4, 9.9 and 9.3 kg/cap/yr in 2011, respectively). Although annual per capita apparent consumption of fish products has grown steadily in developing regions (from 5.2 kg in 1961 to 17.9 kg in 2011) and in LIFDCs (4.4 kg in 1961 to 8.6 kg in 2011), it is still considerably lower than in developed regions (from 17.1 kg in 1961 to 23.0 kg in 2011). It is clearly evident that rising population is nullifying the effect of growth in food grain production, keeping aside several other factors which determine the access to food grains. In this context, increasing fish production to meet the challenges of nutritional security has drawn the attention of the planners and policy makers. In this context, aquaculture is considered as a promising food production sector for high quality protein food and providing livelihood to the rural populace. Hence, it is essential to make it more efficient and cost-effective. However, there is multitude of challenges associated with the growth of this industry.

The fishery sector is a major foreign exchange earner for any developing countries. In India, its foreign exchange earnings were estimated to increase by 16 to 20 per cent by 2005 and 26 to 42 per cent by 2015. In view of higher production in fisheries, producers may lose from price fall in the domestic market; where prices were estimated to fall by 15 to 20 per cent by 2005 and 27 to 54 per cent by 2015. Nearly 85 per cent of the export benefits are projected from shrimp export alone. Because of its potential and rich source of animal protein, fish demand has been rising in both the developed and developing world at more than 2.5 percent per year (Peterson and Fronc, 2007) and demand levels were raised in proportion to increase in income in highly populated countries like China and India, (Garcia and Rosenberg, 2010). In spite of the phenomenal success of the sector, still there are concerns for the economic and nutritional conditions of fisher folk in addition to some important concerns in the context of rising environmental hazards, depressing prices world over, emerging new economic order following establishment of WTO, IPR & SPS issues, compliance of several multilateral agreements, etc.

In the post- harvest front, the processing industries used to face the problems of complicated exporting procedures, high shipping costs, cut-throat competition in the industry, changing quality standards of importing countries, irregularity in supply of raw materials, hygiene problems and non-availability of quick transportation facilities from the fishing port to the processing units, etc. As a result of which trade-driven commercial fish farming is suffered that reduce the livelihood opportunities of small scale dry fish processors, petty traders within the communities and poor fishermen.

Environmental degradation poses a challenge to the phenomenal success of the fishery sector in promoting food security and adversely creates impact on nutritional rights and livelihood of the fishermen communities for whom fish and fishery products are critical to health and wellbeing. As per directives of international conventions like Kyoto Declaration and Code of Conduct of Responsible Fisheries, this trade-driven, resource depletion sector can be sustained through by-catch reduction and ban on juvenile fishing. The benefit of this may be accrued through policy level intervention by institutions within the legal framework.

Small-scale fisheries are normally characterized by low capital input activities, low capital investments and lack of equipment, labour-intensive operations followed by traditional fishers. They also usually operate as semi-subsistence, family-based enterprises, where a share of the production is kept for self-consumption (Garcia *et al.*, 2008). Traditional fishers dominate the marine sector and they are socially deprived, educationally weak with very high occupational rigidity. There is inequity in the distribution of yield and effort in marine fishing. They are unorganized with least social security benefits. The informal social security system in the form of sharing of earnings for the community and social organizations prevailing in the traditional fishing is absent in the mechanized fishing. There are also huge regional variations in productivity.

Technologies are the main drivers of growth. Hence, systematic technological interventions backed by adequate policy and institutional support are vital for making the aquaculture operations sustainable and economical. Generally, the technologies and trade interventions reinforce each other which can be characterized as skill-based, cost effective, capital intensive which can bring a change in the performance of the sector. Following strategies have been suggested for an accelerated fishery development with focus on poverty alleviation of poor fishers:

- Commodity-centered approach
- System approach
- Prioritize technology on the basis of needs and problems at micro and macro levels
- Innovate and strengthen institutions and policies
- Upgrade the skills of the fishers
- Enhance investment and reorient policies to facilitate percolation of benefits to all sections of the society.
- Follow ecological principles
- Emphasize on domestic market demand and consumers' preferences
- Monitoring the technology demonstrations programs and assess the impacts.
- Strengthen database and share it for a better planning and policy making in the sector.

Extension systems for sustainable development

Unlike India, the economy of developing and underdeveloped countries in sub Saharan Africa, Latin America, Asia inclusive of 22 Low Income Food Deficit Countries (LIFDCs) is predominantly agrarian economy where agriculture sector provides employment and livelihood to majority of the rural households, but the condition of both farmers and farming is in alarming state.

Agriculture stands on the very complex interaction between biological, climatic and geographical factors in addition to human activities. The information under such a complicated system is unpredictable, unstable, subjective, site specific and reliant on empirical decision given the inherent variability of biological phenomena. In spite of nation's priorities and developmental strategies for reducing poverty, hunger and ensuring quality of life to its people, we are still lagging behind in human development index as expected. People particularly small, marginal and landless farm households are still far from the reach of good education, nutrient nourished diet, better health care facilities and modern age amenities.

Hence, there is an urgent need to reform agriculture in holistic, scientific and systems approach to meet the present day challenges in agriculture due to climate change and global competitiveness so as to achieve sustainable agriculture production and growth under different agro-climatic conditions.

In agricultural parlance, sustainability means maintaining the crop productivity without enhancing input levels. Sustainable agriculture is a form of agriculture aimed at meeting the needs of the present generation without endangering the resource base of the future generations. According to the concept laid by the Technical Advisory Committee (TAC) of the Consultative Group on International Agricultural Research (CGIAR) "*Sustainable agriculture is the successful management of resources for agriculture to satisfy the changing human needs, while maintaining or enhancing the quality of environment, and conserving natural resources*". Sustainable agricultural systems must be resource-conserving, socially supportive, commercially competitive, and environmentally sound. Hence, the agriculture research system must place emphasis on generation of required technology along with strong linkage between research-extension system and vice versa. It involves design and management procedures that work with natural processes to conserve all resources, promote agro-ecosystem resilience and self-regulation, minimize waste and environmental damage, while maintaining or improving farm productivity and profitability (MacRae et al., 1990).

The role of extension in agricultural system cannot be ignored. Strong extension system is the key to the desired change to meet the present day challenges in agriculture. Basically the end product of the extension system is to work with farmers within a climate and economic environment by providing suitable technologies to widen their horizon, enriching knowledge and upgrade skills to improve better handling of natural farm resources and applying scientific production technologies to achieve desired production level. Extension system plays a pivotal role in empowering farmers and other partners to make it more farmers' participatory, demand-driven, knowledge oriented and skill supportive for disseminating most appropriate technical, management and marketing skill to improve profitability in agriculture that can overcome the emerging challenges and concern thus developing a synergistic pathway for enhancing productivity along with quality produce in order to sustain production base and ecological and livelihood security. The extension system needs to disseminate a broad array of information starting from seed to seed, field to fork in an integrated manner for safe delivery from field to the consumer concerning all the aspects of conservation and production technologies, post-harvest management, processing and value addition. Such knowledge based decision should be incorporated in reshaping of extension approaches. In present scenario, the extension system envisages a transformation from technology driven to market driven extension where farmers would give emphasis on commercialization of high value products, maintenance of quality control, fulfilling market demands, cost effectiveness etc. thus economic indicators become theme to the program planning process for the effectiveness of any programme.

With the advent of global competitiveness and market liberalization, our prevailing extension system has to be strengthened with innovative extension approaches to tackle the recent challenges in agriculture *viz.*, climate change and weather aberrations, dwindling resources and population stress, so that farmers can adjust their production portfolio keeping eye upon the emerging trends in food consumerism in domestic as well as global markets. Grooming farmers with information support for taking right decision to improve their production in agriculture and allied fields essentially requires a strong network of extension systems, along with government initiatives and strong linkage among extension scientists and functionaries working for agricultural development. This would ensure the livelihood security of millions of farmers by improving the quality production and creating of better job opportunities in rural areas, which intends to bring out planned changes to meet the needs of the present generation without compromising the future generation's requirements.

Innovative extension approaches for technology dissemination

Earlier in developing countries, the extension personnel were involved in diffusion of farm technologies generated by public research organizations, mostly disseminated through appropriate mechanism, viz., On Farm Trials (OFT), front line demonstrations (FLD), field visits, farmers' meetings, media use, etc. This process had the conceptual backup from the 'diffusion of innovation' model. But in the last two decades, the paradigm shifts in development pivots to the enhanced concern for future generations to meet their basic needs, accordingly the nature of agricultural technology design and integration is drawing attention of the extension professionals and practitioners across the globe. In India, different models for transfer of farm technology have been tested and also robust extension education approaches have been validated. Furthermore, the frontline extension system of the country has been sharpened through more farmer-centric approaches for technology adaptation and dissemination. The extension system in India has been designed to move beyond technology and beyond commodity through ensured reciprocal farmer-research-extension linkages. Farm producers located at far-off and those unreached still suffer from lack of access to appropriate services like credit, inputs, market, extension, technologies etc. Keeping eye upon this, the World Development Report had focused on need to restructure and revamp agricultural extension system as a pivot for realizing the growth potential of farm sector against the widening demand–supply pressures for ensuring sustainable, inclusive, and pro-poor agricultural and economic development. Therefore, farmer's participatory technology development and client's participatory extension approaches emerged as a part of integration of the '*interdependence model*' and the '*innovation systems framework*' that offered more inclusive ways of involving the institution in technology generation, diffusion and use of new knowledge. Extension approaches have to be redefined depending upon the components involved for sustainable growth and livelihood security of the farmers for which a conceptual framework has to be developed in response to recognizing and considering different livelihood assets viz., *human, social, physical, natural and financial resources*. Some of the following innovative extension approaches originating from multiple sources must be adopted on trial basis to make agriculture more profitable to provide food, nutrition and livelihood security to farmers, which can be replicated in the fishery sector interwoven with numerous issues including increased production with sustained natural resources, growing market demand for processed products having entrepreneurial opportunities, protection and conservation of environment, and even international trade.

a. Asset Based Community Development (ABCD) approach

As per the traditional approach to development, poor people see themselves as people with special needs that can only be met by outside supporting agencies. But Asset Based Community Development (ABCD) approach intends for the development of community based on the principle of identifying and mobilizing individual and community 'assets', rather than focusing on problems and needs. It is an extension approach in which a community's micro-assets are linked with its macro environment. It believes that communities can initiate and sustain the process of growth and development themselves by recognizing and harnessing the existing, but often unrecognized assets, and thereby promoting local economic potential to drive its development process (Rans & Green, 2005). The approach is optimistic in nature, because the focus is on what is possessed by the community, rather than the problems of the community.

The focal point in this approach is asset and not the need of the community. Assets of individuals, associations and institutions are identified after an extensive survey and assets are then matched with the need of the people to empower communities to control their futures and create tangible resources such as services, funds and infrastructures etc.(Foot and Hopkins, 2010).In agriculture, ABCD approach gives greater emphasis on reducing the use of external inputs and on a high degree of social mobilization in which the assets of the poor (social, physical, financial as well as human) can be utilized to bring sustainable livelihoods through variety of different agricultural and non-agricultural activities.

Five Key Assets in ABCD

As per ABCD approach there are 5 categories of asset inventories such as individuals, associations, institutions, physical assets and connections

1. **Individuals**: Every individual has got certain assets, gifts and qualities; such individual is at the center of ABCD approach.
2. **Associations**: Groups of people working with a common interest are critical to community mobilization.
3. **Institutions**: The assets of institutions help the community capture valuable resources and establish a sense of civic responsibility.
4. **Physical Assets**: Physical assets such as land, buildings, space, and funds are other assets that can be used.
5. **Connections:** These are the exchange between people sharing their assets by various methods.

b. Rural advisory services (RAS)

Rural Advisory Services (RAS) refer to all the different activities that provide the information and services needed and demanded by farmers and other actors in rural settings, to assist them in providing their livelihoods by developing their technical, organizational and management skills and practices (GFRAS, 2011; FAO, 2010). RAS designers and implementers must recognize the diversity of actors in extension and advisory fields (public, private, civil society); the need for extending support to farmers' producer organizations (FPO) and rural communities (beyond technology and information sharing) including advice related to farm, organizational and business management; and explaining the role of facilitation and brokerage in rural development and value chains. In the case of aquaculture, large-, medium- and small-scale farmers need different types of RAS support. The large farms are mostly self-reliant and need only regulatory support, while medium-sized farms need mobilization and facilitation support in addition to regulatory support. Small aquaculture farms need more education and input provision alongside facilitation (Kumaran, 2014).

In fishery sector, RAS helps in

- ⇨ Providing management and business development support appropriate to the scale, resources and capacities of each fisherman.
- ⇨ Better understanding markets (prices, seasonality, standards, value addition etc.) related to fish and fish products.
- ⇨ Linking fishers to other stakeholders involved in provision of varied support and services.
- ⇨ Creating platforms to facilitate interaction and sharing among the various stakeholders including FPOs to ensure coordinated support to fishers.
- ⇨ Exploiting information communication technologies (ICTs) to provide fishers with a range of information related to weather, prices, extension programmes and generic information regarding fisheries.
- ⇨ Facilitating the formation of FPOs and also collaborate with FPOs to strengthen the demand and supply side of RAS.
- ⇨ Promoting institutional and policy change to enable and support small-scale fishery.

RAS encourages the formation/ organisation of groups by involving individual family farmers, who have little influence over the social, economic and political processes affecting them, but as a group/ organizations and networks they can deal with their specific challenges and make their voice heard. Such groupings can act as platforms to articulate concerns, exchange knowledge, influence policies and engage in collective action so that their agriculture remains sustainable and profitable. Effective formation of Rural Resource Centres (RRCs), Fishermen Cooperative Society, Farmers producers Organisations(FPOs) can be instrumental by galvanizing collective action in order to ensure better access to markets and to support innovation by their members in related activities (Sundaram, 2014).

c. Model Village System of Extension (MVSE) approach

MVSE is an integrated and holistic extension approach where *community participation* was prioritized for suitable technological interventions in the farmers' field to bring all round development in agriculture and allied sectors in the community in terms of *socio-economic upliftment, technological empowerment, self-governance* thereby enhancing the futuristic knowledge base and skills through *participatory framework.* MVSE emphasized oninvolvement of all stakeholders in the process to converge their activities with a stake in the food value chain *linking producer to consumer.* Nevertheless, MVSE is an action research taken up in farmers' field based on the principle of leveraging the activities, investments and resources from outside agencies/ externally aided projects resulting higher productivity, ensuring food security and sustainable improvement in overall quality of life by promoting leadership, self-dependency of the community in food chain. Economically viable, ecologically compatible and socially acceptable suitable technologies were successfully intervened in farmers' field in a cluster adopted as model village through participatory mode by integrating the multi-disciplinary research which was later replicated to other villages. The village was developed as a commodity village branding for a particular commodity in the market.

MVSE approach works on the following principles:

- Promotes self-governance among the farmers
- Skill improvement and leadership development among the community members.
- Establishing linkage through pluralistic convergence of different stakeholders associated in the sector.
- Encouraging the market opportunities through commodity based village development.

d. Farmers Field School (FFS) approach

This extension approach is an alternative to the top down extension approach which was evolved as a method to solve complex field level issues in agriculture and allied sectors. The FFS approach is an innovative, participatory and interactive learning approach that emphasizes problem solving and discovery based learning. FFS also provides an opportunity for farmers to practice and evaluate sustainable land use technologies, and introduce new technologies by comparing with their conventional technologies developed in congruent with their own tradition, culture and resource use pattern. FFS aims to build farmers' capacity to analyze their production systems, identify problems, test possible solutions, and eventually encourage the participants to adopt the practices most suitable to their farming systems (FAO, 2003 c). This is a learning-by-doing approach which emphasizes group observation, discussion, dissection, modification, and promotes field-based experimentation, analysis for collective decision making followed by actions. The goal of the approach is such that, after observing and comparing the results of field level experimentation farmers will eventually "own" and adopt improved practices by themselves without any external compulsion. Field day is being organized at the end of the season to give visibility to the entire activities to convince the non-adopters. Exchange visits with other FFS is also encouraged to learn by association and comparison A group of 20-25 farmers can form a farm school under the guidance of a FFS facilitator. Extension workers, NGO workers, farmer organization staff or previously trained farmers can become Farmer Field School facilitators. The facilitators are trained by master trainers, who has expertise in the particular subject matter. FFS is a time bound activity usually covering one production cycle or a year.

The basic component of FFS is setting up of a Participatory Comparative Experiment (PCE), commonly referred to as Participatory Technology Development (PTD), whereby the farmers put the FFS concept into practice under close monitoring and supervision by the FFS members. A PCE can be developed in the field of agriculture, livestock, fishery, forestry, agro-forestry, livelihood system and others. Principles of Farmer Field School (FFS) are as follows: -

- Field is the learning place.
- Emphasizes hands on and discovery based learning.
- Farmers become experts.
- Integrated and learner defined curriculum.
- Doing is better than learning/ seeing.
- Experiences are the start of all learning.
- Link to actual field situations and should be relevant to local needs and problems.
- Participatory monitoring and evaluation.
- Farmers are decision makers.

e. Market led extension approach

In order to make agriculture more enterprising, extension professionals need to be pro-active beyond the regular objective of maximizing the productivity of the farmers/producers by transferring improved technologies rather farmers should be sensitized on various aspects of produce like quality, consumer's preference, market intelligence, processing and value addition and other marketing information. This will help the farming community to realize high returns for the produce, minimize the production costs, and improve the product value and marketability that may lead to realize the concept of doubling farmers' income. With the globalization of agriculture, emphasis on productivity and profitability to the farm enterprises increased and, therefore the demand driven agriculture (and allied sectors) has led to the paradigm shift from production-led extension to market led extension. There are many challenges in the agricultural marketing system which can be resolved through the efforts of market led extension models.

In this approach farmer/producer is viewed as an 'Agripreneur' who expects high returns 'Rupee to Rupee' from his produce by adopting a diverse baskets of package of practices suitable to local situations/ farming systems with optimum cost benefit ratio (C: B ratio) ensuring maximum share of profit by exploring the market demand. Goal of market led extension is to facilitate farmers to get. Market led extension focuses on harnessing the ICT tools to access market intelligence including likely price trends, demand position, current prices, market practices, communication network, etc. besides production technologies.

For farmers, as the extension system is more credible source of farm technologies, the extension personnel ought to be knowledge- and skill-oriented in relation to production and marketing of agricultural goods. Thus, revamping the extension system will have a catalytic role for ushering in farmer-led and market-led extension; which can subsequently alleviate poverty and ensure livelihood security. In the light of this, the challenge remains to motivate the extension personnel to learn the new knowledge and skills of marketing before assigning them marketing extension jobs to establish their credibility and facilitate significant profits for the farming community. SWOT analysis of the market, Organization of Farmers' Interest Groups (FIGs), capacity development, establishing linkage and synergy, harnessing ICTs, digital marketing etc are the competencies required by the extension personnel in order to effectively implement market led extension.

f. Digital extension approach

Extension reforms brought a transformation in agricultural extension system through introduction of Information and Communication Technologies (ICTs). The ICT-enabled extension systemreferred to as Digital Extension has the potential for enabling the empowerment of farming communitiesby improving their access to information and sharing knowledgewith innovative e-agriculture initiatives (Saravanan, 2010a).

With the phenomenal growth in information and communication technology, use of IT application in agriculture will bring remarkable change in the attitude and knowledge level of user. Basic requirement is to provide most appropriate information in such a capsule that can be easily understood and used by them. This approach will strengthen the extension system for better dissemination of technology. As a case study the contribution of Digital Green, a NGO that uses an innovative digital platform for community engagement to improve lives of rural communities across South Asia and Sub-Saharan Africa is remarkable. Digital Green associate with local public, private and civil society organizations to share knowledge on improved agricultural practices, livelihoods, health, and nutrition, using locally produced videos and human mediated dissemination. As per the study, the Digital Green project (participatory digital video for agricultural extension) increased the adoption of certain agriculture practices seven times higher compared to traditional extension services and the approach was found to be 10 times more cost-effective per dollar spent. Hence, along with ICT-based advisory services, input supply and technology testing need to be integrated for greater impact and content aggregation from different sources require to be sorted in granular format and customized in local language for rapid adoption of technologies (Balaji et al., 2007&Glendenning and Ficarelli, 2011).

The effectiveness of this innovative extension approach depends on capacity building, people's participation along with government initiative to provide strong infrastructure to be worked with the cutting edge technologies. The farmer friendly technology dissemination process needs to be handled with careful planning by the incorporation of information communication technology. The use of ICT application can enhance opportunities to touch the remote farmers to live in close proximity of the scientific input. The computer based web portals namely aAQUA, KISSAN Kerala, TNAU AGRITECH Portal, AGRISNET, DACNET, e-Krishi, ASHA, India Development Gateway (InDG) portal, Rice Knowledge Management Portal (RKMP), Agropedia, KIRAN, AGMARKNET, ITC-e-Choupal, Indiancommodities.com, Mahindra Kisan Mitra, IFFCO Agri-Portal, Agrowatch Portal, iKissan, etc. along with some mobile based Apps like mKRISHI® Fisheries, riceXpert, Pusa Krishi, Krishikosh, m4agriNEI etc. launched in India are some of the successful digital intervention for technology dissemination.

The use of internet, mobile and video- conferencing assists the IT enabled farmers to utilize the facilities for their favors for which the most suitable permanent infrastructure is the basic requirement. Strong linkages need to be established between direct ICT interventions and it should be part of the national level program on agricultural development.

g. Disruptive Extension approach:

Recently, a new extension approach christened as 'disruptive extension' comes into limelight which is considered as an innovative extension approach that creates a new paradigm of extension that eventually disrupts an existing approach followed by extension professionals in the field of agriculture and allied sectors.It is an entrepreneurial oriented sustainable extension system that can able to transform every link in the food chain, from seed to fork. It is a cost-recovery extension approach the fulcrum of which lies between resource exploitation on one side and resource conservation on another side that influence the livelihood security and technology sustainability for small scale farm holders. It deals with the following principles:

- Importance of good governance in agriculture (and allied fields) that considers the resource rights of the farmers.
- Emphasis on growing interest among the stakeholders by explicit analysis of field level issues for technology adoption.
- Potential to resolve the social conflicts for equal access to community resources through Memorandum of Understanding (MOU).
- Based on cost recovery mechanism.
- Ensure commitment to optimum resource management and maximum economic benefit to improve food security.
- Provision of community based social insurance.
- Maintaining the sustenance of the technology supports through custom hiring approach.
- Focus on pluralistic convergence of different partners to build a network of linkage with various entities around the farm households.

- Encouraging the farmers-scientist interaction for technology development, assessment and application through Farmers' FIRST approach.

Global agriculture embraces diverse actors in its endeavour to feed about 10 billion people in the planet by the end of 2050. The small, marginal & landless farmers are extremely vital for food security due to shrinking of resource day by day. The contribution of women farmers also cannot be ignored particularly in on-farm operations, harvesting, post-harvest management, processing etc., especially in fishery and animal husbandry sector. Hence, in today's scenario innovation in agriculture extension is the key to address the growing challenges, which need to be validated, integrated and scaled up and further recommended for large scale implementation by the policy makers. The innovative extension approach should be on capacity building, people's participation along with government initiative to provide strong infrastructure to be worked with the modern age technologies. Much effort has been initiated in going beyond the farm and the farmer, and focus on beyond a technology to the wider innovation system.

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Chapter 34

Fish stock assessment and management for sustainable fisheries

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INTRODUCTION

The ultimate goal of stock assessment is to devise management systems to mitigate fishery resource depletion. Recent examples of such management regulations in Indian fisheries are implementation of minimum legal size for fish catch, regulations brought out to control length and size of fishing fleet etc. With multi-dimensional expansion of fishing activities in India, it is necessary to analyse stock data critically bringing out suitable recommendations for fishery management.

Fish stock assessment is an evaluation of the state of the stock as relating to changes in the abundance or composition of the stock to changes in the amount of fishing. It involves the use of theories, laws, models and methods propagated by various scientists. There are two general approaches - population model (Schaefer, 1954, 1957) in which the stock is treated as a single entity subject to simple laws of population growth and the analytic approach (Ricker, 1958, 1975) which considers the abundance of the population as determined by the net effect of the growth, reproduction and mortality of individual members of the stock.

Stock assessment gives us the maximum sustainable yield (MSY), fish mortality, the input and output into the fisheries. The various environmental changes as they affect biological and physical features of a fish species, family or the group need to be assessed by using a model for its stock assessment and the basic data is got from research and commercial surveys.

Research survey is a detailed investigation of the fish based on the objectives. It involves taking the data on biological parameters of the fish (length, weight, sex etc), the food of the fish including the percentage composition. Other factors include the environmental features such as time, weather, position of catch, physico-chemical parameters of the water body. Commercial survey involves taking note of basic and important information of commercial usefulness *e.g* length-weight frequencies, percentage composition etc which are strictly for economic purpose.

STOCK STRUCTURE – POPULATION MODEL

The total population can be divided among one to many biological entities, and the numbers-at-age of each entity are tracked over time. Some of these can have unique biology (gender, growth and natural mortality) and some can have a unique season of birth within a year. The total of all entities born within a year is referred to as a year-class or cohort. Each of the biologically or birth season delineated entities will be referred to as a morph. Each morph can be divided into males and females with gender-specific growth and natural mortality rates. In addition, each morph can be sub-divided into slow-, medium- and fast-growing entities termed platoons (Goodyear, 1997).

The population in the initial year can be simply an unfished equilibrium population, a population in equilibrium with an estimated mortality rate that is influenced by data on historical equilibrium catch, or a population that has estimable age-specific deviations from an equilibrium for a user-specified number of the younger ages. Fish of each gender grow according to their current size and current year's growth rate K and asymptotic lengthL_∞. Selectivity is used to define the relationship between the age-length matrix of fish in the population for year y, and the expected numbers at age-length that would occur in a sample from the population using a particular fishery or survey. For fisheries, selectivity also describes how fishing mortality is distributed across ages.

FISH STOCK ASSESSMENT MODELS

There are two main groups of fish stock assessment models:

- holistic, or biomass dynamic models, building on the overall stock as the basic unit where individually based processes such as growth and reproduction are inherently encapsulated in the stock model. The starting point of these models are population abundance indices generated from catch and effort data.
- Analytical models building on individual fish as the basic unit and where dynamic processes such as age, growth, mortality, and maturity are each represented by a sub-model. These models are age- or length structured and deal with a partial or the entire demographic structure of the population. (Baranov, 1918, Thompson and Bell, 1934 and Beverton and Holt, 1957).

Catch per Unit Effor (CPUE) The basic assumption in fisheries theory is that catch (C) and stock abundance, or standing biomass (B) are related by

$$C = q.f.B$$

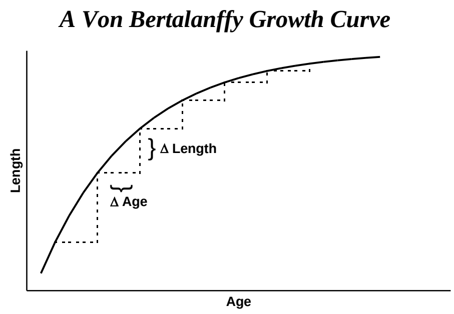
where f is a measurement of the nominal fishing effort or intensity, and q is the catchability coefficient. This equation can be rewritten in terms of catch per unit effort (CPUE) - which serves as the abundance index –

$\frac{C}{f} = CPUE = q.B$.

Growth at length : Measured using length of fish given as L_t (at time t). Population dynamics involves length frequency analysis which are based on the observation that the length composition of a population often exhibits modes (peaks) among the younger age groups. It is furthermore assumed that the growth in length is a random variable (i.e. each individual has its own set of growth parameters; L_∞ - the maximum length of the infinitely old fish called the asymptotic length, K - the growth or curvature parameter and t_0 - theoretical age at L=0 or the initial time if the von Bertalanffy's growth function is adopted), but with the same probability function, i.e. a normal distribution.

The Von Bertlanffy growth function or VBGF is given by

$$L_t = L_\infty(1 - e^{-k(t-t_0)})$$



The VBGF parameters can be derived from length frequency analysis.

The basic unit in frequency analysis are the cohorts, i.e. a batch of specimens of approximately the same age that have entered the stock and which by size/age can be discriminated from the rest of the stock.

There are several methods for finding the number of cohorts, their relative contribution, and the mean length of each cohort at different times in one or several composite length frequency distributions:

Visual methods

- The `Petersen` method.
- Modal progression analysis

Petersen method (1892) : It assumes that length at age varies around a single mean value and the fish of the same length have approximately the same age. Then, by simply counting the number of discernible modes and relating these to the respective lengths and frequencies, a rough estimate of the numbers and mean length of each cohort is obtained. Care must be taken that the modes in fact belong to successive age groups and not to dominating cohorts separated by more scarce broods.

Modal Progression Analysis (MPA) : This is based on a series of samples from the same population taken at known time intervals. The method is particularly applicable for short-lived species or for species which show considerable variation in cohort abundance (the method is especially useful with shrimps). When arranging the samples on the same length scale one over the other in successive order and with their relative distances proportional to the time span in sampling sessions, it may be possible to follow the progress of one or several dominant cohorts over length. By measuring or calculating the means, a direct impression of the growth is obtained.

Graphical methods

- Bhattacharya method
- Cassie method
- Tanaka method (parabola method)

Bhattacharya method. This method assume normal distributions of the components in a composite length frequency distribution and transformation of the normal distributions into straight lines. The N, mean and standard deviations are calculation by regression analysis.

This regression is the main element of the Bhattacharya method. When the frequencies in the length intervals (dl) are assumed to be normally distributed, they are regarded as the function values. Then, by the use of the logarithms of the frequencies, computing the difference of two adjacent pairs by subtraction (i.e. (ln(dl+1) –ln(dl)), and by plottings of the difference against the upper limit of dl, a scatter diagram that can be linearised by regression is obtained. The intercept and slope of the regression line will then be an estimate of the corresponding values of the true normal distribution, approximating the frequency distribution. In a composite length frequency distribution with several more or less overlapping normally distributed components, the procedure is to identify and calculate the relative contribution of each component step by step. In other words, one component at a time must be isolated:

1. Find the mean and variance of the first component by the above method
2. Use these figures to calculate the theoretical number of elements in each interval of the first component (this is only necessary in the overlapping length intervals of the first and second component)
3. Subtract these values from the elements in the sample, so the sample now is composed of all parts minus the first component
4. Repeat the whole procedure with the second component (which in fact now has become the 'first')
5. Repeat as long as proper identification of components is possible

The points used for regression are selected on two criteria:

1. Visual inspection of the scatter diagram, identifying those points in the beginning approximating a straight line. This line corresponds to the first normally distributed component, which is interpreted as the N1 cohort.
2. Also an inspection of the slope, the intercept with length axis, and the first and last point used in regression will give an indication of the mean and range of the elements belonging to the examined component, which can be compared to conform with the configuration of the frequency distribution.

Computerised versions

- MAXIMUM-LIKELIHOOD-METHOD- NORMSEP (Tomlinson,1971 , MacDonald and Pitcher, 1979)
- MIX (FORTRAN)
- ELEFAN (Electronic LEngth Frequency Analysis) (Pauly and David,1981)
- LFSA (Length Frequency Stock Assessment) (Sparre ,1987)
- FiSAT (FAO/ICLARM Stock Assessment Tools) (Gayanilo and Pauly 1997) is a package combining ELEFAN and LFSA together with additional features and a more user-friendly interface.

Isometric relation between length and weight of fish :Growth is a process of increase in size or progressive development of an organism. Typically, growth can be defined as the change in size (length, weight) over time. Increment in size is due to conversion of food matter into building mass of the body by the process of nutrition. The length weight relationship is one of the standard methods that yield authentic biological information with two objectives, firstly it establishes the mathematical relationship between the two variables, length and weight, so that to know the variations from the expected weight for the known length groups and secondly this in turn reflects its fitness, general well being, gonad development and suitability of environment of the fish (Le Cren. 1951).

The weight of fish can be denoted in terms of length using the following function (Huxley, 1924):

$W = aL^b$ where 'a' and 'b' are constants.

Mortality : The population contains unique dynamic features such as birth rates, death rates, age structure, phenotypic plasticity, and gene pool. These attributes, which are shaped by the environment (evolution under natural selection) can be collectively summarised under the term life-history traits (Stearns 1976), and their configuration determines the resistance of the population to external disturbance and stress. The survival, mortality rate, fecundity and expectation of life span duration linked to the general environmental conditions. The full set of this information will provide not only a complete description of the population ecology but will, in theory, also enable one to deduce the controlling factors that determine its population dynamics. The key parameters used when describing death are called the mortality rates. The chance of dying as a function of time, i.e. the mortality rate, is, closely correlated to the predictability of the environment, i.e. the frequency of random fluctuations that somehow endangers the survival of the population.

Z is called the instantaneous rate of total mortality, the total mortality coefficient, or simply the total mortality rate. Total mortality Z is F+M which is the sum of natural mortality and fishing mortality. All mortality rates are in units per time, normally per year.

Let N_t denote the number of survivors of a particular cohort during time t. Z is given by the relation $N_t = N_0 e^{-Zt}$ where N_0 is the number alive at t=0. This is the traditional model for describing mortality in a fish stock (fishing or natural causes), the so-called exponential decay model.

Estimation of Z from catch and effort data It is possible to estimate the total average mortality rate when the number of fish in a cohort is available for two different moments in its exploited phase under the assumption that fishing and natural mortality are constant in time for certain (older) age groups.

$$Z_{(t_1,t_2)} = \frac{1}{t_2 - t_1} \ln\left(\frac{N_{t_1}}{N_{t_2}}\right)$$

For the estimation of Z with this formula, it is not necessary to know the absolute values of $N(t_1)$ and $N(t_2)$; only their ratio is required. This permits an estimate, Z, from the CPUE data, since CPUE = q. N_t.

Beverton and Holt's Z-equation based on length data This model, developed by Beverton and Holt (1956), assumes that growth follows the VBGF, that mortality can be represented by negative exponential decay, and that L is estimated from a sample representing a steady-state population.

$Z = K\left(\frac{L_\infty - \bar{L}}{L - L'}\right)$, where $\bar{L}$ is the mean length of fish of length L' and longer, and L' is "some length for which all fish for that length and longer are under full exploitation".

The natural mortality coefficient, or instantaneous rate of natural mortality (M), is an important, parameter in most mathematical models of fish population dynamics. Normally, all other causes besides fishing are incorporated into this one parameter and is then often assumed to be a constant.

There are three different approaches to estimate M in fish populations (Vetter 1988)

1. Analysis of catch data from commercial fisheries, sampling programmes, or mark and recapture experiments.

2. Correlation with other life history parameters.

3. Estimation of predation from stomach content analysis and consumption experiments.

Pauly's M formula Pauly (1980) made a multiple regression analysis of natural mortality (year) in 175 species on corresponding values of the VBGF parameters K (per year) and L (TL in cm) and the annual average habitat temperature T (1C of the water in which tha stock considered lives), giving the following empirical relationship

$M = 0.8 * e^{-0.0152\ 0.279.\ln(L_{\infty}) + 0.6543(\ln(\mathrm{K}) + 0.463\ln(\mathrm{T}))}$ where 0.8 is an adjustment factor used for 'schooling species'.

VIRTUAL POPULATION ANALYSIS (VPA)

VPA is an analysis of the catches of commercial fisheries combined with the detailed information on contribution of each cohort to the catch which is obtained through sample programmes and age reading. The idea behind the method is to analyse the catch in order to calculate the population that must have been in the water to produce this catch.

The total landings from a cohort in its lifetime is the first estimate of the numbers of recruits from that cohort. It is however an underestimate as some fish must have died from natural causes. Given an estimate of M, we can do a backwards calculation and find out how many fish belonging to a cohort were alive year by year and ultimately how many recruits there were. At the same time we learn about the fishing mortality coefficient F because we have calculated the numbers alive and know from the beginning how many of them were caught in any particular year.

VPA methods require age-structured data:

- Total catch in number by age and by cohort (usually one per year)

- Estimates of natural mortality (M) by age

In addition, many of the VPA-types of models are incorporating additional information, such as:

- Abundance estimates in absolute terms, each estimate representing one or several age groups (e.g. from acoustic survey abundance estimates)
- Abundance indices, each index representing one or several age groups (e.g. from bottom trawl CPUE from research surveys)
- Effort indices (e.g. effort data from fisheries statistics)
- Mean weight by age and by year corresponding to the catch

While some or all of these elements may not be available, the total catch broken down by demographic structures (age or alternatively lengths) and estimates of natural mortality rates must be present for the VPA methods to be used. Output from VPA methods are:

- Estimates of the (virtual) total population size, stock in numbers (N), by age and by cohort
- Population size at time of capture (tc) used as index of recruitment
- Estimates of the fishing mortality by age (so-called F-array, or fishing pattern)
- Estimates of the catchability coefficient (q) when effort data available
- Estimates of the Spawning Stock Biomass (SSB) when mean weight by age and maturity ogive by age and year are available

Jones' Length Based Cohort Analysis (LBCA)

Jones' Length Based Cohort Analysis (Jones and van Zalinge 1981) is a simple way of decomposing size groups into ages using a growth model (VBGF). In this analysis, the growth is assumed deterministic from the model and the sample is sliced up according to back-transformation of the VBGF (the inverse VBGF) where

$$\Delta t_{L_2-L_1} = \frac{1}{K}\ln\left(\frac{L_\infty - L_1}{L_\infty - L_2}\right)$$

$$N_{i+\Delta t} = N_i . e^{-(F_i+M_i)\Delta t}$$

Given the change in age over each size class (Δt), the population within each size class can be constructed in the same way as a VPA.

LBCA works on a single length frequency sample assuming the population has been in steady state.

- The method is insensitive to errors in the terminal exploitation rate if F>>M
- The model is extremely sensitive to errors in M
- The narrowest length interval that makes data reasonably smooth should be used. Size classes should be chosen such that $M\Delta t \leq 0.3$.
- Considerable care should be taken when only poor growth estimation is available.

PREDICTION MODELS

The knowledge of the past can be used to predict future yields and biomass at different levels of fishing using the prediction models. In other words, these models can be used to forecast the effects of development and management measures such as increases or reduction in fishing fleets, changes in minimum mesh sizes, closed seasons, closed areas, etc. Therefore these models form a direct link between fish stock assessment and fishery resource management.

The first prediction model was built by Thompson and Bell (1934). Beverton and Holt gave the yield-per recruit model for prediction in 1957 which is widely used by researchers.

Yield per recruit (YPR) models are useful to fishery resource managers for predicting the effects of alterations in harvesting activity on the yield available from a given year-class or cohort (Gulland 1983). Two elements that define the model and that are usually regulated by resource managers are fishing mortality (*F*) and the pattern of harvesting activity on different sizes of fish.

Beverton and Holt (1957) noted several important results from the yield per recruit analysis. First is the ratio of the growth parameter (K) to the natural mortality coefficient (M), which estimates the potential of a fish to complete its potential growth before dying of natural mortality.

If M/K is small ($M/K \leq 0.5$), then growth is high relative to mortality, and the cohort will reach maximum biomass at a larger size relative to the maximum size, or the stock (in the absence of fishing) will contain relatively larger fish. From a fishery perspective, management should maximize the size or age of entry to the fishery with only light fishing mortality on smaller fish. If M/K is large ($M/K \geq 2.0$), then natural mortality exceeds growth, indicating many fish will die before completing their potential growth. Again, from a fishery perspective, management should allow heavy fishing with a small size (age) at first capture, so as to harvest the maximum biomass before they die of natural causes.

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Chapter 35

Prospects of micro-financing in fisheries sector

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Unless all the discoveries that you make have the welfare of the poor as the end in view, all your workshops will be really no better than Satan's workshops.

- Mahatma Gandhi

The major challenges to any developing society are poverty and economic deprivation of its ruralpopulation.Eradication of poverty, the focus of all developmental efforts has remained a very complicated and serious concern among developing countries. Poverty is abysmal rooted covering several interlocked aspects such as lack of asset, under employment, uncertain and relatively unproductive employment, low remuneration, economic vulnerability, illiteracy, social disadvantage etc.

The rural areas were found to be more prone to poverty, even if it exists in urban areas also. The rural poor are perpetuating poverty and are the victims of the "vicious cycle of poverty". Fishing communities in the coastal belts all over the world are also not an exception to this. Poverty in fishing communities is very common and is characterized by high population density, poor living conditions, lack of proper education and poor access to education and health care. Due to poor attention paid by the state, the infrastructure support like roads, electricity, good drinking water, markets etc also are be poor. Though efforts for reducing fishing pressure is taken by Government, scope for alternative employment opportunities are less. Thus those sector that are in engaged inthe world's most dangerous occupations, are considered on par with SC/ST communities as far as India is concerned. The loss of a boat, gear or an active fisherman in the family can be tragic and lead to total financial deprivation of the family. Hence poverty and vulnerability in fishing communities is widely known but poorly addressed issue. As in rural farming sector, dependence of fishing communities on private moneylenders continues in many areas, especially for meeting emergent requirements. For various reasons, credit to these sections of the population has not been institutionalized.

The emergence of microfinance as an alternative financial delivery mechanism was a response to the failure of past efforts by government and international agencies effectively to provide financial services to the poor. But while considering micro finance programmes for fisheries sector, there should be special considerations that are unique to fishing communities and need special consideration. Instead of random payment of loans to target sectors and populations, efforts were taken for setting up and building local institutions that cater for the poor. This resulted in the materialization of microfinance institutions (MFIs) that serve the rural poor. MFIs initially started providing microcredit but have now extended their services to savings, insurance etc.

What is Micro Financing?

Micro finance refers to a category of financial services, including loans, savings and insurance, to benefit poor entrepreneurs and small business owners who have no collateral and wouldn't otherwise qualify for a standard bank loan or lack access to the mainstream finances.

Micro Finance Institution, also known as MFI, a microfinance institution is an organization that offers financial services to low income populations. Almost all give loans to their members, and many offer insurance, deposit and other services.

Microcredit is the extension of very small loans (microloans) to impoverished borrowers who typically lack collateral, steady employment and a verifiable credit history

In Indian context, Microfinance Institutions Network (MFIN) is an association for the microfinance sector. Its member organizations constitute the leading microfinance institutions in the country. MFIN is a primary representative body and the Self-Regulatory Organization (SRO) for Non Banking Finance Companies (NBFC)

The mechanics of a microfinance operation basically involve three levels:

i) the borrowers who take out loans that they invest in micro businesses;

ii) the loan delivery and recovery system; and

iii) the institution or organization that manages the delivery system.

The successful operation of these levels is premised on the twin principles of client discipline, where borrowers take responsibility for their decisions and agreements made with the MFI; and institutional discipline where MFIs offer and provide products and services characterized by quality, efficiency and commitment.

These are individual and group-based approaches. Individual lending is credit provision to individuals who are not members of a group that is jointly responsible for loan repayment. As it is documented and asset-based, lending is provided to individuals based on their ability to give the MFI assurances of repayment and some form of collateral, or a willing co-signer.

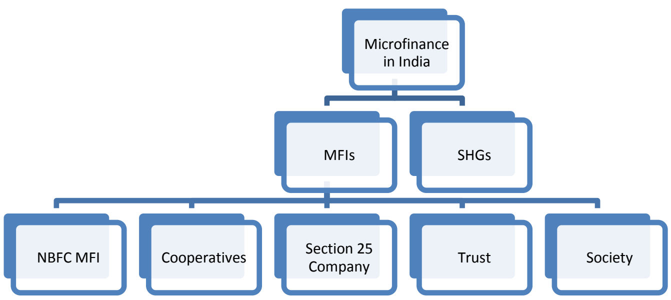
Group-based lending may have a more practical applicability for small-scale fishers and fish farmers. This involves lending to groups of people, either to individuals who are members of a group who guarantee each other's loans, or to groups that sub loan to their members. Self-help groups (SHGs) are prominent in this model.

Micro banking –Indian context

Microfinance Institutions (MFIs)are regulated by the Reserve Bank of India (RBI). MFIN currently has a membership of 42 NBFC MFIs, which on an aggregate basis constitute over 89% of the microfinance business in India.

The major types of microfinance involving credit linkages with banks in India are (i) SHG - Bank Linkage Model: This model involves the SHGs financed directly by the banks viz., CBs (Public Sector and Private Sector), RRBs and Cooperative Banks. (ii) MFI - Bank Linkage Model: This model covers financing of Micro Finance Institutions (MFIs) by banking agencies for on-lending to SHGs and other small borrowers.

Figure 1: Microfinance Situation in India



MFIs currently operate in 29 States, 4 Union Territories and 588 districts in India. The reported 166 MFIs with a branch network of 12,221 employees have reached out to an all time high of 39 million clients with an outstanding loan portfolio of Rs 63,853 crore. Of the total, NBFC-MFIs contribute to 85% of clients outreach and 88% of outstanding portfolio, while NGO MFIs contribute to the remaining. MFIs with portfolio size of more than Rs 500 crore contribute significantly to the total outreach (85%) and loan outstanding (88%) of the sector.

In the last one and half decades, Self Help Groups have emerged as a new paradigm for combating poverty and rural unemployment in India. 'Grameen Bank of Bangladesh, the brain child of Prof. Mohammed Yunus, can be referred to be the precursor of Self Help Groups or micro credit groups or lending groups. Self Help Group (SHG) mode of Savings and Credit was reported to be very efficient by NABARD and ILO due to their potential to bring together the formal banking structure and the rural poor for mutual benefit and that their working has been encouraging. Now it has become a country wide movement, followed by the NABARD sponsored SHG-Bank linkage programme, which started in 1992.Pathak (1992) observed that the SHG, being comprised of group of persons, gets empowered to solve most of their problems like, raw materials and input supply, marketing, better adoption of technology, education and training for realizing the human potential for development. Since the SHG movement is now a country wide programme, it is essential to assess the impact of SHGs in terms of empowerment, especially in view of the dearth of such studies. Same was reported to be true in the case of fisheries sector by Vipinkumar.V.P* & Swathi Lekshmi.P.S (2012)

Coming to Indian fisheries, constituting about 6.3% of the global fish production, the sector contributes to 1.1% of the GDP and 5.15% of the agricultural GDP. The total fish production of 10.07 million metric tonnes presently has nearly 65% contribution from the inland sector and nearly the same from culture fisheries. But the coastal fishing villages in India are thickly populated as fishermen prefer to stay along the coast line owing to access to sea. As in other part of the world, especially in the developing countries, poverty and vulnerability are the typical features portraying the traditional fishing communities.

The scope of extending micro finance to fishing communities is already explored in India and has found fruitful in the past few years. The scattered attempts are to be further extended and scaled up at national level, for which efforts are on the way.

Who are providing micro finance providers?

Microfinance providers can be classified as formal financial institutions, semiformal institutions and informal providers. Formal financial institutions are subject to banking regulation and supervision and include public and private development banks and commercial banks, among others. Semiformal financial institutions, notably NGOs, credit unions and cooperatives and some SHGs, are not regulated by banking authorities but are usually licensed and registered entities and are thus supervised by other government agencies. Informal providers are those entities that operate outside the structure of government regulation and supervision.

Experience shows that governments are inefficient microfinance providers and therefore should not lend funds directly to poor borrowers. Government-implemented microfinance programmes that are usually subsidized and operated through state-run financial institutions are unsustainable, as they are often perceived as social welfare

While attempting to provide micro finance in fisheries sector, those services could include the following:

Principles of financially viable lending to poor entrepreneurs

Principle 1. Offer services that fit the preferences of poor entrepreneurs

- Short-term loans, compatible with enterprise outlay and income patterns
- Repeat loans - full repayment of one loan brings access to another. Repeat lending allows credit to support financial management as a process rather than as an isolated event
- Relatively unrestricted uses - while most programmes select customers with active enterprises, they recognize that clients may need to use funds for a mixture of household or enterprise purposes
- Very small loans, appropriate for meeting day-to-day business financial requirements
- A customer-friendly approach - locate outlets close to entrepreneurs, use simple applications and limit the time between application and disbursement to a few days
- Develop a public image of being approachable by poor people

Principle 2. Streamline operations to reduce unit costs

- Develop highly streamlined operations, minimizing staff time per loan

- Standardize the lending process
- Make applications very simple and approve on the basis of easily verifiable criteria, such as the existence of a going enterprise
- Decentralize loan approval
- Maintain inexpensive offices
- Select staff from local communities

Principle 3. Motivate clients to repay loans

Substitute for pre-loan project analysis and formal collateral by assuming that clients will be able to repay. Concentrate on providing motivation to repay such as:

- *Joint liability groups.* An arrangement whereby a handful of borrowers guarantee each other's loans is by far the most frequently used repayment motivation. Individual character lending can be effective when the social structure is cohesive
- *Incentives.* Guaranteeing access to loans motivates repayments, as do increases in loan sizes and preferential pricing in exchange for prompt repayment. Institutions that successfully motivate repayments develop staff competence and a public image signalling that they are serious about loan collection

Principle 4. Charge full-cost interest rates and fees

The small loan sizes necessary to serve the poor may result in costs per loan requiring interest rates that are significantly higher than commercial bank rates (although significantly lower than informal sector rates)

(Source: Rhyne and Holt, as cited by Ledgerwood, 1999.)

Some more points to take into account are given below:

- As seasons play a critical role in the success of capture fisheries and fish farming, the availability of credit should be assured in time. Also, as capture as well as culture fisheries are occupations requiring fairly good level of skill, required training and technical guidance are crucial for the success of their endeavours. The organisations involved must take a note of these point also to enable the fisherman succeed in his venture and repay the loan in time.

- A thorough understanding of the socio-cultural context in fishing communities is made more critical in microfinance because it requires strong social bonds among the borrower groups to enforce discipline to repay loans.

- Analysis of different socio-economic subgroups in fishing communities, to identify the subgroups most in need of financial services to support their enterprises

- It is highly relevant to study important demographic and socio-economic changes have taken place in recent years in coastal fishing communities

- As income is not regular or uniform from both capture and culture fisheries, an estimation of the market size for microenterprises and their products must be made to ensure that enough demand for financial services exists, thereby ensuring the long-term sustainability of microfinance operations.

- Preference should be for those who already have identified or existing microenterprises but who need financial services, either to expand or build up their asset base, compared to those planning to start from scratch

- Globally, women constitute the majority of microfinance clients, primarily because of their better repayment records. This also makes them a particular target group for microfinance activities in fishing communities. It is recognized that women play an important role in fishing communities, encompassing social and economic responsibilities and duties, both within and outside their households. Women are more involved in land based trading/vending, processing and marketing activities to generate continuous earnings to make up for the seasonal nature of their husbands' incomes. Loan size requirements are small, which makes them appropriate clients of microfinance.

- Global experience has demonstrated that subsidized interest rates are not financially sustainable. Therefore, a balance between a market-based interest rate regime that allows the MFIs to cover all their costs on the one hand and what the clients can afford and what the market will bear, on the other, must be reached

- Successful group-based lending usually starts with small loans, gradually increasing based on repayment history. The guiding criteria for both fishery and non-fishery based projects should be the viability and profitability of the chosen economic activities.

- For most MFIs, repayments are made on an instalment basis (weekly, biweekly, monthly) for activities that generate ongoing revenues. In fishing communities, this would be appropriate for fish marketing and trading projects. For seasonal activities, such as in aquaculture and fish farming, where expected revenues are realized at harvest time, lump sum payments would be appropriate.
- There are two kinds of savings services provided by MFIs: compulsory and voluntary savings. Compulsory savings are funds contributed by borrowers as a condition for receiving a loan. Voluntary savings operate on the principle that the poor already save and only require appropriate institutions and services to meet their needs. (Uwe Tietze and Lolita v. Villareal 2003)

Paying attention to the voice of the poor is as paying attention to the Almighty. Saving our planet, lifting people out of poverty, advancing economic growth... these are one and the same fight. We must connect the dots between climate change, water scarcity, energy shortages, global health, food security and women's empowerment. Solutions to one problem must be solutions for all...Ban-Ki-moon

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Chapter 36

Gender in fisheries development

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Fisheries as a source of food, livelihood and income is probably as old as human civilization. Millions of men and women across the world, especially the developing world, are dependent on the sector. While fish capture in the open seas has generally been a male preserve conditioned by various social, cultural and economic factors; women also have significant contributions for sustaining household nutritional and income security. They have been engaged in fishing in inshore coastal waters, inland water bodies like rivers and ponds; and in post harvest activities like pre-processing, processing, drying, salting, and allied activities like marketing, net making and mending etc. With increasing volumes of fish coming from culture fisheries the participation of men and women in these activities are also increasing. Suffice to say that both men and women contribute to the overall growth and development of the fisheries sector. However, often women and their contributions tend to be marginalized in the fisheries development debate.

Women's roles in fisheries

In the marine fisheries sector, fishing is largely a male preserve. Women rarely venture into the sae, conditioned by cultural and social taboos rather than by skill and endurance. However, the support from women in managing the households and in taking up subsistence or other livelihood activities related to fisheries activities that may actually go into the household income security need to be acknowledged. Studies show that women comprise about 46% of the labour force in small-scale capture fisheries-related activities (FAO, World Bank, IFAD, 2008). It is as high as 73% in Nigeria to a low of 4% in Mozambique. At least 50 % of the workforce in inland fisheries and 60 % of those marketing fish are women in Asia and West Africa.

Women glean for fish, shell fish, molluscs and crustaceans. There are traditional women divers in various parts of the world who fish with primitive fishing implements. Women have been more predominant post-harvest activities like marketing; drying; smoking; salting; fermenting; and other seafood industry oriented pre-processing and processing. Women generally occupy the lowest rung of workers in seafood factories at the floor level and their work comes under the unskilled category which results in lower pay structures when compared to male workers.

The loading and unloading work at landing centres are also mostly done by men. Post landing women are actively engaged in sorting, rarely in auctioning and trading, and very active in marketing, especially in retail trade. In trading it is the access to credit and availability of resources that effect participation. It is seen that where women have access to and control over resources their interventions and participation in markets is high. It has also been observed that when women establish themselves in markets, the men from their households slowly step in and then the business goes into their hands. Fish marketing in most developing countries are poorly organised and lack of cold chain and other infrastructural facilities force vendors to transact their businesses on the same day. Women are usually relegated to the poor market spaces and have to jostle with other players in the market. Women are also engaged in sun drying of excess fish or fish procured for drying purposes. They are also the backbone of the seafood pre-processing and processing sectors all over the world with almost all of the floor level work like peeling, sorting, grading, cooking and packing being carried out by them. However, in all countries it has been observed that women are disadvantaged as far as the wages are concerned and invariably earn less than the men engaged in this industry. The working conditions also leave a lot to be desired.

While it is a fact that there are few women in sea fishing, women harvest fish from inshore coastal waters by gleaning, and fish in inland water bodies in Asia, East and West Africa, and the Pacific. Much of the catch is for household subsistence and goes for meeting the household needs.

Women are active in small scale aquaculture where they perform myriad roles like helping men in pond preparation, feeding, packing etc. They are involved in pond preparation, stocking, feeding and harvesting operations along with the men. However, their labour tends to be classified as family labour and thus often goes unrecognised. Ownership of farms is still largely male dominated. Just like in agriculture a focussed shift towards empowering women by creating ownership and providing technical guidance and providing suitable inputs, the production can be further enhanced and their contributions increased considerably.

In large scale aquaculture they are paid for their jobs, which are similar to the ones they carry out in small scale aquaculture, like feeding and packing. Women's roles sometimes are restricted due to the location of aquaculture sites which may be inaccessible and employers prefer male employees as they are supposed to fend for themselves under difficult living conditions, while women need special attention. In some states of India, women's involvement in aquaculture is limited to collection of wild seed of shrimp in inter-tidal regions. A recent study by the Network of Aquaculture Centres in Asia-Pacific in Thailand, Vietnam, Cambodia and Lao PDR that focussed on small scale aquaculture systems found that, women were present in all the major nodes of the aquaculture value chains. They contribute in almost all activities right from pond preparation, stocking, feeding, water management and health care to harvesting.

A sector which is having great potential and can be exploited is the ornamental fish breeding. Thailand has seen a lot of success in generating entrepreneurship for women in this sector.

Women are also involved in net making and mending which is a supplementary activity in coastal areas. Mariculture activities like cage and pen culture, seaweed culture also have potential for generating employment for women in fishing communities.

Women also manage households attending to cooking, cleaning and care giving when they are engaged in these fisheries related activities. However women in fishing communities are rarely involved in decision-making related to fishing at the household, community, regional and national levels. Women's access to resources like credit, education and health care also tends to be poor. Due to the changes taking place in fisheries across the world, there are increasing insecurities and irregularities when it comes to assuring incomes to women's work and they tend to be bigger losers and more vulnerable.

FAO (2012) makes the following observations:

- In Bangladesh, women's non-governmental organizations and other entrepreneurs have encouraged women to participate in aquaculture activities.
- In Belize, most workers involved in processing are women from rural communities where unemployment levels are high and poverty is greatest.
- In Cuba, female workers constitute 27% of the aquaculture workforce (19 % are intermediate and higher education technicians; 11% have attended higher education institutions).
- In Estonia, the gender ratio of the aquaculture workforce is 1:1.
- In Israel, the workforce is a skilled one because of the highly technical nature of aquaculture in the country. In a sector where women make up about 95 % of the workforce, most workers have a high school diploma while a high percentage has a degree (Bachelor of Science or Master of Science).
- In Jamaica, about 8–11 % of fish farmers are women who own and operate fish farms; and in processing plants, women dominate the workforce.
- In Malaysia, women account for about 10 % of the total aquaculture workforce, and they are mostly involved in freshwater aquaculture and hatchery operations for marine fish, shrimp and freshwater fish.
- In Panama, 80 % of the workforce in processing plants is women, but in the production sector only 7% of workers are women.
- In Sri Lanka, women constitute 5% of the workforce in shrimp aquaculture and 30 % of those engaged in the production and breeding of ornamental fish.

Gender Mainstreaming for development

'Mainstreaming' means bringing out gender concerns in all aspects of executing policies and programmes from implementation to evaluation so that there is equality in sharing benefits.

It is now well accepted that participation of women is very important in maintaining economic growth and development. Participation does not merely mean involvement, it means ensuring equal access to all the productive resources required for production. It requires empowering women and investing in women competencies. The Food and Agriculture Organization (FAO) considers that feminisation has serious implications for the producers' economic agency and productivity and farm income. Provided the same access to productive resources as men in the world, farm yields could be raised by 20–30%, thereby increasing the overall agricultural output in developing countries by 2.5 to 4%. Besides increasing women's income, this gain in production could lessen hunger in the world by 12–17%.

In the context of fisheries, the issues are much more complex as fisherwomen are excluded from some of the activities in the sector. Even after making significant contributions to households as well as communities, they are marginalized. This is mainly because of poor access to and control over productive resources. There is also need to improve their participation in decision making and governance of fisheries as a whole. What is easily accessible to the men are often not available to women due to social, cultural, political and economic reasons. Overcoming these may not be easy but affirmative policies can ensure that changes are brought about. Most fisheries in the developing world are small scale. And in this context the community's place in the fisheries development context is important. The FAO Voluntary Guidelines for Securing Sustainable Small-Scale Fisheries in the Context of Food Security and Poverty Eradication adopted in 2015 clearly states 'Gender equality and equity" as fundamental to any development and has stated it as a guiding principle.

Some gender concepts

- Gender has been defined as 'a concept that refers to the social differences, as opposed to the biological ones, between women and men that have been learned, are changeable over time and have wide variations both within and between cultures.
- Gender equity refers to the process of fair and justice treatment of women and men to reach gender equality.
- Gender equality refers to the equal enjoyment by women and men or boys and girls of rights, opportunities, services and resources.
- Gender analysis is the systematic attempt to identify key issues contributing to gender inequalities so that they can be properly addressed.
- Gender analysis provides the basis for gender mainstreaming and is described as 'the study of differences in the conditions, needs, participation rates, access to resources and development, control of assets, decision-making powers, etc., between women and men in their assigned gender roles'.

Source: http://www.rflp.org/ (Regional Fisheries Livelihoods Programme for South and Southeast Asia)]

Fisheries related natural resources like seas, rivers, lakes, ponds etc, are common property resources. In effect there is no restriction on use, though traditions and conventions usually regulate access. National and regional agreements can also restrict access. Aquaculture ponds are privately owned and in most cases the owners are men. Where traditional rights are exercised, women do not figure in the decision making process. Most decisions are taken by the men in the community. Access also therefore is governed by men. This is one reason why there are very few women who actually venture into the sea for fishing. The fishing that women carry out is smaller in scale and operation and at best supportive in nature. Fisheries Development activities that focus on increasing fish production also thus are male centric. That there are women fishing in inshore waters and any development activity that is carried along the shore will have an impact on their activity is hardly ever noticed. An off-shoot has been that many activities performed by women have become excluded or banned when planning and policy making on fisheries management are formulated. Ownership and inheritance of land and of major fishing implements is also through men.

Traditionally, net making was a women centric activity. While the men went fishing, women made and mended the fishing nets, Mechanization of the netting yarn and net making process has played a part in reducing the role of women in net mending. The increasing size and type of nets has also made women leave the sector. Now fishermen themselves are engaged in making and repairing of the gear. Mechanization of craft and gear has resulted in the 'economic displacement' of many fish wives.

Credit is another important resource that determines the scale of operation of any enterprise. Rural credit has always been dominated by informal sources. In fisheries craft and gear; and marketing activities are all financed by large scale traders or auctioneers. Women find it extremely difficult to find credit support for their activities. Women usually get access to credit through their husbands or other male relatives, because of the interdependency between trade and finance. However, credit availed by women for specific activities are sometimes seen diverted for household requirements. Women fish traders usually face high costs of transportation, fluctuating prices and travel during odd hour's transportation. Very poor facilities also leads to health problems. Competition from male fish retailers is also high. Men generally own vehicles and transportation is easier.

One of the most important ways of improving the levels of participation of women is by improving access to the resources that were described earlier. State level policy instruments are necessary to achieve this. Community traditions are difficult to change but requirements under law need to be followed. Specific laws to include women in community decision making bodies will be a starting point. The passing of the Panchayati Raj Act in India resulted in the dramatic increase in number of women in local self-governance. Self-Help-Groups (SHGs) have improved access to credit in many countries. Through SHGs women in small units come together and get engaged in productive activities by promoting savings and providing short term loans at lower rates of interest. At a larger scale Cooperatives can perform the same role.

Equal access to skill development and technology in fisheries are also important in gender mainstreaming. Technological innovations in harvest sector have been responsible for transforming fisheries sector from a traditional subsistence to a commercial level. The use of labour saving technology is always gender specific and has differential impacts. Since women are predominant in post harvest activities related technologies can play a major role in their empowerment. Better technologies for handling, curing and drying and processing of fish have helped women improve their incomes. The technology development process is generally gender neutral. However, it must take into account the ability of the women in handling or using the technology.

The way forward

Fisheries like all other primary production sectors are undergoing changes. The impacts of mechanization, climate change, natural disasters etc. are all serious concerns in the sector. Women in fisheries contribute significantly to household incomes however their control over the same is a challenge. Conditions of work need improvement in tune with changes in all other spheres of life. Skills need to be developed to make them capable of adapting to the technological changes. Organising is another way of trying to achieve common goals and need to be encouraged by both Governments and NGOs. However, it must be ensured that in the process of 'inclusion' of women in more areas of fisheries should not result in increasing the burden of already existing roles.

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Chapter 37

Technology Application, Refinement and Transfer through KVKs

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Introduction

India has made considerable progress in improving its food security. The agricultural development strategy pursued in the country, particularly since the mid-sixties, is recognized and appreciated world over. The integration of agricultural research with quality education and a properly planned extension education system has been one of the fundamental foundations of this developmental strategy, which also led to revolutions in many other sectors of agriculture and allied enterprises. As a part of this strategy, several programmes of transfer of technology from research stations to farmers' fields were launched in the country. These included National Demonstration Project, Lab to Land Programme, Operational Research Project and Krishi Vigyan Kendras (Farm Science Centers). The programmes were continuously reviewed from time to time and reformulated for their effectiveness. Presently the Krishi Vigyan Kendras (KVKs) have been recognized as an effective link between agricultural research and extension system in the country (Venkatasubramanian *et. al.*, 2009).

Krishi Vigyan Kendras (Farm Science Centers), an innovative science-based institution, were established mainly to impart vocational skill training to the farmers and field-level extension workers. The concept of vocational training in agriculture through KVK grew substantially due to greater demand for improved/agricultural technology by the farmers. The farmers require not only knowledge and understanding of the intricacy of technologies, but also progressively more and more skills in various complex agricultural operations for adoption on their farms. The effectiveness of the KVK was further enhanced by adding the activities related to on-farm testing and front-line demonstrations on major agricultural technologies.

With the consolidation of other front-line extension projects of the Council during the Eighth Five Year Plan, such as National Demonstration Project (NDP), Operational Research Project (ORP), Lab to Land Programme (LLP) and All India Coordinated Project on Scheduled Caste/Tribe, the mandate was enlarged and revised to take up on-farm testing, long term vocational training, in service training for grass root extension workers and front-line demonstrations on major cereal, oilseed and pulse crops and other enterprises.

The application of technology in the farmers' field is achieved through conducting of On-farm trial which include technology assessment and refinement. The proven and recommended technologies are then introduced in the system through conducting of frontline demonstrations followed by training programmes to empower the farmers, field extension personnel and rural youths for its adoption. The extension activities such as field day, exhibitions etc are conducted to disseminate the technologies across the system.

The KVKs have witnessed several changes in their functions over the years. Accordingly their functional definition also has radically got refined so as to meet the new challenges in agriculture. "KVKs are grass root level organizations meant for application of technology through assessment, refinement and demonstration of proven technologies under different 'micro farming' situations in a district" (Das, 2007). By end of 2016-17, 680 Krishi Vigyan Kendras were operating in 707 districts of India.

It should be clearly understood that transfer of technology is not a primary function of KVKs and the same is the responsibility of State departments. The KVKs on the other hand will assess (and if needed refine also) the newly released technologies, demonstrate the proven ones and train farmers and extension workers of the district on the same.

Role of KVKs in the context of Agricultural/Fisheries Extension in India

Extension in India is largely deployed by government, implemented mainly through government institutions and to some extent through non-government agencies. Krishi Vigyan Kendras (KVKs) or Farm Science Centres as institutes of inducing behavioural change, are being managed by both government and non-government organizations. Literally, Krishi Vigyan Kendras have to serve as repository of scientific knowledge that is useful to the entire district, which is its jurisdiction. In India, agricultural/fisheries extension and extension education are interchangeably used with the same connotation as used in American tradition, meaning "Extending Information" as a means of educating people to solve their problems. As a result, agricultural/fisheries extension in India is more of "Informative Extension" than "Emancipatory Extension".

In India, the extension efforts, particularly transfer of technology efforts, have largely been taken up by the state departments of agriculture and other disciplines as a state subject. The Indian Council of Agricultural Research (ICAR) as the apex body to provide new technologies in agriculture and allied aspects has its own transfer of technology activities too. The extension efforts of ICAR have evolved through National Demonstration Projects, Operation Research Projects, Lab to Land Programmes, and integrating of these approaches to Krishi Vigyan Kendras (KVKs) since 1974.

Technology and farm technology

Technology is any systematic knowledge and action applicable to any recurrent activity. Technology involves application of science and knowledge to practical use, which enable man to live more comfortably. The Merriam-Webster dictionary offers a definition of the term: "the practical application of knowledge especially in a particular area" and "a capability given by the practical application of knowledge”.

Technology can be most broadly defined as the entities, both material and immaterial, created by the application of mental and physical effort in order to achieve some value. In agriculture/fisheries, the term technology often confuses practitioners. This is because farm technology is a complex blend of materials, processes and knowledge. Swanson (1997) has classified farm technologies into two major categories: 1) Material technology, where knowledge is embodied into a technological product; and 2) Knowledge based technology, such as the technical knowledge, management skills and other processes that farmers need for better farm management and livelihood support.

KVK scientists need to have clarity over the technologies which they are assessing and refining in response to a specific problem in a specific micro-location. For example, a KVK Subject Matter Specialist may be assessing the efficacy of a particular management practice on a crop/fish’s yield or growth in the KVK district. Such management practices can be broadly classified as Knowledge based technology. Alternatively, all technological products tested and demonstrated under OFT and FLD fall under material technology. Ex: Seeds/fish seeds, pesticides, fertilizer, farm machinery, irrigation systems etc.

Agricultural/Fishery Technology Development

Technology Development (also called technology innovation) in agriculture/fishery is a process consisting of all the decision and activities which a scientist does from recognition of a need/ problem with planning, testing, conducting research, verification, testing and dissemination for adoption. During the same time, some problems on the technology might get back to the scientist for solution thus resulting in refinement of the same. Thus, technology development is a continuous process. The KVK scientists have to equip themselves for 'technology application' - a process which includes the above mentioned processes; thus contributing their part in the overall process of agricultural/fishery technology development.

Agricultural/Fishery TechnologyManagement

Technology management can be defined as the integrated planning, design, optimization, operation and control of technological products, processes and services. A better definition would be "the management of the use of any technology for farmer advantage." The KVK role under fishery technology management is very huge where-in it selects latest fisheries technologies, tests them for suitability in different micro-locations of the district and demonstrates the proven ones to farmers and extension system.

Technology fatigue in agriculture/fishery

Linkages between the laboratory and farmer fields have weakened and extension services often have little to extend by way of specific information and advice on the basis of location, time and farming system. Good quality seeds at affordable prices are in short supply and spurious pesticides and bio-fertilizers are being sold in the absence of effective quality control systems. Farmers have no way of getting proactive advice on land use, based on meteorological and marketing factors. No wonder the prevailing gap between potential and actual yields, even with technologies currently available, is very wide (National Commission on Farmers, 2007). In case of KVKs, it was found utilizing old and obsolete technologies for OFTs, FLDs and training programmes thus resulting in poor feed-forward to the extension system. A knowledge deficit as mentioned above coupled with the usage of obsolete technologies and package of practices together leads to a situation called 'technology fatigue'. Indian agriculture, particularly agriculture/fishery by resource poor farmers in rural areas is now bearing the brunt of technology fatigue. The KVK role lies in providing timely supply of proven technologies specific to various micro-locations of the district thus alleviating the technology fatigue existing in the district.

Technology Gap

Technology Gap is the gap between the level of recommendation and the extent of adoption (against recommendations). Technology gaps are a major source of concern for extension system. The successes of traditional transfer of technology (TOT) models were mainly evaluated on the basis of the extent of narrowing down in technology gaps achieved by them. KVK system being primarily focused on assessment, refinement and demonstration of new technologies, its role lies in feeding proven technologies to the main extension system. Thus, the primary focus of KVK should not be mistaken as reduction of existing technology gaps. Rather, they are meant at alleviating “technology fatigue” by providing timely supply of proven technologies specific to various micro-locations of the district. Alleviation of technology fatigue is accomplished through processes of technology and methodology backstopping.

Agricultural/Fishery Technology backstopping

Backstopping refers to any precaution taken against an emergency condition. Accordingly, agricultural technology backstopping can be defined as any technology precaution taken to combat technology fatigue in agriculture. In simple terms agricultural technology backstopping is the process of making available ready to use technologies for farm families through assessment, refinement and demonstration processes in order to combat the existing/forecasted technology fatigue.

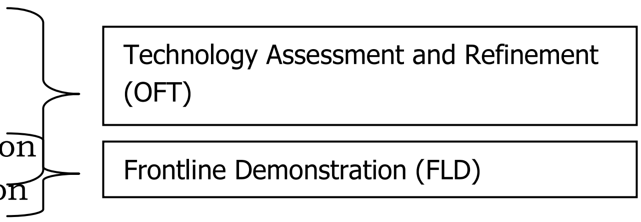
Agricultural Methodology backstopping

This is a process almost similar to agricultural technology backstopping but differs with respect to the kind of technology solution offered. Instead of material technology, methodology backstopping aims at assessment, refinement and demonstration of knowledge based technologies often referred to as methodologies/package of practices. It provides detailed procedures to carry out the technology application functions by the extension personnel in the field. It includes methodologies for conducting OFT, which includes TAR, demonstrations, training, conducting surveys, impact assessment and evaluation etc.

Conceptual paradigm of Agricultural/Fishery Technology Development

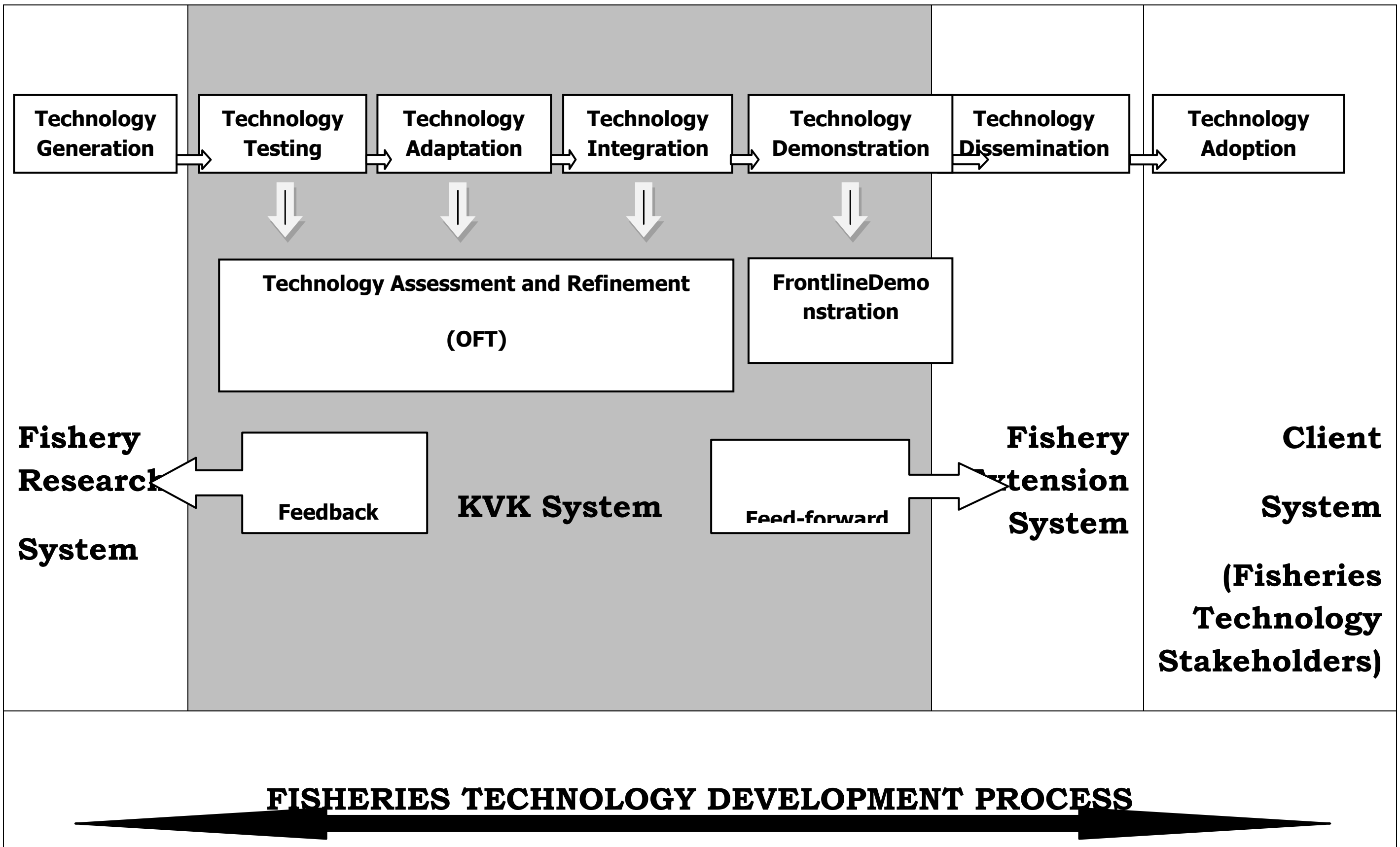
Understanding technology development process in agriculture/fishery and its components is vital for success of KVK scientists. Farm technology development basically constitutes seven processes. They are:

1. Technology generation
2. Technology testing
3. Technology adaptation
4. Technology integration
5. Technology demonstration
6. Technology dissemination
7. Technology adoption



Technology generation, the starting point of technology development process is mainly a function of agricultural research system. Testing, adaptation and integration processes constitute technology assessment and refinement which KVK system executes through OFTs. The feedback is passed over to research system. KVK system also involves in technology demonstration through FLDs. Feed-forward from successful OFTs and FLDs is communicated to the extension system for mass popularization in the district. Technology adoption; the final act, occurs among the members of client system i.e. farmers.

We are presenting a new conceptual model of fishery technology development process depicting the components and actors involved for discussion of stakeholders involved. The role of KVK system between research system and extension system with respect to technology application is identified and highlighted here.



(Sajeev & Rejula, 2017)

Research system generates new technologies. In India, research system comprises of ICAR institutes, SAUs, Fishery Universities, departments like DBT, DST, other Science and Technology Institutions and Commodity boards. NGOs, Corporate and farmer innovators also contribute to technology generation.

Extension system comprises of State departments of agriculture, animal husbandry and veterinary, fisheries, sericulture etc. SAUs, ICAR institutes, commodity boards, NGOs and Corporate sector also contribute to extension system.

Earlier, due to the primary focus on vocational training, KVKs were categorized under extension system itself. But today, with mandates being focused on assessment, refinement and demonstration of frontier technologies, the KVK system positions itself clearly between the research and extension systems thus acting both as a feedback and feed-forward mechanism. In this paradigm, it is necessary to understand the pathways or passage of technology through KVK system.

Typology of technology passage through KVK system

KVK system has successfully established itself between the research and extension systems. Technology development process as explained earlier, invariably has assessment, refinement and demonstration components. Hence, there is a passage of technologies through various stages in a KVK system. We found that this passage doesn't follow a uniform pattern. For example, a technology may go through assessment stage and demonstration stage but not through refinement stage. Based on analysis of OFTs and FLDs conducted by KVKs, we identified five different typologies of technology passage through KVK system. A proper understanding of these typologies will help KVK personnel in deciding whether a particular technology has to go for OFT and FLDs or both. The typologies are:

1. Source - Demonstration

In this type the technology from any source/provider directly goes to demonstration by KVK. This happens when the KVK is completely sure that the technology is fully suited for the district and can go directly for FLD. Here, the technology doesn't pass through assessment and refinement stages.

2. Source - Assessment

In this type the technology from any source/provider goes for assessment by KVK. This happens when the KVK is not sure that the technology is fully suited for different micro-locations of the district. Here the technology fails at assessment stage itself and hence doesn't move to refinement or demonstration stages.

3. Source - Assessment - Refinement

This type is a variation of type 2. Here, the KVK is not sure that the technology is fully suited for different micro-locations of the district. The technology goes for and succeeds in assessment but needs refinement and hence moves to refinement stage. Here, the technology fails in refinement stage and hence doesn't move to demonstration stage.

4. Source - Assessment - Demonstration

This type follows type 3. This happens when the KVK becomes sure that the technology is fully suited for different micro-locations of the district. The technology fully succeeds in assessment and hence moves to demonstration stage. Here, the technology doesn't require refinement and hence move to demonstration stage.

5. Source - Assessment - Refinement - Demonstration

This type also follows type 3. This happens when the KVK becomes sure that the technology is fully suited for different micro-locations of the district. The technology succeeds in assessment and refinement and moves to demonstration stage. Here, the technology is successfully refined by KVK and taken to demonstration stage i.e. FLD.

FLDs are supposed to be taken up on proven technologies only. Hence, it makes obvious that once demonstrated it will go to the extension system and client system. Rarely FLDs may fail thus preventing the technology passage. But KVKs are not supposed to demonstrate such technologies which are not fully proven. The failure of FLD can be due to some extraneous factors rather than technological factors.

Client system comprises of the ultimate end-user i.e. the fish farmer/fishery technology stakeholder. Although KVK system does assessment, refinement and demonstration of new technologies as part of technology development process, some technologies get refined or rejected even in the last stage at farm/user level. Hence, client system even though being the final actor in technology development process, plays the ultimate decisive role.

Conceptual paradigm for Technology Assessment and Refinement in agriculture/fisheries

Technology Assessment and Refinement (TAR) in agriculture refers to a set of procedures whose purpose is to develop recommendations for a particular agro-climatic situation/ location through assessment and refinement of recently released technology through farmer participatory approach. It refers to the process or a set of activities before taking up new scientific information for its dissemination in a new production system. *OFTs conducted by KVKs are based on this concept and thus distinguish it from agronomic and research trials*. The process of TAR has three components. They are technology testing, technology adaptation and technology integration. TAR should be site specific, holistic, farmer participatory, providing technical solution to existing problems, inter-disciplinary and Interactive.

This process involves Scientist-Farmer linkage in terms of sufficient understanding of the farming situations, adequate perception of farmers' circumstances and their needs, the variability of conditions on the research status as compared to farmers' fields and problem orientation instead of disciplinary approach.

Thus, Technology assessment in agriculture by KVKs should be understood as the study and evaluation of new technologies under different micro locations. It is based on the conviction that new discoveries by the researchers are relevant for the farming systems at large, and that technological progress can never be free of implications. Also, technology assessment recognizes the fact that scientists at research stations normally are not trained field level workers themselves and accordingly ought to be very careful while passing positive judgments on the field level implications of their own, or their organization's new findings or technologies. Considering the above factors, the ICAR has envisaged On Farm Trials (OFTs) through its vast network of KVKs covering almost the entire geographical area of the country (Anon, 1999).

On Farm Trials (OFTs)

An On-Farm Trial aims at testing a new technology or an idea in farmer's fields, under farmers' conditions and management, by using farmer's own practice as control. It should help to develop innovations consistent with farmer's circumstances, compatible with the actual farming system and corresponding to farmer's goals and preferences. On-farm-trial is not identical to a demonstration plot, which aims at showing farmers a technology of which researchers and extension agents are sure that it works in the area. *It should be noted that OFTs are strictly to be conducted in collaborating farmer fields and not in KVK land.*

Stakeholders of On-farm trials

There are various stakeholders in an on-farm trial. Understanding them and their roles can help KVKs to develop better OFTs. The stakeholders are:

1. The farmers who are the clients for the out-coming results,
2. The SMS who should help the farmers to overcome their problems and improve their economical situation. On farm trials can give them valuable information in this respect.
3. The Scientist who needs to apply promising on-station results under farmers' conditions before releasing the technology to the extension service,
4. The extension system and government itself, who is interested in seeing an efficient and participatory technology development model evolving, since most top-down approaches have failed miserably.

Typology of On Farm Trials

We can distinguish three types of OFTs in India according to the stakeholder who is going to take the lead role:

- **Type 1, Research driven:**

Research system designed and managed (with the assistance of extension)

- **Type 2, Extension driven:**

Extension System or KVK system designed and managed by farmers

- **Type 3, Farmer/User driven:**

Farmers/user designed and managed, with the assistance of Extension system/KVK system.

Type 1. Research driven

Rationale:

Research has shown promising results in on station trials. Now the concerned researcher wants to evaluate the new technology in multi location as the on station trial does not represent the wide range of conditions (e.g. soil fertility, weed flora, altitude, rainfall, farmers' conditions).

Objective:

Assess the performance of the new technology under various conditions and test the acceptability by farmers.

Particular characteristics:

The trial is usually planned in advance and included in the annual work-plan of either research or extension. Objective and layout of the trial is thoroughly discussed by the researcher with the Institute/Division head and the respective Extension agency. Here,

a. Extension agency involved helps to locate suitable fields
b. Usually plots are of small size
c. Researchers design and manage the trials with the help of extension agencies
d. If necessary, researchers furnish inputs and may exceptionally hire labour
e. Trails are used for the purpose of field day

Outputs:

Information on the performance of new technology under various conditions; information on the acceptability by farmers and interesting positive results are published in various journals.

Type 2. Extension driven

Extension driven OFTs should not be confused as to only extension system managed. The OFTs by KVKs also fall under this type since the whole purpose of OFTs by KVKs is to give feed-forward to the extension system.

Rationale:

Type 1 trials have confirmed that the new technology will work in farmers' conditions; therefore SMS plan to implement the trial on a wider scale with active involvement of the farmers. Researchers are interested in getting the information on both biophysical and farmers assessment of the technology. KVK and SMS have developed their own ideas how to improve aspects of the new technology. They want to try it out in real farm situation.

Objectives:

a. Assess the biophysical performance of a new technology in a wide range of micro-locations within the district,
b. Obtain the farmers viewpoint about the technology,
c. Assess cost/benefit ratio.

Particular Characteristics:

a. Interest of farmer having the trial on his land must be ascertained. Objective must be very well understood by farmers,
b. SMS discuss their ideas with PC and researchers
c. SMS determines on the design and provides instruction
d. Plots are often larger than in type 1
e. Farmers' assessment of the result is essential
f. Scope for refinement after assessment
g. Feed back of the results to research and
h. Feedforward of successful technologies to extension system

Outputs:

a. Farmers' reaction on technology, on management requirement and economical sustainability of the technology.
b. Feedback for the design of new future trials and

c. Compilation of a large number of similar trials will give fairly reliable data on performance over a broad range of farm types and circumstances.

Type 3. Farmer/user driven

Toughest of all types, yet the most sought after one. It involves Participatory Technology Development thus contributing to sustainability of results. The KVKs are also expected to bring their OFTs to this level from being an extension driven one at present.

Rationale:

a. Farmers are aware of a given technology, they like what they see and would like to experiment it by themselves.
b. Farmers are aware of a problem and would try some methods to solve them and
c. Researchers want to know to which extent and how a technology is adapted by farmers

Objectives:

a. To study how farmers adapt and adopt technologies,
b. To investigate what factors affect the performance of technology,
c. Provide on station researchers with feed back on problems at farm level and provide new research issues and
d. Participatory technology development

Particular Characteristics:

a. Farmers identify problems and choose from menu of technologies.
b. Farmers decide to choose the technologies and modify them to fit their particular farming system. Control plots are not really necessary unless the farmer decides to have one
c. High level of participation and self mobilization
d. Feed back of the results to research and other interested entities
e. Feed-forward to other farmers.

Outputs:

a. SMS document the farmers' decisions, preference and the management strategies.
b. Information is collected on the uptake of the new technology by fellow farmers.
c. Feedback to researchers on technology performance and on further research needs

Points to consider:

a. It is not wise to force collection of the biophysical data (yield, climate, and soil fertility) in type 3 because of too many confusing factors.
b. Constant monitoring, recording of farmers' comments is necessary.
c. Encourage farmer to take some notes himself (inputs, yield etc.)
d. Self-diffusion of the technology needs to be monitored (e.g. seed distributed to neighbours, area expansion etc) and
e. Socio-economic data should be collected.

KVKs have to spend considerable time and efforts in planning and implementing OFTs. The basic principles of conducting successful OFTs are to be followed in this process. The principles are:

1. *Define a clear question you would like to have an answer for:*

Narrow the trial down to its simplest form; define a clear simple question to which the OFT should give an answer.

2. *Keep it simple:*

Limit the trial to a comparison of two (or maximum three) treatments.

3. *Go step by step:*

Farmers usually do not adopt entire new systems of production; they go step-by-step adapting components of the technology. Therefore the OFT should not include too many new steps/practices at once.

4. *Seek help:*

When the problem is clear and the idea on how to go about the trial has evolved, the SMS should contact a competent researcher to discuss the plan of the OFT. He/She can also take help from other SMS and PC of the KVK.

5. *Replicate and randomize*

Plan on enough field space (in farmers' field) to do more than one strip of each treatment being tested. Mix treatments within blocks.

6. *Stay uniform:*

Treat all the plots exactly the same except for the differing treatments. If possible, locate the experiment in a field of uniform soil type (slope, fertility etc.).

7. *Harvest individual plots:*

Record data from each individual plot separately. Do not lump all treatment types together or the value of replication will be lost.

8. *Remain objective:*

The results may not turn out as expected or planned. Be prepared to accept and learn from negative results. Negative results show that the technology under testing is not suitable in the present form for the specific micro-location of the district. Such results are equally valuable for the benefit of farming systems at large.

9. *Manage time wisely:*

Expect to devote extra time to OFT during busy seasons. Make sure to can carry out the trial even though busy, or get extra help from other SMS.

The success of an OFT should not be confused with success of the technology tested. A negative result of a technology tested shows that the technology is not suited for the specific micro-location of the district. This finding also refers to the success of the trial. Some technologies may not need refinement thus qualifying directly for frontline demonstrations. Some may successfully undergo refinement and reach the demonstration stage while some technologies fail to get refined in the farmer field. The technologies which successfully come out of On Farm Trials are then recommended for Frontline Demonstrations (FLDs).

A study conducted by National Institute of Labour Economics Research and Development during 2015 on impact of KVKs on dissemination of improved practices and technologies revealed that KVKs are having an edge over other organizations in providing technology services by virtue of their having better technical expertise and demonstration units. At national level, on an average each KVK covers 43 villages and 4,300 farmers, and it organize more field level activities than on campus activities. About 25% of the persons trained by KVKs on agri-preneurship had started self-employment venture.

Krishi Vigyan Kendra Knowledge Network Portal

Krishi Vigyan Kendra Knowledge Network Portal facilitates KVKs to update and upload all types of information so that the related information and knowledge can reach to the farming community in time. A KVK Mobile App for farmers has also been developed for Android users and is available in Google Play Store. Farmers need to register and select concerned KVK in the App for accessing information. Farmers can ask any farm related query to the experts of KVKs for solution.

Conclusion

With current reforms and policies, the public extension system would continue to play a prominent role in technology dissemination. The large scale of small and marginal farmers and landless labourers are benefited by the public extension system. The other players involved in extension/transfer of technologies such as NGOs, Farmers organisations, Private sector (both corporate and informal), para-workers etc. would actively complement/ supplement the effort of the public extension agency. Extension mechanism will have to be driven by farmer's needs, location specific and address diversified demands. There is room for both the public and private sectors in the development of a demand based and feedback driven system. Technologies required to address total farming systems are knowledge intensive. Public extension system will need to be redefined with focus on knowledge-based technologies to upgrade and improve the skills of the farmers.

Farmers' capacity building is often seen within the limited perspective of giving them the knowledge and skills required to practice crop and animal husbandry in a better way. Though, knowledge and skills are fundamental to efficiency in any enterprise, the Indian farmers need more than that because of the limitations and complexities under which they operate. The KVKs which have been mandated to work with farmers, farm workers and rural youth directly as well as through field extension functionaries have the greatest challenge to make their clients more efficient, specialized and to be economically active. The fact that the need for agricultural/fisheries and rural information and advisory services is to intensify in the immediate future exerts more pressure on KVK performance. This article has attempted to assist the extension practitioners in equipping themselves for the future challenges by providing a conceptual paradigm regarding technology assessment and refinement, the most important mandated activity assigned to them.

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Chapter 38

Value chain management in fisheries

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Value chain analysis and its management is a strategic planning tool used in analyzing the value chain of a company or sector or a product. Initially, it was used to assess the process of a company or single unit. Then, it was visualized as a holistic and integrated framework in upgrading the activities of companies as a whole with the coordinating efforts of the various units or sub-systems. It is useful in improving the existing system or through introducing a new component in the system.

Value chain

The word 'value chain' was first introduced by Michael porter in his book 'Comparative Advantage' during 1985. Value chain is defined as "*the full range of activities which are required to bring a product or service from conception, through the different phases of production (involving a combination of physical transformation and the input of various producer services), delivery to final customers, and final disposal after use*".

Value chain comprises of full range of activities required to bring a product or service from the stage of conception, production and distribution to consumers (Kaplinsky and Morris, 2001).The study on value chain is intended to achieve comparative advantage through cost minimization and attaining consumer satisfaction. It is the preliminary step in the mapping of market (FAO, 2006).The value chain can be analyzed using Value Chain Analysis (VCA) through either quantitative or qualitative tools or both.

Supply chain versus value chain

Supply chain covers the activities of the downstream flow of activities from source (supplier) to consumer. But, value chain flows reverse i.e., from consumer to supplier. This is also referred as 'demand chain', as consumers are the source of value and the demand is created due to value. The focus of supply chain is on upstream activities i.e., integrating the supplier and producer and improving efficiency. While value chain focuses on downstream activities such as consumer satisfaction. The supply chain is on reducing costs and increasing efficiency in operation and value chain is towards innovative product development and marketing.

Value chain studies are the integrated approach which involves value addition at each stage. This is in reverse to the traditional studies, which was mainly on production concepts alone. The ultimate aim of value chain studies is to identify cost effective value chain for the actors separately or for the whole value chain. A value chain has mainly two components viz., actors and activities.

i. Actors: Actors are the drivers of the value chain who are the major driving force in operating the value chain. Ex: Suppliers, producers, wholesalers, retailers.

ii. Activities: A typical value chain consists of activities such as design, production, marketing, distribution and support to the final consumer.

Based on the number of actors, their interactions and interlinkages, value chain can be as classified into simple or complex.

Simple and complex value chain

Simple value chain comprises of input supplier, producer, wholesaler, retailer and consumer with single channel only. It doesn't have interactions and inter-linkages among the actors. But, in practice, value chain is too complex and very difficult to manage. The simple value chain is illustrated and presented in fig. 1.

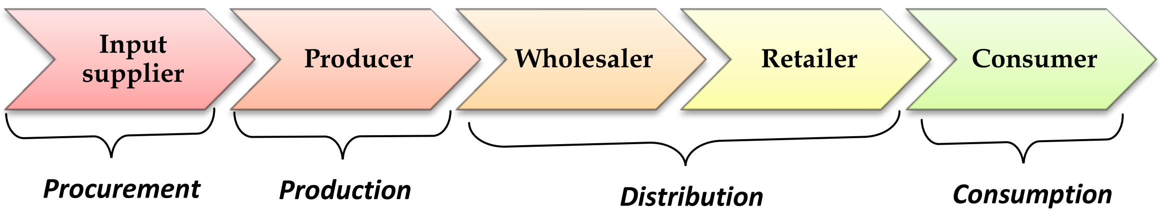


Fig. 1. Illustration of simple value chain

The complex value chain is presented in fig. 2.

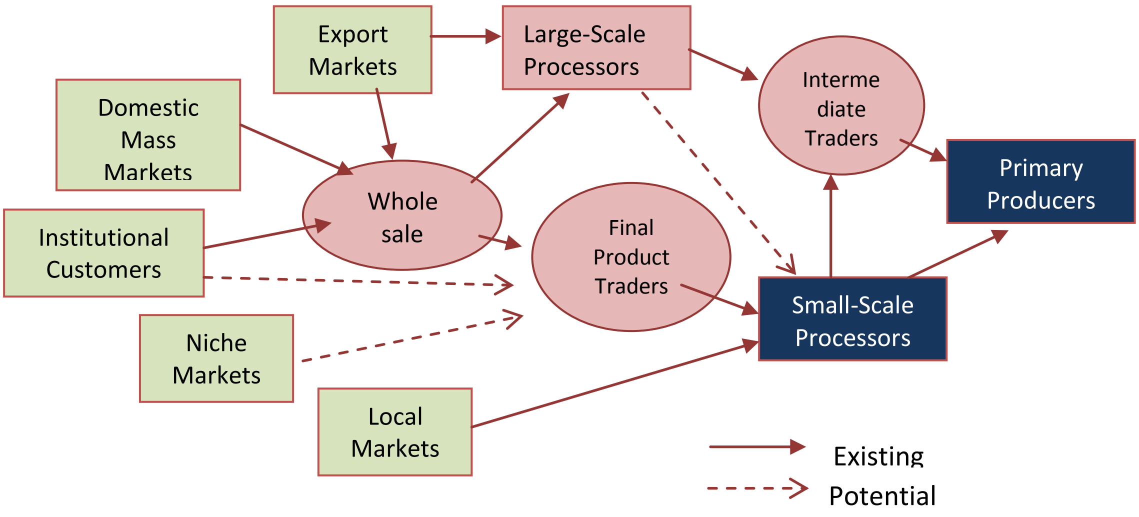


Fig. 2. Illustration of complex value chain

Complex value chain comprised of two or more chains with many actors involved in variety of activities. There is often interactions and inter linkages among actors with many final destinations. Like other sectors, fish value chain is also complex. There are vast differences in performance of value chain at the field level (Fig. 4).

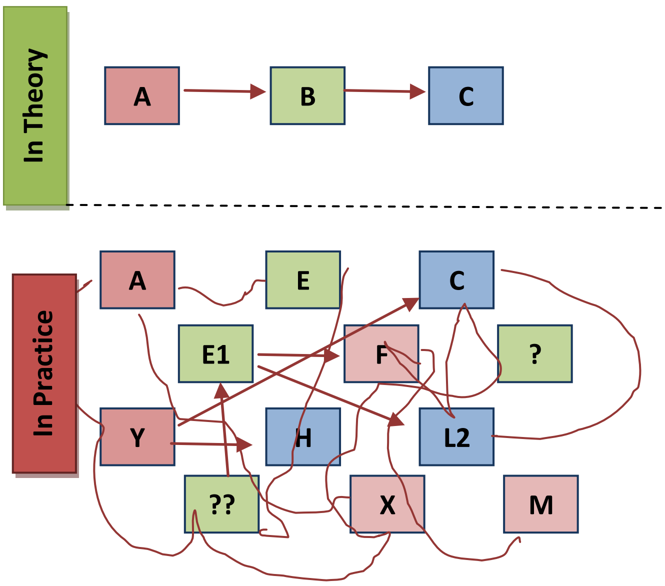


Fig. 3. Value chain: Theory and practice

Value chain analysis in fisheries

Value chain in fisheries is used as a managerial tool to reduce processing costs and improve quality and productivity of the product and reduces distribution cost. The advantages of studying value chain in fisheries are,

i. Increase the producers' share
ii. Minimum cost of the processes
iii. Increase the efficiency and effectiveness of the actors
iv. Eliminate the unwanted processes i.e., non-value addition
v. Quality assurance in product development
vi. Ensure consumer satisfaction

The value chain approach is a useful practical tool towards assessing the status of development of fisheries and aquaculture. It also analyzes the opportunities and constraints for future development. It is useful for the key actors such as fishers, managers and policy makers towards streamlining their activities in a cost effective way.

Steps involved in value chain process

The process of value chain analysis involves number of sequential steps. The steps used in selection of value chain analysis was discussed by two authors has been presented in fig. 4 & 5.

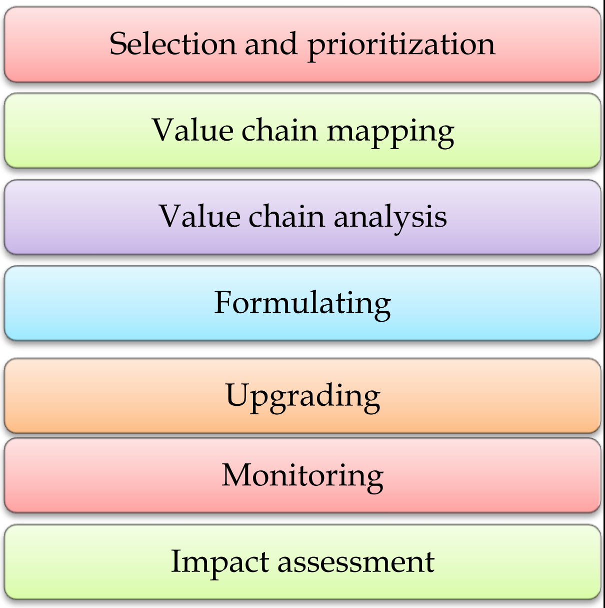


Fig. 4. Process I

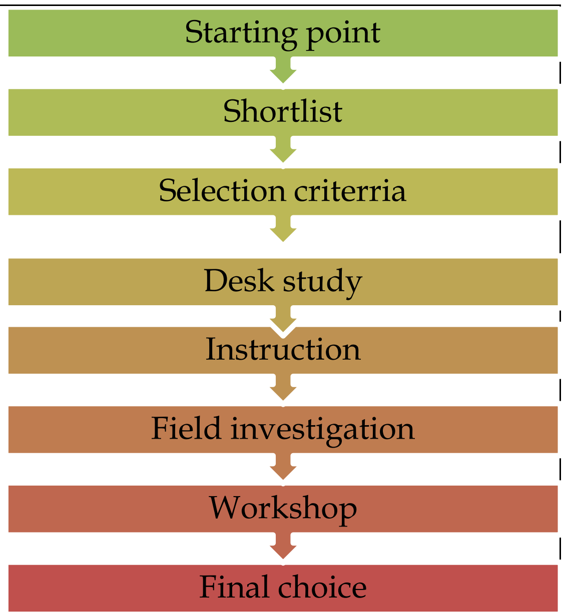


Fig. 5. Process II

Source: CRFM, 2009

Fig. 4& 5. Steps in value chain analysis

Process I: The process starts with the selection and prioritization followed by value chain mapping and analysis. After the value chain analysis, the formulation, up gradation and monitoring was carried out. The final step is for assessing the impact of the value chain.

Process II: This process follows eight steps comprising of three phases. There are,

i. Preparatory phase – includes three steps i.e., starting point, short listing and criteria selection.
ii. Data collection phase – includes three steps i.e., desk study, instruction and field investigation.
iii. Concluding phase – includes two steps work shop and final choice.

The steps for selecting the value chain aremainly based on author's discretion without diluting the objectives of study. The typical value chain includes the steps viz., own value chain, customers value chain, potential cost advantages and potential value added for the consumer.

Methodology for undertaking value chain research

The methodology for assessing the value chain was formulated by using the steps involved in value chain analysis (Fig. 7).

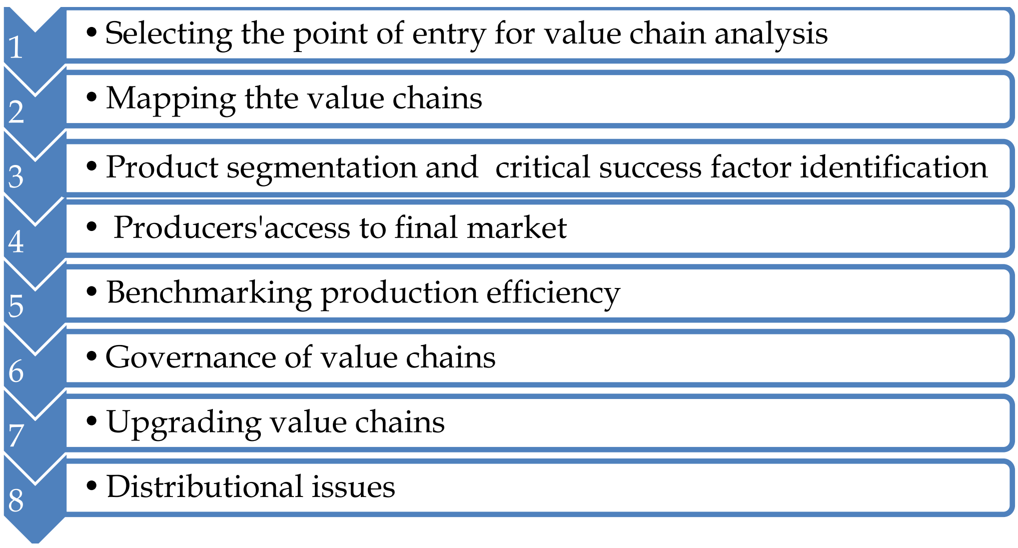


Fig. 7. Methodology used for value chain analysis

The methods for carrying out the value chain research include selection of point of entry, mapping and analysis. The bench marking, governance, upgradation of value chain should also be assessed. The identification of distribution and impact issues are also part of the methodology. The steps in implementing the value chain approach in fisheries include a value chain mapping, stakeholder mapping and detailed strategies for addressing the challenges and constraints.

Tools used in value chain analysis

The data required for the analysis can be collected using either quantitative or qualitative or both. The questionnaire or interview schedule is used for collecting the quantitative data. The qualitative data can be collected through semi-structured questionnaire and focus group discussion. The data collected were analysed using various econometric tools viz., means, proportions, ranks, factor analysis, cronbach's alpha and regression analysis. These analyses are used to find out the dominant actor and activities in terms of cost and value. The tools used for data collection and data analysis in value chain analysis are presented in Table. 1.

Table. 1. Tools used in value chain analysis

Data collection tools	Data analysis tools
I. Quantitative tools	I. Means, proportions and ranks
i. Questionnaire / interview schedule	II. Factor analysis Eigen values Chi-square values Kaiser-Meyer-Olkin (KMO) Barlett's Test of sphericity
II. Qualitative tools	III. Cronbach's Alpha
i. Semi-structured interview ii. Focus group discussion	IV. Regression analysis

Approaches in value chain analysis

Earlier value chain studies were concentrated on tradition approach. In this approach, the focus was mainly to economic dimension. The social, behavioural and institutional dimensions were focused separately without any interconnectedness. While, new approach is a holistic and integrated approach with inter connection of all the dimensions together (Social, economics, behavioural and institutional dimensions).

Value chain in Fisheries and Aquaculture

The typical seafood value chain (Marine fisheries) is given in fig.8.

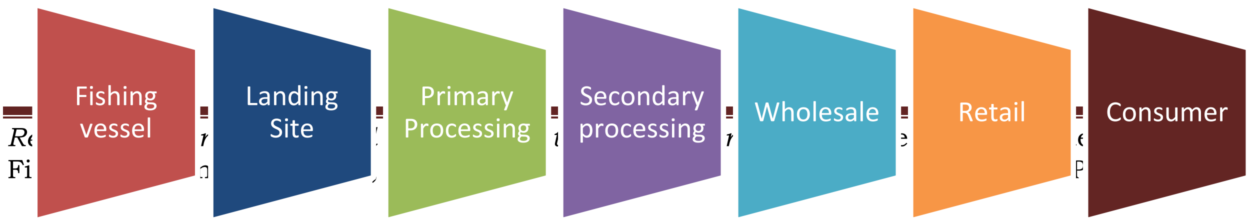


Fig. 8. Typical seafood value chain

The fish value chain usually starts at harvesting stage at sea, and then the catch is brought to landing sites (centres). After processing, the fish is marketed by wholesalers to retailers and finally it reaches to the end users (consumers).

The value chain of inland fisheries (aquaculture) showed a varied chain. Generally, in aquaculture, the chain starts at hatchery i.e., brooding stage and followed seeding, nursery and growth, trading and finally reaches the final consumer (Fig. 9).

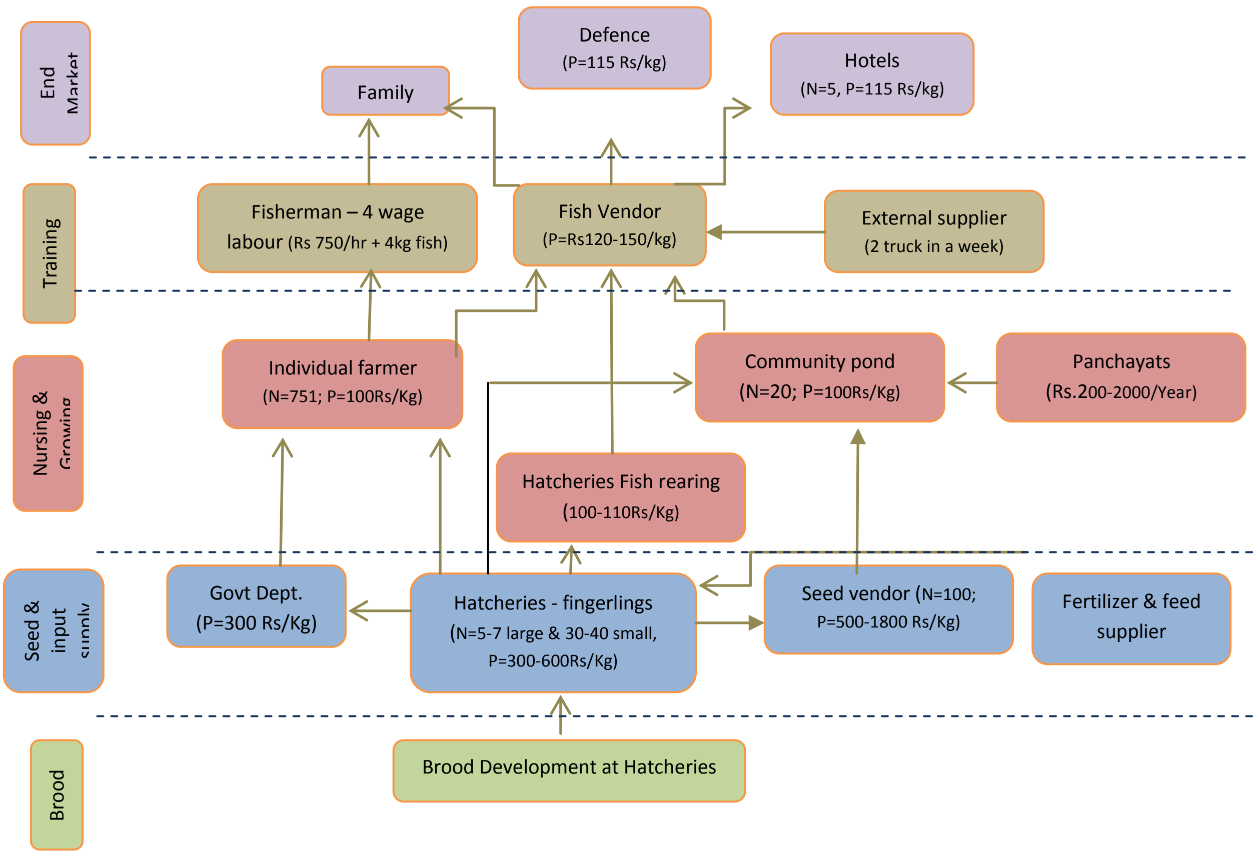


Fig. 9. Value chain of inland fisheries

There would be variation in length and actors of the value chain based on time, region and resource availability. The value chain in fisheries and aquaculture could be improved by focus on the following aspects. There are,

- Sustainable resource management

- Increasing production level
- Improving the quality and safety of products
- Ensuring co-operation among value chain actors
- Better consumer service
- Minimizing the transactional costs
- Capacity building and technology assimilation

Porter's value chain approach

Porters' VCA is a popular approach developed during 1985 (Fig.10). The model is an integrated framework comprised of two activities i.e., primary and supporting activities. Primary activities are directly concerned with product development or service delivery. And, each primary activity is linked with the support activities towards improving the efficiency and effectiveness of the system.

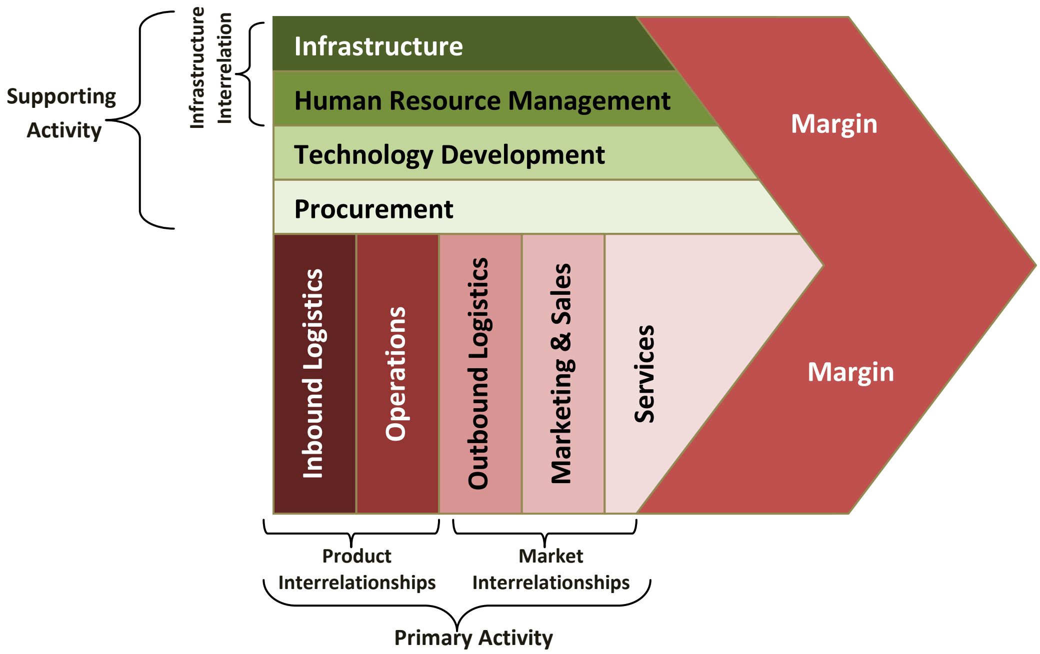


Fig. 10. Porter's value chain model, 1985

Primary activities: Includes five main areas viz., inbound logistics, operations, outbound, marketing and sales,

Support activities: Includes procurement, technology development, human resource management and infrastructure. The term 'Margin 'is the profit margin that depends on the activities linked with the value chain (Porter, 1985).

Global value chain (GVC)

Global value chain emphasizes on the incorporation of local production to the global markets.

Table2. Dimensions of Global Value Chain

Dimensions	Description
Input – output structure	Process of transforming raw materials into final products
Geographical consideration	Identification of lead firm/ country in the global scale
Governance structure	How the VC are controlled (way of controlling and co-ordinating actors)
Institutional context	Institutional set up in which VC is embedded
Upgrading	dynamic movement within the value chain by examining how producers shift between different stages of the chain

The governance of GVC depends on various dimensions. The input-output structure, geographical consideration, governance structure, institutional context and upgrading are the various dimensions through which the local production can be improved towards linking with the global value chain (Table. 2).

Types of governance in the GVC

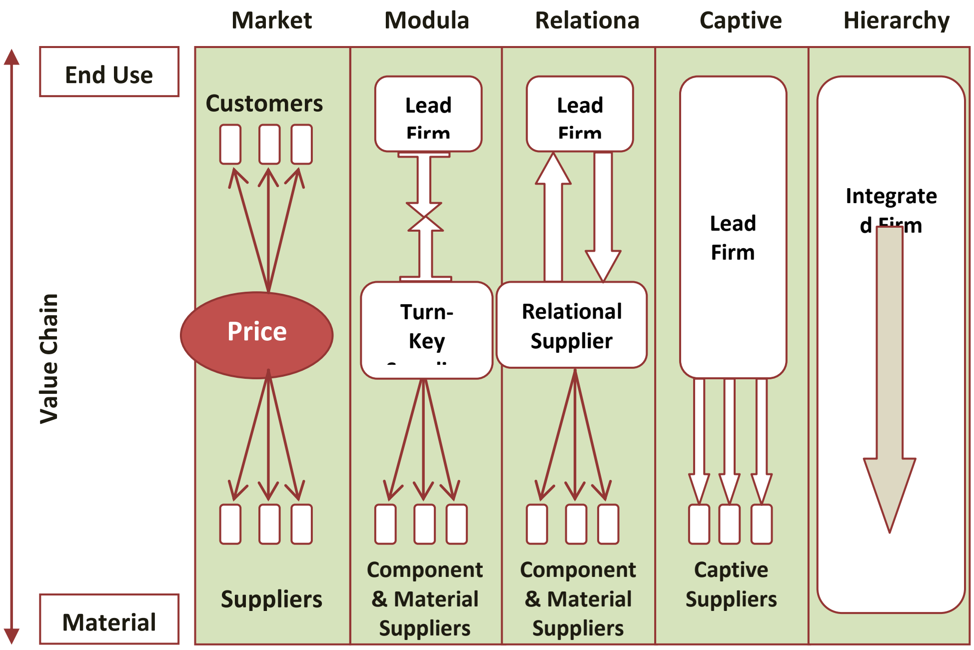
The governance of GVC depends on the degree of co-ordination and power asymmetry. There are five types of value chain governance viz., market, modular, relational, captive and hierarchy.

Issues in the VCA

The VCA is controlled by various constraints and issues. There are,

- Infrastructure facilities
- Input supply
- Credit facilities
- Quality and safety standards
- International regulations
- Middlemen intervention

The management of value chain would be possible through up gradation. It can be upgraded by improving the process, product, changing the functional positions and move out to a new value chain.



Source: USAID

Fig. 11. Types of value chain governance

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Chapter 39

Food and nutritional security from inland fisheries

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Introduction

Fish symbolizes as prosperity and fertility of the region rather than for its food and nutritional security in many parts of the world. The abundant inland waters resources such as reservoirs, rivers and wetlands contribute to meet the food and nutritional security of a nation. The rich diversity of freshwater fish fauna supplements as a quality animal source protein, macro and micro nutrients for the health benefits of all age group of human population. Hence the fishery activities such as fish catch and production enhancement from inland water resources are emphasized to scale up to meet the growing demand. The world fish production through inland capture fisheries has increased from 10.5 million tons in 2009 to 11.9 tons in 2014. The utilization of the existing vast inland resources through technical interventions would impact on food and nutritional security and livelihood of the fishers and rural masses of the developing countries.

Freshwater inland fishery resources

It is estimated the earth has 35 029,000 km^3 of freshwater which is only 2.5% of all water resources. The amount of freshwater available as rivers, lakes and wetlands *etc* is 113,000 km^3 or only to 0.01% of the earths water resources. Asia is the continent having large amount of useable surface freshwater resources but the per capita availability of the resource is the least (Nguyen and De Silva, 2006). India next to China has the largest freshwater inland water resources comprising 29000 kms of rivers, 126,334 kms of creeks and canals 2,10,000 ha of floodplain lakes and 30,20,000 ha of reservoirs. The freshwater resources for fish production through culture based fisheries and capture fisheries of

Country	Rivers	Flood-plains (ha)	Lakes (ha)	Reservoirs (ha)	
				large & medium	Small
Bangladesh	24 000 km^2	2 946 950*		58 300	
China	7 650 000 (ha)	NA	7 140 000	211 000	
India	29 000 (km)	354 213**	720 000	1 667 809	1 485 557
Indonesia	12 000 000 (ha)		1 800 000	50 000	
Myanmar	1 300 000 (ha)	8 100 000		115 687	
Nepal	395 000 (ha)		5 000	1 500	
Republic of Korea	2 800 km^2			110 800	
Sri Lanka	NA	4 049		109 450	39 271
Thailand	4 100 000 (ha)				400 000
Vietnam				340 000	

NA – data not available; * includes ox bow lakes, beels, haors and baors; ** includes flood-plain lakes and associated wetlands different countries are given in Table

Table.1 The varying types of freshwater resources utilised for fishery enhancements in ten countries

Inland water fish production

World catches in inland waters were about 11.9 million tonnes in 2014, continuing a positive trend that has resulted in a 37 percent increase in the past decade (Table.3). The bulk of global production is contributed by only 16 countries, which represent 80 percent of the world total. Decreases in fish catch from inland waters are also reported in some countries due to heavy pollution, environmental degradation and, due to their limited habitats, resources being easily overfished. The species wise fish production of India for 2012 is given in tab 4.

Table.3 Inland waters capture production *(in tons)*: Major producer countries

COUNTRY	2003-2012 (AV.)	2013	2014
CHINA	2215351	2307162	2295157
MYANMAR	772522	1302970	1381030
INDIA	968411	1226361	1300000
BANGALADESH	967401	961458	995805
CAMBODIA	375375	528000	505005
UGANDA	390331	419249	461196
INDONESIA	324509	413187	420190
NIGERIA	254264	339499	354466
TANZANIA	307631	315007	278933
EGYPT	259006	250196	236992
BRAZIL	243170	238553	235527
RUSSIA	228563	262050	224854
CONGO	225557	223596	220000
PHILIPPINES	168051	200974	213536
THAILAND	212937	210293	209800
VIETNAM	198677	196800	208100
TOTAL (16)	8111756	9395355	9540591
WORLD TOTAL	10130510	11706049	11895881
SHARE OF 16 (%)	80.1	80.3	80.2

Table.4 Inland Fish Landings by species in Indian states and UT'S, 2012

INDIA	MAJOR CARPS	MINOR CARPS	EXOTIC CARPS	MURREL	CAT FISHES	OTHER FRESH WATER FISHES	OTHERS	TOTAL
STATES /UT	3418794	338252	525844	150081	279684	622722	264317	5609694

The contribution of China among the countries supplying inland fish production is the highest approximating about 35 percent. Importantly, the bulk of the inland fishery production occurs in Asia, the region contributing almost 70 percent to the global production (DeSilva, 2010). This trend has existed over the last two decades depicting its significance to the region as a whole (Fig.1).

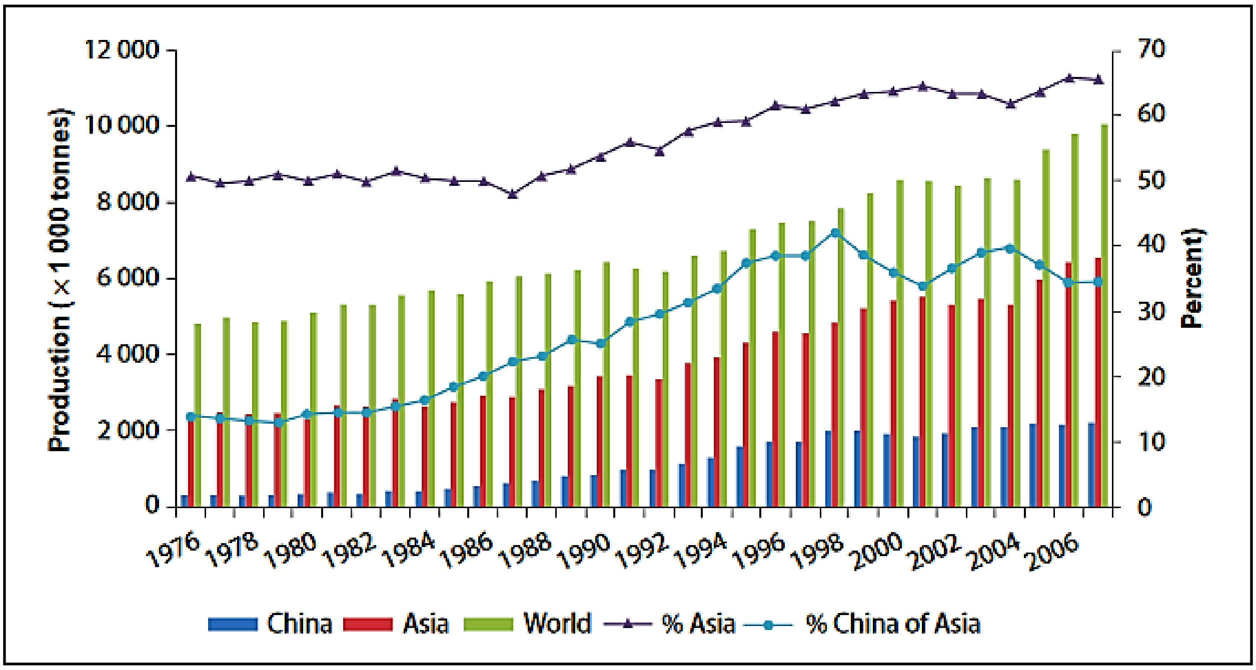


Fig.1 The trend in inland fish production in PR China, Asia and the world and the percent contribution of the former to the world production.

Fish species contributing inland fish production

Significant populations of indigenous fishes and alien fish species have enhanced the stock of inland waters and in China, higher number of native and introduced species such as *Acipenser dabryanus,C. Asiatica, Siluris meridionales, Xenocypris davidi* and *X. microlepis* triggered its total production. In India, Indian major carps *Catla catla, Labeo rohita, Cirrihinus mrigala* and exotic carp *Cyprinus carpio,* tilapia, *O. mossambicus* and *O. niloticus* profoundly supported the inland fish production. Native fishes, *Puntius sarana, Labeo calbasu, Wallago attu, Ompok bimaculateus and Mystus aor* share at large in the total fish yield of peninsular reservoirs in India. The major species supporting inland fish production in some other Asian countries are given in Table.5.

Table. 5 Important fish species supporting inland fish production.

Species	Bgd	China	India	Indo	Myn	Nepel	RoK	SL	Th	Vn
Anabas testudineu	+		+	+						+
Anguilla japonicus		+					+			
Hypophthalmichtys nobilis	+*	+	+*		+*	+*		+*	+*	+*
Barbonymus gonionotus	+			+*					+	
Clarias gariepinus				+					+	
Carassius auratus	+*	+	+		+*	+*	+			+*
Catla catla	+		+		+	+		+*	+*	+*
Chana striata				+	+					+
Chitala chitala				+	+					
Cirrhinus mrigala	+		+		+	+		+*	+*	+*
Ctenopharyndogon idellus	+*	+	+*	+*	+*	+*		+*	+*	+*
Cyprinus carpio	+*	+	+*	+*	+*	+*	+	+*	+*	+*
Eriocheir sinensis		+					+			
Heteropneustes fossilis	+			+	+					
Hypophthalmichtys molitrix	+*	+	+*	+*	+*	+*		+*	+*	+*
L. rohita	+		+		+	+		+*	+*	+*
Leptobarbus hoevenii				+					+	
Macrobrachium rosenbergii	+		+	+	+			+	+	
Mastacembelus armatus	+		+		+					
Morulius chrysophekadion				+*					+	
Mylopharyngodon piceus		+								+
Neosalanx spp.		+**								+*
Oncorhynchus mykiss[#]						+				+
Oreochromis mossambicus[#]	+		+	+	+			+	+	
O. niloticus[#]	+		+	+	+	+		+	+	+
Osteochilus hasselti				+					+	
Pangasianodon hypopthalmus				+*	+				+	
Probarbus jullieni				+*					+	
Salmo gairdneri[#]		+		+					+	+
S. salar[#]		+		+						
S. trutta[#]		+		+					+	+
S. richardsonii[#]					+	+				
Tor douroensis			+	+						
T. putitora			+			+				
T. Tor			+		+	+				
Trichogaster pectoralis				+*	+*				+	
Trionyx sinensis		+					+			

alien to the region; * alien to the country; ** translocated across water sheds with in a country for stock enhancement purposes

Bgd = Bangladesh; Indo = Indonesia; Myn = Myanmar; RoK = Republic of Korea; SL = Sri Lanka; Th = Thailand; Vn = Vietnam

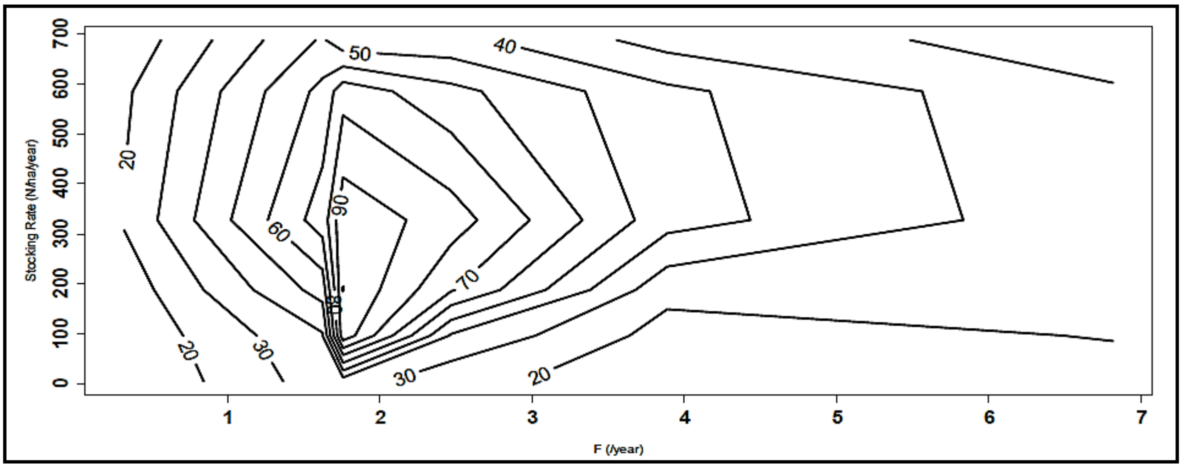
Inland Fishery Practices:

Inland water resources are utilized to improve fish production through stock enhancement and culture based fisheries in many countries for various purposes. Stock Enhancement in rivers is practiced with a view to augment fish production and to conserve the riverine stocks particularly with seed stocking of indigenous species. In flood plains and associated waters the practice called leasable fisheries where areas of the flood plain are leased through auction. In lakes and reservoirs stock enhancement activities are well managed through culture based fisheries by stocking hatchery reared seeds or collected form wild. This is wildly practiced in Sri Lanka, India and China. To operate these kind of fisheries fisher communities and societies are established. Other than these practices any fishery related enhancements are operated such as provision of fish hatcheries, improvement of spawning habitats, introduction of closed seasons and gear restrictions which ensures the capture of the stocked fish.

Culture based fisheries in small reservoirs in India:

About 1.5 million ha of small reservoirs in India hold enormous potential for the intensification of aquaculture practices to enhance productivity per unit area. Small reservoirs both perennial and seasonal are intensively exploited for fish production by active scientific management and enhancement where the yield is strongly related to trophic status. In India also fish production from small reservoirs has substantially increased from the national average of 50kg/ha to manifold through intervention in certain hydrological parameters to improve the trophic status of the reservoir or suitable culture management strategies. A culture-based fishery in small reservoirs is a successful aquaculture practice in vogue in many parts of the world and in India also for enhancement for fish production. In Indian reservoirs, Aliyar, Thirumoorthy and Kanhirapuzha (Fig.2) suitable management strategies were evolved forming guidelines on key issues of stocking density, size and species composition for production enhancement.

Fig.2 Estimation of optimum stocking density of catla fingerlings using VBGF growthmodel in Kanhirapuzha reservoir, India.



Nutritional prospects of inland fishes:

Fish is consumed as an important part of diet by human beings in almost all parts of the world. In inland waters nearly 720 inland fishes are present as edible and they provide rich source of vitamins, minerals amino acids, folic acid, ω-3 or N-3 fatty acids other than protein.Fish eating benefitsto all age group especially for brain development, memory, mental and cardiac health working against Alzheimer disease and dementia The Ò-3 polyunsaturated fatty acid reduces free fatty acids, plasma triglyceride, cholesterol concentrations and platelet aggregation leading to decreasing blood pressure, blood clotting and atherosclerosis. The proximate composition of important freshwater food fishes of India is given in Table 6 and the average value of different products of freshwater is given in Table 7.

Table. 6 Proximate composition of thirty-nine important freshwater food fishes from India.

Species	Moisture (% ww)	Crude protein (% ww)	Crude fat (% ww)	Ash (% ww)
Ailia coila	82.8 ± 0.2	12.9 ± 0.5	1.8 ± 0.0	2.0 ± 0.0
Amblypharyngodon mola	76.2 ± 1.1	16.3 ± 0.81	4.3 ± 0.0	4.0 ± 0.9
Anabas testudineus	68.0 ± 0.7	16.9 ± 0.51	6.9 ± 0.6	5.3 ± 0.2
Catla catla	76.2 ± 0.3	16.2 ± 0.51	2.8 ± 0.3	2.5 ± 0.1
Cirrhinus mrigala	75.3 ± 0.6	15.5 ± 0.51	2.8 ± 0.3	2.5 ± 0.1
Clarias batrachus	75.9 ± 0.7	16.4 ± 0.31	3.7 ± 0.4	2.3 ± 0.0
Gudusia chapra	76.7 ± 0.3	14.1 ± 0.1	5.7 ± 0.0	2.9 ± 0.0
Heteropneustes fossilis	76.7 ± 1.1	16.3 ± 0.41	2.7 ± 0.5	2.6 ± 0.1
Labeo rohita	75.6 ± 0.5	15.9 ± 0.41	2.7 ± 0.2	2.6 ± 0.2
Puntius sophore	75.7 ± 1.9	16.3 ± 0.91	4.9 ± 0.5	3.4 ± 0.1
Rita rita	77.8 ± 4.3	19.5 ± 1.2	1.6 ± 0.0	1.0 ± 0.1
Sperata seenghala	79.4 ± 1.2	19.0 ± 1.31	0.8 ± 0.4	0.9 ± 0.2
Tenualosa ilisha	66.9 ± 4.2	20.7 ± 2.71	10.5 ± 4.6	Ll ± 0.5
Xenentodon cancila	78.2 ± 0.7	15.7 ± 0.3	0.7 ± 0.0	3.6 ± 0.1

Table.7 Average values of nutrients and micro nutrients in fish products.

Product name	Macronutrients (%)				Elements (mg/100 g)					
	Protein	Moisture	Lipids	Carbohydrate	K	Na	Mg	Fe	Zn	Ca
Fresh water fish	14.8–22.8	68–78.5	0.6–19.4	2.3–6.9	49–501	158–780	22–187	0.31–15.95	0.4–40.2	–
Dry fish (sun dried)	64.9	13.96	4.21	16.9	–	–	–	–	–	–
Dried fish	58.5	19.7	11.24		–	–	–	–	–	–
Salted dry fish	62.2	13.4	6.03	18.4	–	–	–	–	–	–
Smoked dry fish	70.8	10.42	7.23	11.6	–	–	–	–	–	–

Conclusion

Culture based fisheries and capture fisheries in freshwater inland water resources have resulted in successful management, up liftment of livelihood of fishers and fish availability for the overall growth. However the growing concern globally over the biodiversity and conservation of native fishes in the recent years, issues related to stock enhancement in inland waters need to be monitored for responsible and effective fishery management.

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Chapter 40

Fish genetic resources and its conservation

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Finfish and aquatic invertebrates are part of Fish Genetic Resources (FiGR) that has actual or potential value for culture and capture fisheries. Fish as a group, have the highest species diversity among all the vertebrate taxa. Out of 62,305 species of vertebrates recognized world over, 32,064 (~ 52%) are valid fish species; of which, the great majority (97%) are bony fishes, mainly teleosts; and the remaining (3%) are cartilaginous fishes (sharks & rays) and jawless fishes (lampreys and hagfishes) (Eschmeyer and Fricke, 2012). India is blessed with vast fishery resources, like exclusive economic zone (2.02 m sq. km), coast line (8,129 km), ponds and tanks (2.254 m ha), beels, ox-bow lakes and swamps (1.3 m ha), reservoirs (2.90 m ha), rivers and canals (173,287 km), brackish water (1.235 m ha) (Ayyappan *et al.,* 2011). The country is fortunate to possess vast and varied fish genetic resources in different aquatic ecosystems and being home to 7.84% of global finfish diversity, with 3535 species of fish, of which 3035 are native species, representing 46 orders, 252 families and 1,018 genera. The 500 exotic fishes are also covered and majority of them are of ornamental fishes. Out of the 3035 native fishes, 1016 are freshwater, 113 are brackish water and 1906 are marine species and at least 258 species are of commercially important (NBFGR, 2016-17). India harbours a rich diversity of fishes and four out of 34 biodiversity hotspot areas of the world. The biodiversity hotspots *i.e.* the Western Ghats and North East India harbours maximum endemic freshwater fishes. The Western Ghats harboring about 306 finfishes out of which nearly 69% are endemic to the region (Gopalakrishnan and Ponniah, 2000). Likewise North East India, another biodiversity hotspot area, harbors about 240 fin fishes and nearly 40% are endemic to the region (Sarkar *et al.* 2012). In the past one and half decades more than 50 new species were described from these areas and more than 10 new species were described from the marine environment.

The total fish production of the country during 2015-16 is estimated to be 10.79 mmt with marine contributing 3.58 mmt the bulk of the marine catch comprises of; Indian mackerel (6.9%), Oil sardines (6.7%), ribbon fishes (6.0%), lesser sardine (5.4%), croakers (4.4%), cephalopods (6.4%) and penaeid (5.5%) and non penaeids (4.4%), while remaining 7.21 mmt from inland system (Fig.1). More than 80% of the inland fish production is coming from aquaculture. India is earning Rs. 33,441/-

crores by exporting fish and fish products (DAHDF 2016-17). The fish production of the country contributes 5.17 % of agricultural GDP and 0.9 % of total GDP of the country (DAHDF, 2016-17). A total of 3271 species of mollusc distributed among 220 families and 591 genera in which gastropods forms 58.1% and bivalves 33.6%. Among these 8 species of oyster, 2 species of mussels, 17 species of clams, 3 species of pearl oysters, 3 species of giant clams, 1 species of windowpane oyster and gastropods and 15 species of cephalopods are exploited from the marine sector of India.

Aquaculture in India has evolved as a viable farming practice over last three decades with an annual growth rate of 6-7%, placing country second highest in the world in cultured fish production, contributing 4.88 million metric tonnes in 2014 (FAO 2016) (Fig.2). Aquaculture contribute a major share in India's fish production. This was achieved primarily due to three species of India major carps, *viz.,Catla catla*, *Labeo rohita* and *Cirrhinus mrigala* supplemented by exotic species *viz. Hypopthalmichthys molitrix, Ctenophayrngodon idella* and *Cyprinus carpio*, pangas catfish *Pangsianodon hypophthalmus* and freshwater prawn *Macrobrachium rosenbergii* from freshwater aquaculture and shrimps from coastal shrimp farming (Jena & Gopalakrishnan, 2012**)**. In recent, years the exotic shrimp, *Litopenaeus vannamei* is contributing more than 80% of the total shrimp production (MPEDA 2016) (Fig. 3), while the bulk of the shrimp production is coming from Andhra Pradesh (~ 75%) (Fig. 4). Culture for marine species has been initiated in the country and is presently carried out for seaweeds and fish species like seabass and cobia and molluscs, mussels in commercial scale and species like pompano on an experimental basis. In recent years, the exotic fish 'GIFT tilapia' were taken in big way for cage culture. Though, India is rich and diverse in aquatic genetic resources, the index of biodiversity utilized for aquaculture (BUA) is of the order of 0.13 (~85% from Indian major carps; ~ 5% air-breathing fishes; ~10% rest all species together) (Ayyappan *et al.*, 2011), so it is the fact that domestication of resources that can provide sustainable utilization is not proportionate with the level of biodiversity and agro climatic environment possessed. Therefore diversification of aquaculture to enhance the production, exploring the various aquatic resources and agro climatic environments, need to be promoted. Exotic fishes and shrimps, legally and illegally introduced, play a major role in the aquaculture system in the country. Efforts are being made for quarantine the imports of fishes and shrimps by Ministry of Agriculture. Systematic explorations are also being carried out to study the occurrence and impact assessment of exotic fish species in natural waters of the country. A strong disease surveillance programme in the country is under place by Ministry of Agriculture in collaboration with NBFGR the country.

Fish Genetic resources are crucial for their role in direct consumption, providing new species for aquaculture diversification, to improve domesticated species and resource for products of commercial value (Bartley *et al.*, 2007). Diverse genetic resources are the necessary raw ingredients that allow species to adapt changes in their environment. While presently these resources are receiving considerable attention world over from the policy maker and researchers, from the perspective of conservation and sustainable utilization to meet nutritional security of the growing population. In this respect conservation assessment and management plan (CAMP) has identified 327 threatened freshwater fishes in India and classified as critically endangered (45 species), endangered (91 species), vulnerable (81 species), low-risk near threatened (66 species), low-risk least concern (16 species), data deficient (26 species), extinct (1 species), and extinct from the wild (1 species) (Lakra *et al.,* 2007). While the critical issue with these FiGR is how its abundant genetic variation, be it interspecific or intraspecific, is managed, conserved and exploited in the endeavor to reach the present and future food production goals of aquaculture sector (Brummett & Ponzoni 2009; Lind *et al.,* 2012).

India's efforts for fish genetic conservation

Ever increasing anthropogenic and other natural pressure on rich diversity, there have been several initiatives to conserve and manage the resources on sustainable basis. The Indian Fisheries Act of 1897 (modified in 1956) is a landmark in the conservation of fishes. Ministry of Agriculture, Government of India, is modifying the Act to incorporate all the relevant legal measures to conserve fish germplasm resources. The Biological Diversity Act (BDA) 2002 is also in place for protecting indigenous fishes of the country. This encompasses guidelines to address a wide range of issues related to the utilization of bioresources and information within the country as well as by other countries (Lakra *et al.*, 2007; Jena & Gopalakrishnan *et al.,* 2012). A baseline information in the form of a data bank has been made at the National Bureau of Fish Genetic Resources (NBFGR). Efforts are taken to make live Gene Bank programmes by NBFGR in collaboration with regional institutions for management of endangered species. An innovative approach to fish conservation by declaring a State Fish for each of the states was adopted for the first time in the country by NBFGR in 2006. 16 states of the country declared state fish for conservation and enhancement of these fishes. Captive breeding and larval rearing of non-conventional food fish species *viz., Chitala chitala, Ompok pabo, O. pabda, Labeo dussumieri, Semiplotus semiplotus, Clarias dussumieri, Channa diplogramme, Anabas testudineus, Cirrhinus reba, Barbodes carnaticus*, *Puntius sarana* and 15 indigenous ornamental species having export potential such as *Pristolepis marginata, Horabagrus nigricollaris, Chela fasciata, Danio malabaricus, Sahyadria denisonii, Haludaria fasciatus etc* are perfected for conservation of these endemic fishes. Captive breeding and stocking in wild, to compensate the declining fish populations and simultaneous stock enhancement through ranching will be the need of the hour. Stock-specific, breeding-assisted river ranching of two food fishes (*Horabagrus brachysoma* and *Labeo dussumieri*) has been found successful in Kerala (Padmakumar *et al.*, 2011).

Genetics and molecular markers:

Several molecular tools are being employed for accurate identification and documentation of fish genetic resources and for developing stock specific conservation management measures at NBFGR, Lucknow. The NBFGR is the nodal agency in India for DNA barcoding programme and has barcoded more than 750 finfish species (Jena & Gopalakrishnan, 2012). Apart from these, Government of India is already initiated many research institutions and state agricultural Universities for education and research in conservation of fish genetic resources of the country. Fisheries research programme in India has put immense efforts towards genetic improvement through selective breeding programme and could able develop genetically improved rohu popularly known as 'Jayanti Rohu' which recorded 17% more growth per generation after seven generation (Das Mahapatra *et al.* 2007). Similar line of work is under progress towards development of Improved Catla and freshwater prawn *Macrobrachium rosenbergii*. Knowledge of genome analysis, have utility in finding responsible genes for specific traits and their linkage with markers. Efforts have been initiated in India in a consortium mode to decipher the whole genome sequence information of *Labeo rohita*, *Clarias magur,Tenualosa ilisha* and *Penaeus monodon* and population genomic approaches to identify the outlier loci in the genes associated with production traits in prioritized cultivable species, which will be helpful for genetic improvement programmes.

Conclusion

The country has diverse fish germplasm and their effective management can increase fish production. It is expected that the fish requirement by 2025 would be of the order of 16 million tonnes, of which at least 12 million tonnes would need to come from the inland sector and aquaculture is expected to provide over 10 million tonnes. The issues in inland and marine fisheries that need to be addressed pertain to biodiversity loss and depletion of fish stocks and effective compliance of code of conduct of responsible fisheries. There are concerns regarding the stagnating capture fisheries yields. As capture fisheries is still an important component of Indian fisheries, due importance needs to be given to habitat restoration and fish conservation in different ecosystems. Maintaining the genetic health of the fisheries wealth is equally important for up-scaling aquaculture production and sustaining the fish yield from natural waters. Therefore, conservation needs must be aimed towards preserving existing biodiversity and also the evolutionary processes that foster biodiversity. The conservation of fish diversity and aquatic resources of the country requires concerted efforts by integrating capture, culture fisheries and environmental programmes using latest technological innovations. It is important to recognize that aquatic food could form an important part of the Indian diet, critical in view of increasing pressure on land. Though India is very rich in biodiversity, many of the wild FiGR are threatened with genetic change or extinction. These wild relatives of farmed and potentially farmable aquatic species must be valued and protected in order to ensure their future availability for use in aquaculture. With adequate recognition of the value of wild FiGR and sharing of the costs and benefits of their conservation, there is still time and opportunity for aquaculture to avoid losses of wild genetic resources. Fish further becomes important in the context of health food and in order to enhance access to fish and fishery products in the domestic market, ensuring quality and effective distribution would need to receive greater attention.

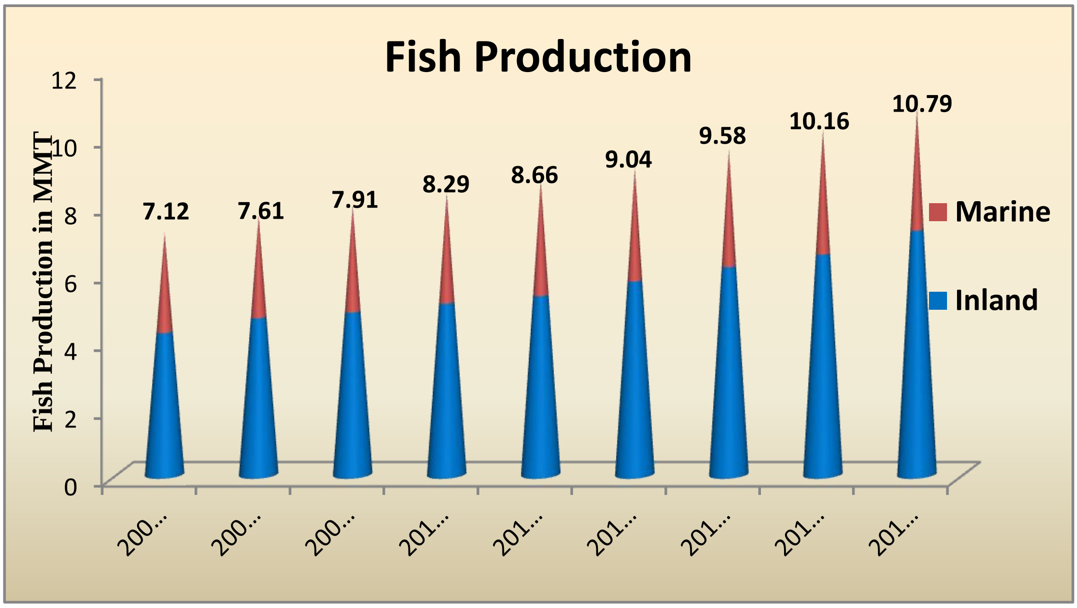

Fig.1: Fish production in India during the period 2007-08 to 2015-16 (Marine and Inland) in million metric ton (MMT). (*Source DAHDF)*

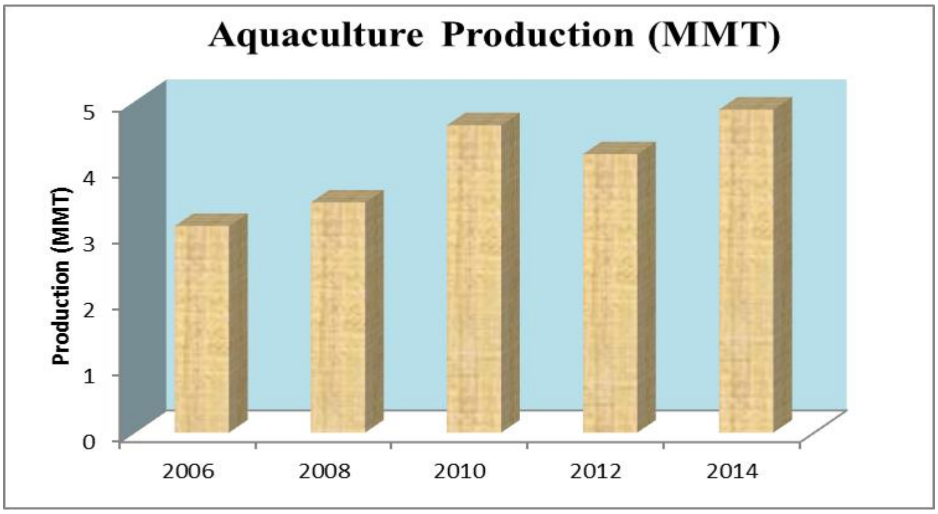

Fig. 2 . Fish production from Aquaculture in India during 2006 to 2014. (*Source: SOFIA, FAO*)

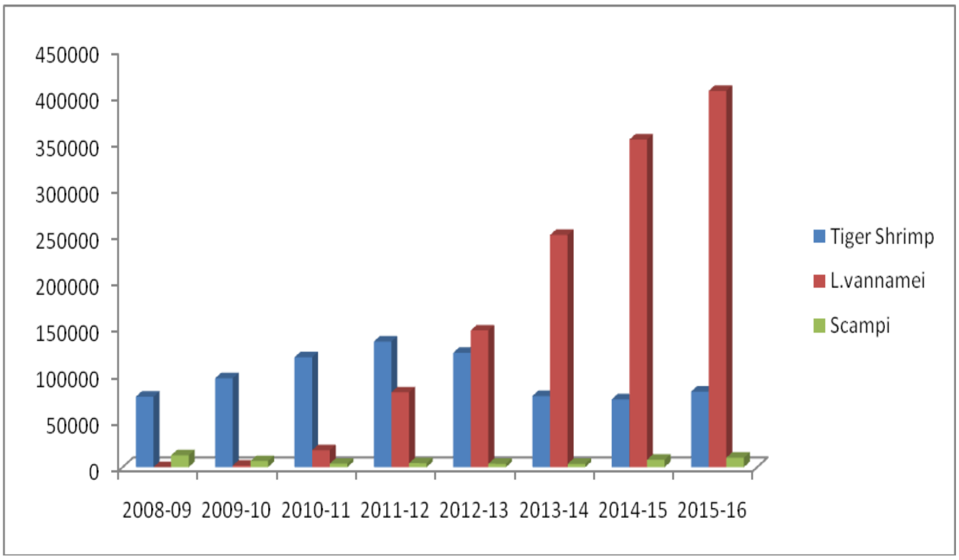

Fig. 3. Total Tiger Shrimp, *L Vannamei*& Scampi production in India. (*Source: MPEDA,2017*)

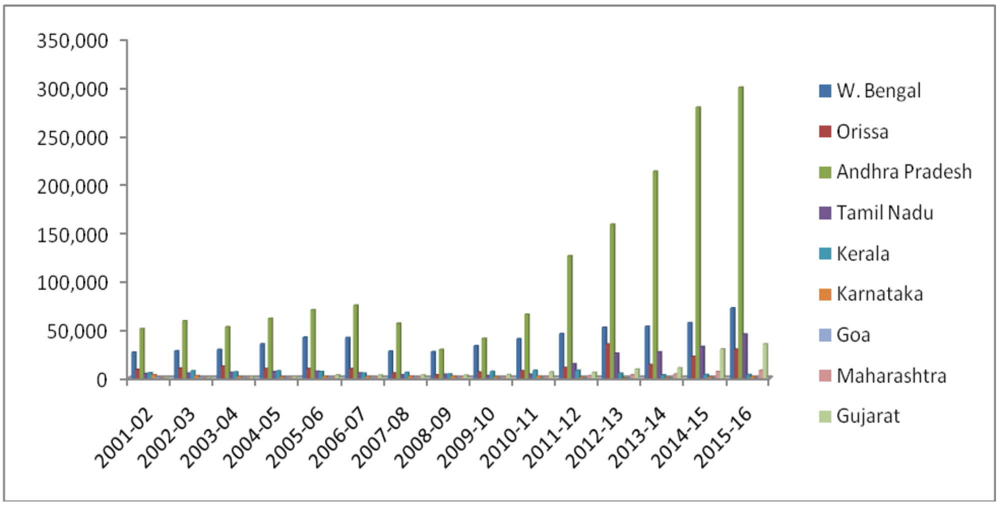

Fig. 4.Statewise shrimp production in India during the period 2001 to 2016.
(*Source: MPEDA, 2017*)

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